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Internet of Things

Unit 2 - IoT Architecture, Protocols, Devices and Sensors

NCI | Lárionad Néal-Inniúlachta Cloud Competency Centre

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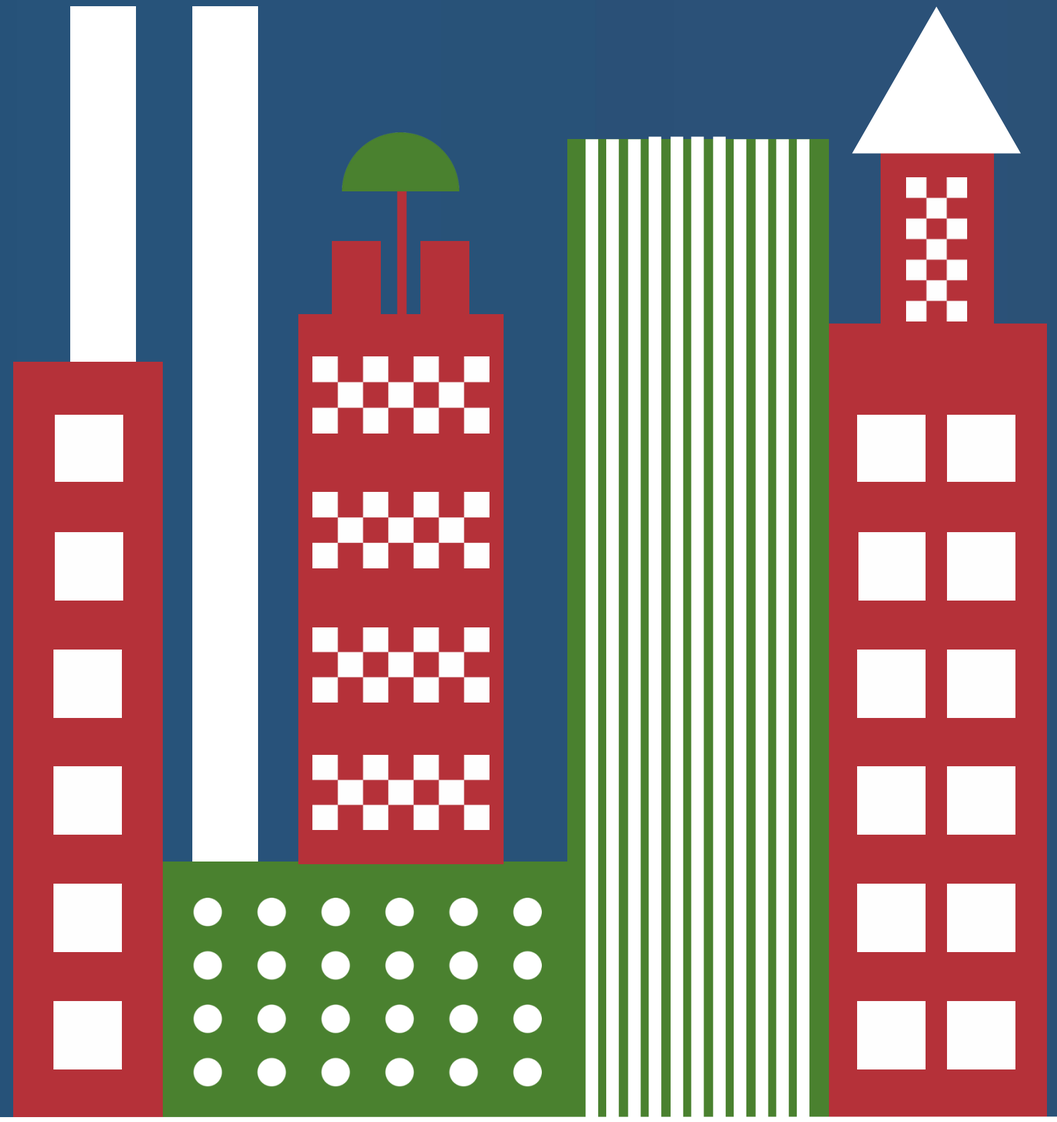

Unit 2 - IoT Architecture, Protocols, Sensors, and Devices

- Introduction to IoT Architectures
- Communication Protocols and Data Management
- Sensors and their Functions
- Applications of IoT
- Challenges of Sensor Security

