Unit 2 DSC

Digital Infrastructure for Smart Cities

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1. Introduction

- A **Smart City** uses digital technology and data-driven governance to improve the quality of life.
- **Digital Infrastructure** is the backbone of Smart Cities – enabling real-time data collection, processing, and communication between government, citizens, and businesses.

2. Key Components of Digital Infrastructure in Smart Cities

- **(a) ICT Backbone**
- **High-speed Internet**: Optical fiber networks, 5G, and public Wi-Fi.
- **IoT (Internet of Things)**: Sensors, smart meters, RFID, GPS trackers.
- **Cloud Computing**: For storing and analyzing large volumes of data.
- **Data Centers**: Local and regional centers to host digital platforms securely.
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- **(b) Urban Platforms & Digital Governance**
- **Integrated Command & Control Centre (ICCC):**
  - Central hub for monitoring city functions (traffic, waste, energy, water supply, emergencies).
  - Uses AI/ML for predictive analysis.

- **e-Governance Portals:**
  - Online services (taxes, certificates, grievances, licensing).
  - Digital payments and paperless documentation.
- **Citizen Engagement Apps:**
  - Mobile apps for reporting issues, accessing transport info, healthcare services, etc.
- **(c) Smart Mobility Infrastructure**
- **Intelligent Transport Systems (ITS):**
  - Smart traffic lights, GPS-enabled buses, e-ticketing.
- **EV (Electric Vehicle) Charging Infrastructure.**
- **Smart Parking Solutions:** Real-time availability display and booking.

- **(d) Smart Utility Management**
- **Energy:**
  - Smart grids, smart meters, renewable energy integration.
- **Water:**
  - IoT-based water distribution monitoring, leakage detection.
- **Waste:**
  - Smart bins with sensors, GIS-based collection and route optimization.
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- **(e) Digital Security Infrastructure**
- **Surveillance & Safety:**
  - CCTV with AI-based analytics, facial recognition.
- **Cybersecurity Measures:**
  - Data privacy, secured networks, encryption.
- **Disaster Management Systems:**
- Real-time alerts for floods, earthquakes, fire, or pandemics.

- **3. Technologies Driving Digital Infrastructure**
- **5G Networks** – Ultra-fast and low-latency connectivity.
- **IoT Sensors** – Real-time monitoring of air quality, traffic, utilities.
- **Artificial Intelligence & Machine Learning** – For prediction and optimization (traffic, energy demand, crime prevention).
- **Big Data Analytics** – Decision-making based on huge datasets.
- **Blockchain** – Secure digital transactions (property, healthcare, supply chain).
- **GIS & Remote Sensing** – Mapping, planning, and spatial decision support.
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- **4. Examples of Digital Infrastructure in Smart Cities**
- **India:**
  - **Bhopal Smart City** – ICCC for integrated monitoring of traffic, waste, and utilities.
  - **Pune Smart City** – Smart parking, citizen grievance redressal app.
  - **Surat** – Smart water meters and waste management with RFID.
- **Global:**
  - **Singapore** – Nation-wide Smart Nation initiative, real-time traffic monitoring.
  - **Barcelona (Spain)** – Smart lighting and waste collection using IoT.
  - **Amsterdam (Netherlands)** – Open data platform for citizens and businesses.

- **5. Benefits of Digital Infrastructure**
- **For Citizens:**
  - Better quality of life, improved mobility, efficient service delivery, safety.
- **For Government:**
  - Transparency, accountability, data-driven decision-making.
- **For Economy:**
  - Promotes innovation, startups, and sustainable economic growth.
- **For Environment:**
  - Optimized energy use, waste reduction, and sustainability.

- **6. Challenges in Implementing Digital Infrastructure**
- **High Cost of Deployment –** Fiber optics, IoT, and data centers require heavy investment.
- **Digital Divide –** Unequal access to technology among citizens.
- **Cybersecurity Threats –** Risk of hacking and data breaches.
- **Interoperability Issues –** Multiple technologies may not integrate smoothly.
- **Privacy Concerns –** Handling of citizens' data responsibly.
- **Capacity Building –** Need for skilled professionals to manage advanced systems.

- **7. Way Forward**
- **Public-Private Partnerships (PPP):** Mobilize investment and expertise.
- **Robust Cybersecurity Framework:** Protect digital assets and citizen data.
- **Inclusive Access:** Affordable internet and digital literacy for all citizens.
- **Sustainable Technologies:** Promote renewable energy and green ICT.
- **Policy & Regulation Support:** National Smart City Mission guidelines, global best practices.

Urban Sensing and Data Collection Technologies

- **Urban Sensing** refers to the deployment of various sensing devices and technologies in cities to monitor real-time conditions such as traffic, pollution, energy use, water supply, and citizen activities.
- **Data Collection** is the process of gathering, processing, and analyzing this information to support **data-driven decision-making** in urban planning, governance, and service delivery.
- Together, they form the **foundation of smart cities** by enabling **continuous feedback loops** between citizens, infrastructure, and administrators.

2. Objectives of Urban Sensing & Data Collection

- Improve efficiency of urban services (transport, energy, waste, water).
- Enhance quality of life and citizen safety.
- Enable **predictive analytics** (e.g., forecast traffic congestion, pollution spikes).
- Support sustainable urban growth.
- Provide open data for innovation and entrepreneurship.

Types of Urban Sensing Technologies

- **(a) Fixed Sensing Technologies**
- Installed at **static locations** for continuous monitoring.
- Examples:
  - **CCTV cameras** (security, traffic monitoring).
  - **Air quality monitoring stations**.
  - **Smart streetlights** with sensors.
  - **Water/energy smart meters**.

(b) Mobile Sensing Technologies

- Mounted on **moving objects** like vehicles, drones, or smartphones.
- Examples:
  - **GPS in vehicles** → real-time traffic data (Google Maps, Ola/Uber).
  - **Drones** → aerial surveillance, disaster assessment, construction monitoring.

Garbage trucks with RFID sensors → waste management tracking.

Types of Urban Sensing Technologies

- **(c) Citizen-Sensing (Crowdsourcing)**
- Data generated directly from citizens using mobile apps or wearable devices.
- Examples:
  - Apps for reporting potholes, accidents, or civic issues (e.g., "MyGov," "FixMyStreet").
  - Health & fitness wearables tracking urban lifestyle data.
  - Social media analysis for disaster response (Twitter during floods/earthquakes).

(d) Remote Sensing Technologies

- Use of **satellite imagery and aerial sensors** for large-scale data.
- Examples:
  - Land use and land cover mapping.
  - Heat island effect monitoring.
  - Flood-risk and environmental vulnerability assessment.

- **(e) Internet of Things (IoT) Sensors**
- Small, interconnected devices embedded in urban infrastructure.
- Examples:
  - Smart bins (waste level monitoring).
  - Smart parking sensors.
  - Environmental sensors (noise, temperature, humidity).
  - Water leakage detection sensors.

4. Data Collection Methods

- **Manual Data Collection**
  - Surveys, census, field inspections.
  - Slower, but useful for qualitative insights.
- **Automated Sensor-Based Collection**
  - Continuous real-time monitoring (IoT, CCTV, smart meters).
- **Crowdsourced Data**
  - Citizens contribute data via mobile apps and platforms.
- **Open Data Portals**
  - Governments publish city datasets (transport, health, pollution) for research and startups.
- **Big Data & AI Integration**
  - Data collected is stored in **cloud platforms** and analyzed with **AI/ML** for predictions (e.g., traffic optimization).

5. Applications in Urban Management

- **Transport:**
  - Smart traffic lights, congestion prediction, ride-sharing optimization.
- **Environment:**
  - Air quality monitoring (PM2.5, CO2 sensors).
  - Noise pollution sensors in industrial areas.
- **Energy & Water:**
  - Smart grids for efficient power distribution.
  - IoT water meters to detect leakages.
- **Public Safety:**
  - Smart surveillance with facial recognition.
  - Emergency response systems (flood sensors, disaster alerts).
- **Waste Management:**
  - Smart bins with fill-level sensors.
  - Route optimization for waste collection trucks.