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IoT Architecture

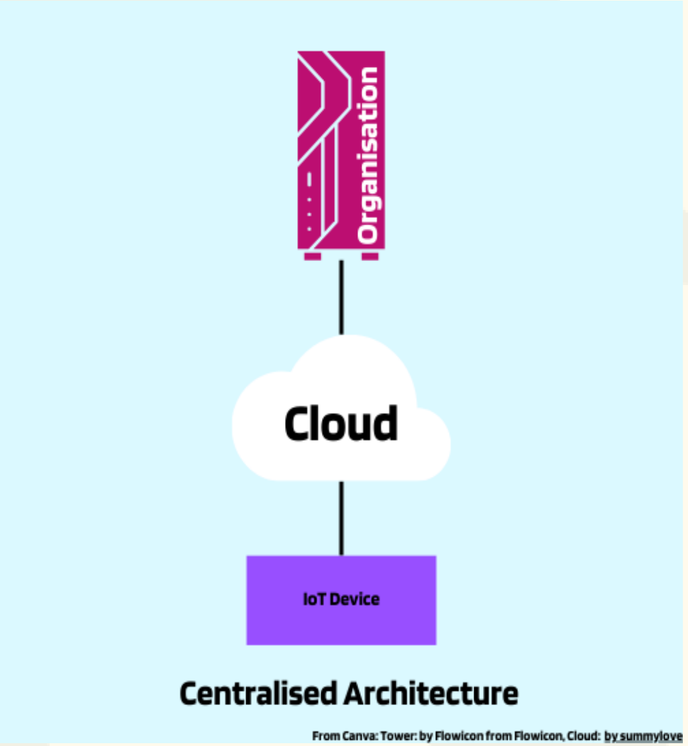
As of yet, there is no single universally accepted standard for IoT Architecture. Broadly speaking, there are two overarching types of architectures, Centralised Architecture and Decentralised Architecture. Within these categories, there are a multitude of architectures emerging and vying to become the standard.

Centralised Architecture

Centralised Architecture refers to a model where an IoT device is fitted with the functionality to communicate directly with a central cloud server or datacentre. With this model, all the data processing, decision-making and storage occurs on the cloud. This can save on initial setup, however these devices can suffer with latency and bandwidth issues.

Decentralised Architecture

Decentralised Architecture involves bringing the processing and automated decision-making closer to the device, such as with an edge and/or fog layer.
Implementation of IoT is often uncoordinated and progresses as opportunities arise. For example, a factory may have started with one IoT device but as time went on had the opportunity to get another for another piece of machinery and another and so on. Hence, IoT is usually dispersed and in need of a distributed, flexible system which can adapt to varying needs and conditions which can be found in the decentralised architecture. However it is important to point out, this system can provide challenges in managing the complexity of the network and also implementing consistent security across the all devices.



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Fog & Edge Computing

Edge Computing

According to Vailshery (2024) Edge Computing was responsible for $217 Billion of global market revenue for 2023 and it's projected to be $350 Billion in 2027.
As described in the name, Edge computing describes computing at the 'edge' of the network. This usually means one hop away from the IoT device, though it's not completely limited to this.

Fog Computing

Fog computing performs many of the same functions as edge computing, including storing and processing data. However, while edge devices are typically located directly at or near the IoT devices (on the edge of the network), fog devices (fog nodes) can be positioned anywhere between the edge and the cloud. It is preferable for fog nodes to be placed close to the IoT devices, but it is not essential for them to be on the very edge of the network.

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Hypertext Transfer Protocol (HTTP)

HTTP is a communication protocol used for transmitting data across the World-Wide Web. It's an application-level protocol that is stateless, meaning each request made by a client to a server is independent and does not retain any information about previous interactions. This design simplifies communication but requires additional mechanisms, such as cookies or session storage, to maintain continuity for tasks like logging in or tracking user activity across multiple requests. It is built on the Transmission Control Protocol (TCP) which provides reliable end-to-end communication over IP-based networks. This ensures the integrity of the data during transmission over HTTP.

A drawback of HTTP however, is that it transmits data in plain-text, meaning the data is not encrypted as it’s transmitted and so, if intercepted the data is easily stolen.

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Hypertext Transfer Protocol Secure (HTTPs)

Like HTTP, HTTPS transmits data over the web, however HTTPS uses Transport Layer Security (TLS) or Secure Sockets Layer (SSL) to encrypt data during transmission.