6. Examples of Urban Sensing in Practice

- **India:**
  - **Delhi** – Air quality sensors under the National Clean Air Programme.
  - **Pune Smart City** – Smart parking sensors, real-time traffic apps.
  - **Surat** – RFID-enabled waste bins and vehicle tracking.
- **Global:**
  - **Singapore** – Nation-wide IoT network for transport and public safety.
  - **Barcelona** – Smart streetlights and environmental sensors.
- **New York City** – LinkNYC kiosks providing free Wi-Fi while collecting urban mobility data

7. Challenges in Urban Sensing & Data Collection

- **Privacy Concerns** – Risk of surveillance misuse and citizen data exploitation.
- **Cybersecurity Risks** – Vulnerability to hacking.
- **High Costs** – Deploying large-scale IoT networks and sensors.
- **Data Overload** – Handling and analyzing massive datasets.
- **Digital Divide** – Unequal participation of citizens in crowdsourced sensing.
- **Interoperability Issues** – Different sensors and systems may not communicate effectively.

8. Future Directions

- **AI-driven Predictive Sensing** → Preventive measures before crises.
- **5G-enabled IoT Networks** → Faster, low-latency data transfer.
- **Blockchain-based Data Security** → Tamper-proof and transparent urban data.
- **Edge Computing** → Processing data near the source to reduce delays.
- **Participatory Sensing** → More citizen involvement in city data collection.

Cloud Computing

- **Definition:**

  Cloud computing is the **delivery of computing services**—such as storage, servers, networking, databases, software, and analytics—**over the internet ("the cloud")**, instead of using local servers or personal devices.

- Users can **access resources on-demand**, scale them easily, and pay only for what they use.

2. Characteristics of Cloud Computing

- **On-Demand Self-Service** – Users can access resources (servers, storage) whenever needed.
- **Broad Network Access** – Available via internet-enabled devices (laptops, mobiles).
- **Resource Pooling** – Multiple users share resources dynamically.
- **Rapid Elasticity** – Resources can be scaled up/down instantly.
- **Measured Service** – Pay-as-you-go model (utility-based).

3. Cloud Service Models

- **(a) Infrastructure as a Service (IaaS)**
- Provides **virtualized computing resources** (servers, storage, networking).
- Users manage OS, applications, and data, while provider manages infrastructure.
- Examples:
  - Amazon Web Services (AWS) EC2
  - Microsoft Azure Virtual Machines
  - Google Compute Engine

- **(b) Platform as a Service (PaaS)**
- Provides a **platform for application development** without managing underlying infrastructure.
- Includes OS, runtime, middleware, and development tools.
- Examples:
  - Google App Engine
  - Microsoft Azure App Service
  - Heroku

- **(c) Software as a Service (SaaS)**
- Ready-to-use **applications delivered over the internet**.
- Users don’t worry about installation, updates, or maintenance.
- Examples:
  - Gmail, Google Drive
  - Microsoft Office 365
  - Salesforce CRM

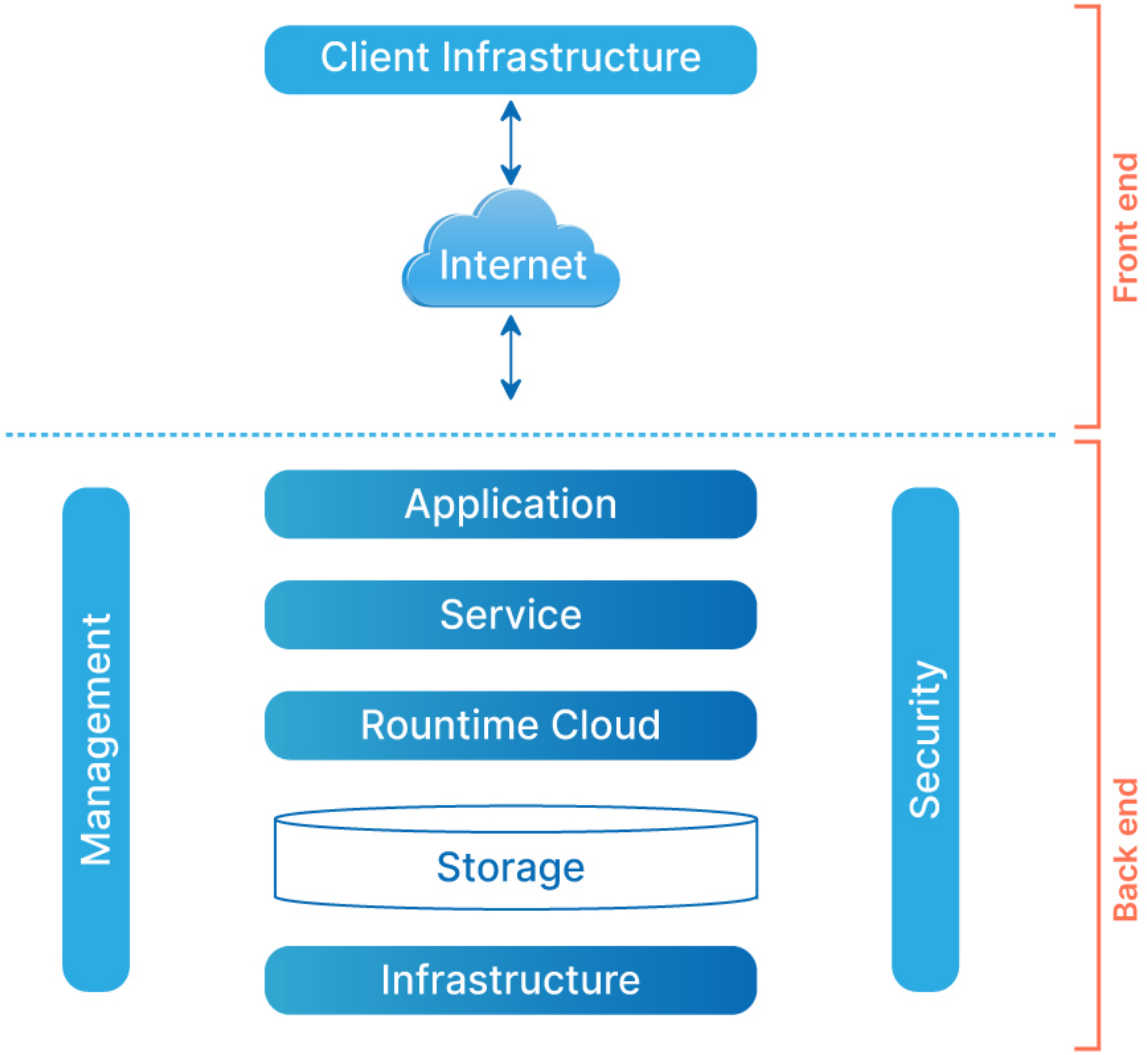
4. Cloud Deployment Models

- **Public Cloud** – Services offered over the internet by third-party providers. (e.g., AWS, Google Cloud).
- **Private Cloud** – Cloud infrastructure used exclusively by one organization (secure, but costly).
- **Hybrid Cloud** – Combination of public + private cloud (flexibility + security).
- **Community Cloud** – Shared by multiple organizations with common needs (e.g., government or healthcare).

5. Cloud Architecture Components

- **Front-end:** Client devices (browsers, apps).
- **Back-end:** Cloud servers, databases, storage.
- **Middleware:** Ensures connectivity and communication.
- **Virtualization Layer:** Creates multiple virtual machines from one physical server.
- **Management Tools:** Resource allocation, monitoring, billing.

ARCHITECTURE OF CLOUD COMPUTING



6. Applications of Cloud Computing

- **Business & IT:** Data storage, collaboration tools, ERP systems.
- **Education:** Online learning platforms, virtual labs, MOOCs (Coursera, Google Classroom).
- **Healthcare:** Telemedicine, patient records on cloud, AI-based diagnosis.
- **Smart Cities:** IoT data storage, traffic management, disaster response.
- **Entertainment:** Video streaming (Netflix, YouTube), gaming (Xbox Cloud, Stadia).
- **AI & Big Data:** Training machine learning models on scalable GPUs/TPUs.

7. Advantages of Cloud Computing

- **Cost Efficiency** – No need for costly hardware/software.
- **Scalability & Flexibility** – Resources adjusted as per demand.
- **Accessibility** – Access data/services from anywhere.
- **Disaster Recovery & Backup** – Automatic data replication.
- **Collaboration** – Multiple users can work simultaneously.