It is essential to an organisations security that data is transmitted over HTTPS.

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IoT Data Flow (Device to Application)

Sensors and Devices

Data Sensing and Acquisition

Network and Protocols

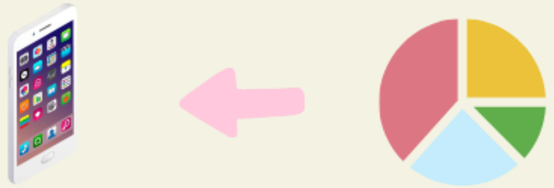
Data Transmission

Middleware

Data Processing and Filtering

Cloud Storage

Data Storage



Applications/End User

Application and User Interface

Data Analysis

Data Analysis and Storage

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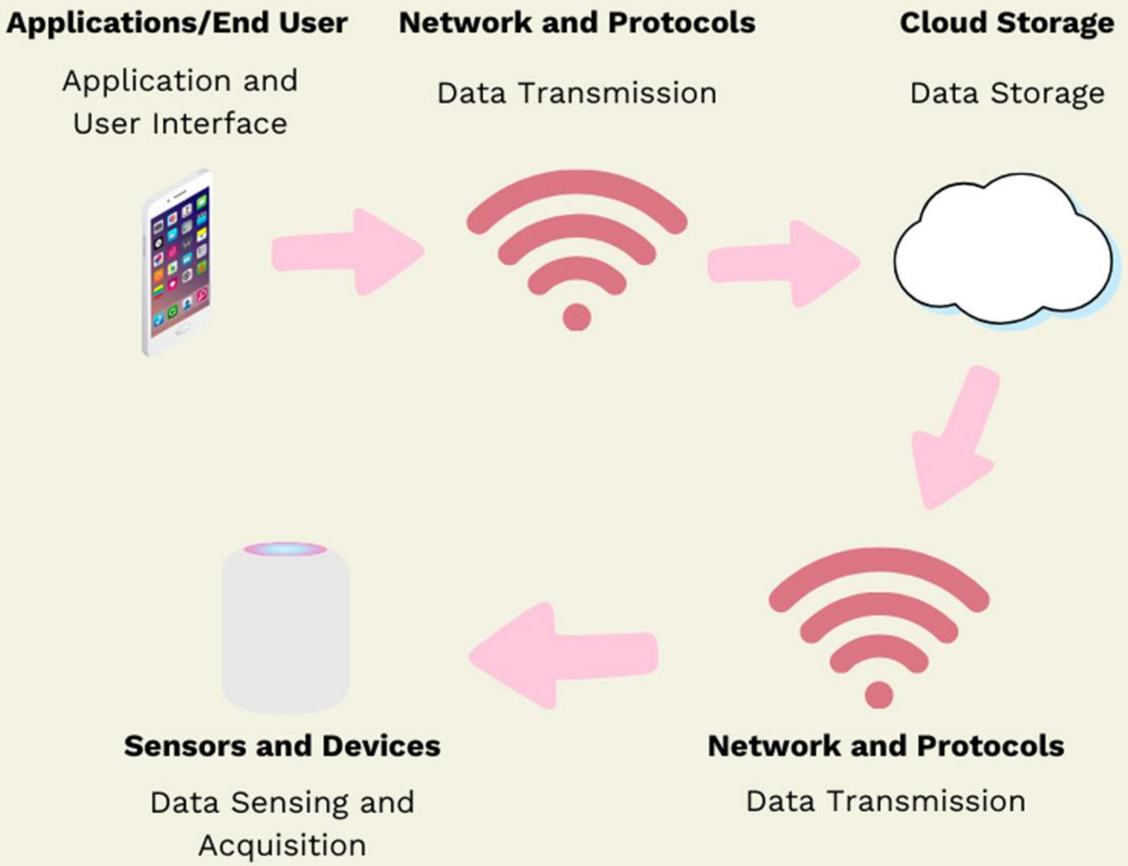
IoT Data Flow (Application to Device)



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Challenges in Data Management for IoT

Data Heterogeneity

The lack of a standardised approach to viewing, organising, or interpreting data.

Governance and Access Controls

Challenges in implementing consistent policies for data access and management.

Security

Risks of unauthorised access to sensitive data.