8. Challenges of Cloud Computing

- **Security & Privacy Risks** – Data breaches, unauthorized access.
- **Downtime Issues** – Internet dependency.
- **Vendor Lock-In** – Hard to migrate between providers.
- **Compliance & Legal Issues** – Data residency laws (GDPR, Indian IT Act).
- **Limited Control** – Users depend on providers for infrastructure management.

9. Future Trends in Cloud Computing

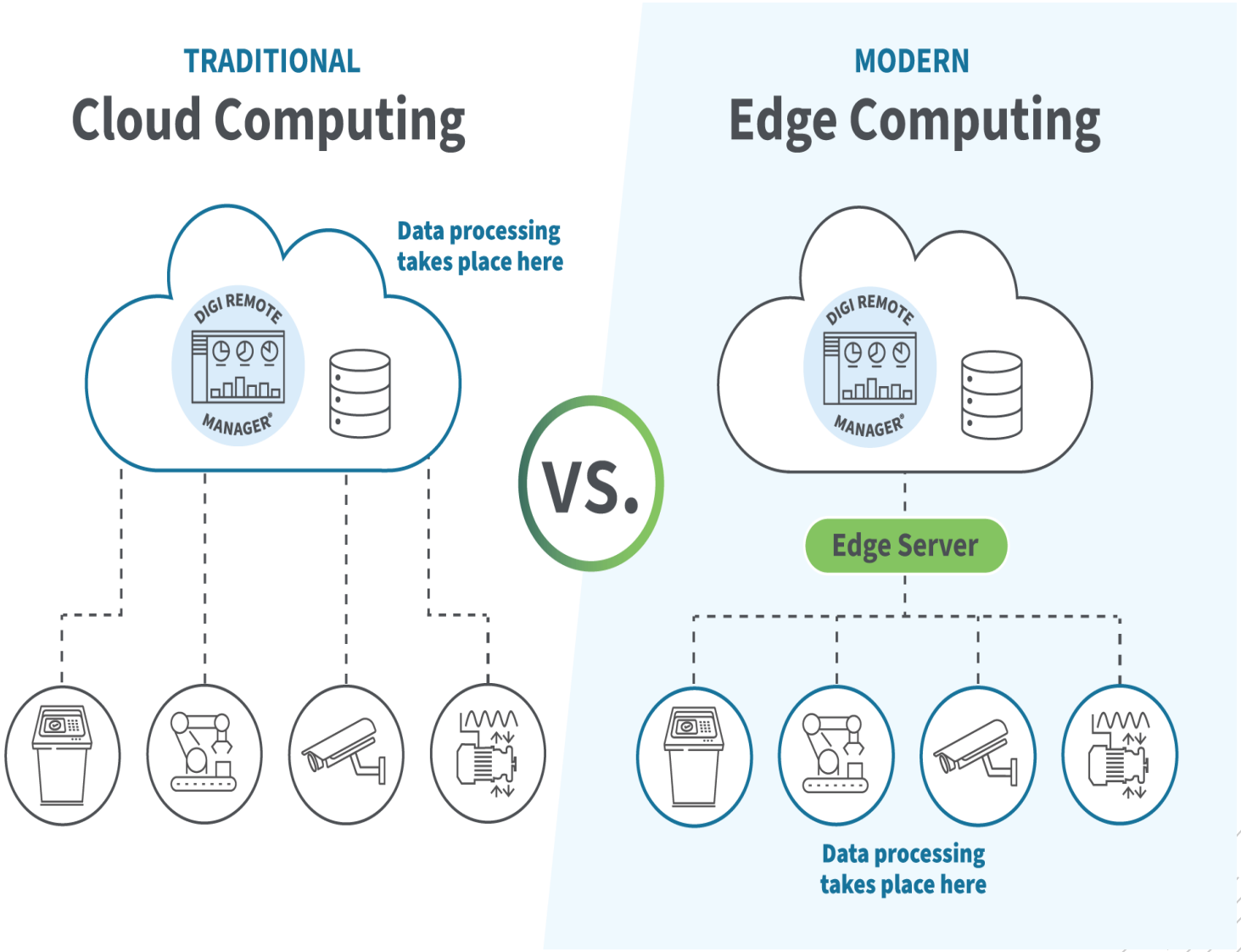
- **Edge Computing** – Processing closer to data source (IoT devices).
- **Serverless Computing** – Developers focus on code, cloud manages servers automatically.
- **AI + Cloud Integration** – AI-driven analytics, automation.
- **Quantum Cloud Computing** – Next-gen computing power for complex problems.
- **Green Cloud** – Eco-friendly data centers using renewable energy.

Edge Computing

- Edge computing refers to **processing data closer to where it is generated** (near IoT devices and sensors) rather than sending everything to a distant cloud server.
- "Edge" = location near the **data source** (e.g., local servers, gateways, routers, or micro-data centers).

Key Features

- **Low Latency** – Immediate processing reduces delays in applications like traffic signals or autonomous vehicles.
- **Bandwidth Optimization** – Reduces unnecessary data transfer to cloud, sending only critical insights.
- **Real-time Decision Making** – Useful for emergency response systems, healthcare monitoring, and smart grids.
- **Security & Privacy** – Sensitive data can be processed locally without always being transmitted to cloud.


TRADITIONAL
Cloud Computing
Data processing takes place here
DIGI REMOTE MANAGER®
VS.
MODERN
Edge Computing
DIGI REMOTE MANAGER®
Edge Server
Data processing takes place here

How does edge computing work?

- To make real-time functionality possible for smart apps and IoT sensors, edge computing solves three interrelated challenges:

- Connecting a device to a network from a remote location.

- Slow data processing due to network or computing limitations.

- Edge devices causing network bandwidth issues.

Applications in Smart Cities

- **Traffic Management**: Cameras and sensors at intersections process video feeds locally to adjust signals in real-time.
- **Smart Grids**: Electricity usage data processed at the edge to balance load instantly.
- **Public Safety**: Local video analytics in CCTV networks to detect unusual activities.
- **Healthcare**: Wearable health monitors process patient data at edge gateways before sending critical alerts.

Edge computing vs Cloud Computing

Parameter	Edge Computing	Cloud Computing
Definition	Edge Computing is a distributed computing architecture that brings computing and data storage closer to the source of data.	Cloud Computing is a model for delivering information technology services over the internet.
Location of Processing	Processing is done at the edge of the network, near the device that generates the data.	Data Analysis and Processing are done at a central location, such as a data center.
Bandwidth Requirements	Low bandwidth is required, as data is processed near the source.	Higher bandwidth is required as compared to edge computing, as data must be transmitted over the network to a central location for processing.

Costs	Edge Computing is more expensive, as specialized hardware and software may be required at the edge.	Cloud Computing is less expensive, as users only pay for the resources they actually use.
Scalability	Scalability for Edge Computing can be more challenging, as additional computing resources may need to be added at the edge.	Easier, as users can quickly and easily scale up or down their computing resources based on their needs.
Use Cases	Applications that require low latency and real-time decision-making, such as IoT devices, autonomous vehicles, and AR/VR systems.	Applications that do not have strict latency requirements, such as web applications, email, and file storage.
Data Security	Data security can be improved, as data is processed near the source and is not transmitted over the network.	Data Security is more challenging, as data is transmitted over the network to a central location for processing.

Data Centers in Smart Cities

•A data center is a **facility equipped with computing resources, storage, and networking infrastructure** to store and process city-wide data.

•In smart cities, data centers act as the **backbone for cloud services, AI analytics, and centralized data storage**.

Types of Data Centers for Smart Cities

- **Centralized Cloud Data Centers**
- Large-scale, located outside or inside the city.
- Handle heavy computation, long-term storage, and city-level analytics.

- **Edge Data Centers (Micro Data Centers)**
- Smaller facilities located close to IoT devices and users.
- Support latency-sensitive and localized services.

- **Hybrid Data Centers**
- Combine central cloud and edge facilities.
- Balance between **real-time response** (edge) and **big data analytics** (central cloud).

Role in Smart Cities

- **Data Integration**: Collects data from IoT devices, sensors, mobile apps, and city services.
- **AI & Machine Learning**: Provides computing power for predictive analytics (traffic prediction, energy optimization).
- **Disaster Recovery & Backup**: Ensures continuity of critical services.
- **Cybersecurity Hub**: Manages firewalls, intrusion detection, and data protection.

Relationship between Edge Computing and Data Centers

- Edge computing **does not replace** data centers—it complements them.
- **Edge Layer**: Processes time-sensitive, localized data.
- **Data Center Layer**: Performs deep analytics, large-scale storage, and cross-city data integration.
- Together, they create a **multi-layered architecture** for smart cities.

- **Example (Traffic Management)**
- **Edge Node**: Detects congestion via local cameras → adjusts nearby traffic lights instantly.
- **Data Center**: Collects long-term traffic patterns → optimizes city-wide traffic planning.

Cybersecurity and Privacy Challenges in Smart City Infrastructures

•A **smart city** integrates digital technologies (IoT devices, sensors, AI, data centers, cloud/edge computing, and communication networks) to provide efficient services.

•While this interconnected infrastructure improves quality of life, it also creates **new cybersecurity and privacy risks**.

•A single cyberattack can disrupt essential services such as **power supply, healthcare, transport, or water systems**.

Key Cybersecurity Challenges in Smart Cities

- **(a) Attack Surface Expansion**
- Billions of IoT devices and sensors are deployed in smart cities.
- Each connected device is a **potential entry point** for hackers.
- Example: Hackers exploiting weak smart traffic sensors to manipulate signals.

(b) Data Breaches

•Smart cities collect **sensitive citizen data** (health, financial transactions, location data).

•Poor encryption or misconfigured databases can expose personal information.

•Example: Leakage of CCTV footage or healthcare IoT device data.

- **(c) Critical Infrastructure Attacks**
- Power grids, water systems, and transport are prime targets for **cyberterrorism**.
- Attacks can lead to **blackouts, traffic chaos, or water contamination**.
- Example: 2021 Florida water treatment plant cyberattack (hackers tried to poison the water supply).

(d) Ransomware and Malware

•Attackers can lock down city systems and demand ransom.

•Example: Ransomware attack on Atlanta city government (2018) disrupted court, police, and utility services.

- **(e) Distributed Denial of Service (DDoS) Attacks**
- Large-scale IoT devices can be hijacked into a **botnet** to overwhelm smart city servers.
- Example: The Mirai botnet (2016) used compromised IoT cameras to launch massive DDoS attacks.

(f) Legacy Systems and Integration Issues

•Many cities still use **outdated IT infrastructure** combined with new IoT devices.

•This creates compatibility gaps and **weak security points**.

Privacy Challenges in Smart Cities

- **(a) Mass Surveillance**
- CCTV cameras, facial recognition, and smart sensors may lead to **constant monitoring** of citizens.
- Raises ethical questions about **loss of anonymity** in public spaces.

- **(b) Location Tracking**
- Mobile apps, GPS sensors, and smart transport systems continuously track **where people go**.
- Risk of misuse for profiling or surveillance beyond consent.

- **(c) Data Ownership and Consent**
- Citizens often **do not know who owns their data** (government, private companies, or cloud providers).
- Lack of transparency in **how data is collected, stored, and shared**.

- **(d) Risk of Re-identification**
- Even anonymized datasets can be cross-matched with other data sources to **re-identify individuals**.

- **(e) Lack of Strong Legal Framework**
- Many countries lack comprehensive **data protection and privacy laws** for smart city data usage.
- Example: GDPR in Europe offers protection, but many developing nations lack equivalent frameworks.

- **Case Studies**
- **Barcelona Smart City** – faced criticism over surveillance and citizen data handling.
- **Singapore's Smart Nation** – raised privacy concerns with nationwide facial recognition and tracking.
- **India's Aadhaar-linked smart services** – security breaches exposed sensitive personal information.

Mitigation Strategies

- **Cybersecurity**
- **End-to-End Encryption** for IoT communications.
- **Zero Trust Architecture (ZTA)** – "Never trust, always verify" for all devices and users.
- **Regular Security Audits** and penetration testing.
- **AI-driven Intrusion Detection Systems (IDS)** to monitor unusual activities.
- **Redundancy and Backup Systems** to ensure continuity during attacks.
- **Privacy**
- **Data Minimization** – Collect only necessary citizen data.
- **Anonymization & Pseudonymization** techniques.
- **Clear Consent Mechanisms** for citizens when using smart services.
- **Legal and Policy Frameworks** – Data Protection Laws (e.g., India's Digital Personal Data Protection Act, 2023).
- **Citizen Awareness Programs** on data rights and privacy.

Previous Year Papers

Student Name: .....

Enrollment No: .....

DS/ML/1107

Mid-Term Examination – October 2024

Programme: B. Tech (AIDS/AIML/IIOT) | **Semester: Seven Semester (Aug. 2024 - Dec 2024)**

Paper Code: 421T | **Paper Name: Digital and Smart Cities**

Time: 1½Hrs. | **Maximum Marks: 30**

Note:
- Question No.1 is compulsory.
- Attempt any two questions from the remaining questions.
- Some questions have internal choice also.

Q. No.	Question 1	Marks	CO
1(a)	Discuss the key technologies needed for smart cities.	[3]	1
1(b)	Explain smart Grid.	[2]	1
1(c)	Enlist the advantages of edge computing.	[3]	2
1(d)	Discuss the various data collection technologies.	[2]	2
	Question 2		
2(a)	Explain the concept of smart city and requirement of smart cities. **OR** Explain the five characteristics of smart cities.	[5]	1
2(b)	Discuss the role of AI, Machine Learning (ML), and the Internet of Things (IoT) in smart city.	[5]	1
	Question 3		
3	What role does cloud and edge computing play in enhancing the digital infrastructure of smart cities? **OR** What are the cybersecurity and privacy challenges in smart city, and how can they be mitigated?	[10]	2
	Question 4		
4	Write short notes on (i) Intelligent Transport System (ITS) (ii) Big Data in Smart Cities (iii) Denial of Services (DoS).	[10]	1, 2

(Please write your Exam Roll No.) Exam Roll No. 0761441(81)

END TERM EXAMINATION

SEVENTH SEMESTER (B.TECH) DECEMBER-2024

Paper Code: OAE-421T **Subject: Digital & Smart Cities**

Time: 3 Hours **Maximum Marks: 75**

Note: Attempt any five questions as directed including Q. No.1 which is compulsory. Internal choice is indicated.

Q1 Attempt **any five** of the following questions: **(5x5=25)**

(a) Define a smart city and its need in today's world?

(b) What are the components of a smart city infrastructure, and how do they interact?

(c) What are the benefits of open data initiatives in smart cities?

(d) Discuss the potential of AI and IoT in improving healthcare delivery in smart cities.

(e) Explain how AI and IoT can be utilized to enhance energy efficiency in buildings.

(f) How blockchain can be useful in smart cities, explain with a suitable use case?

(g) What are the ethical implications of using AI and IoT technologies in smart cities?

(h) What are the emerging trends in smart governance and citizen engagement?

Q2 Explain importance of cloud computing, edge computing, and data centers in the context of smart cities. **(12.5)**

OR

Q3 Evaluate the impact of smart city initiatives on quality of life, economic development, and sustainability. **(12.5)**

Q4 Explain the concept of the Internet of Things (IoT) and its role in data collection and analysis for smart cities. **(12.5)**

OR

Q5 Analyze a successful smart city implementation in India, highlighting its key features, challenges, and outcomes. **(12.5)**

Q6 Discuss the role of AI and IoT in optimizing traffic flow and reducing congestion in smart cities. How can real-time data from sensors and cameras be used to improve traffic management? **(12.5)**

OR

Q7 How can smart waste bins, waste tracking systems, and recycling optimization algorithms reduce waste and environmental impact? **(12. 5)**

Q8 How can e-governance initiatives improve the efficiency and transparency of government services? Discuss the role of digital platforms in facilitating citizen-government interactions. **(12. 5)**

OR

Q9 What are the cyber security challenges associated with smart cities? How can we protect sensitive citizen data and critical infrastructure from cyber threats? **(12. 5)**

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