Compliance

The need to adapt to evolving regulatory requirements.

Standardisation

Absence of uniform data management, exchange, and storage mechanisms.

Database Limitations

Restrictive capabilities of existing database management systems.

Naming Conventions

Lack of standardised frameworks for naming and organising data elements.

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Supporting IoT: Platforms and Frameworks

Cloud Platforms

FiWare

OneM2M

Middleware Platforms

Edge Computing

Fog Computing

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Data Management Techniques

Data Storage Solutions

Systems like AWS S3 or Google Cloud Storage are used to store IoT data, such as temperature readings from smart sensors, ensuring scalability and accessibility for later analysis.

Data Indexing

A database indexing system like Elasticsearch helps quickly locate specific device logs in a smart home network, such as identifying which motion sensor triggered at a given time.

Data Aggregation

Aggregating data from multiple air quality sensors in a city to provide a summarised view of pollution levels by region is an example of this technique.

Data Mining and Analytics

Using tools like Tableau or Microsoft Power BI, retailers analyse IoT data from connected shelves to predict customer demand and optimise inventory.

Data Modelling Languages

JSON or XML is used to define the structure of smart home device data, such as specifying the format for temperature and humidity readings sent from IoT sensors.

Service-Oriented Architecture

A smart factory might use SOA to connect separate services, such as quality control cameras and inventory systems, into a unified workflow for efficient production.

Distributed Data Management

In a smart agriculture system, data from sensors deployed across multiple farms is managed across different servers to ensure local access and global coordination.

Data Stream Management

Real-time analytics platforms like Apache Kafka process live video feeds from traffic cameras to detect congestion and relay insights to city control centres immediately.

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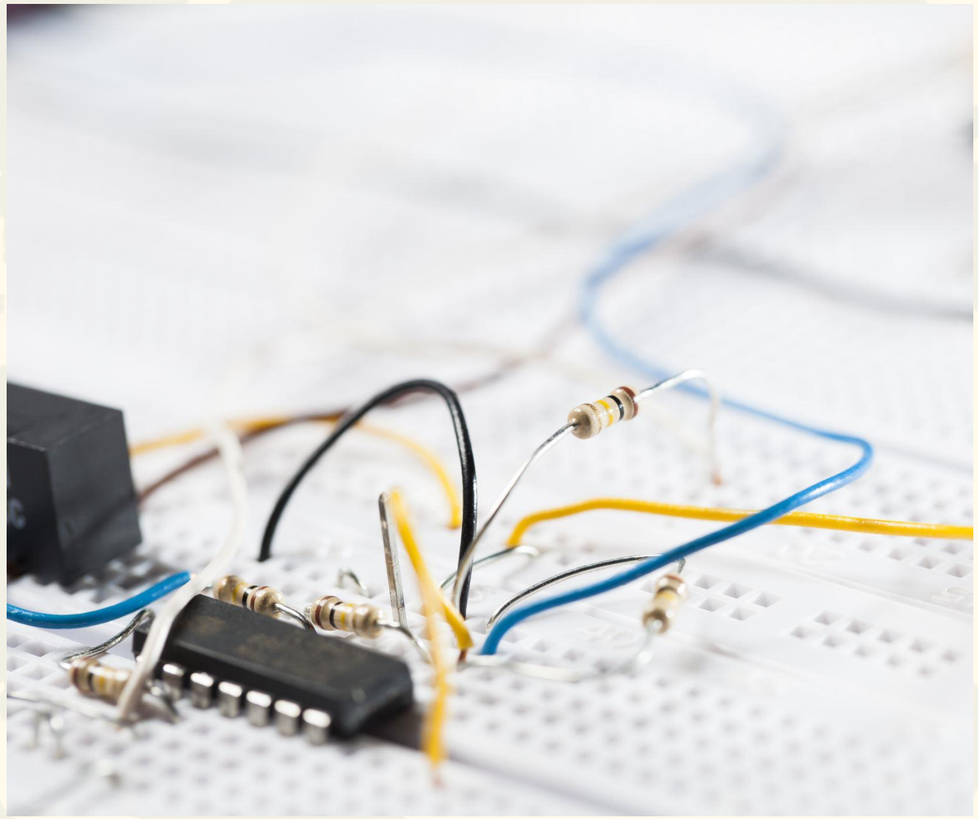
Sensors and Devices

Sensors and devices are the eyes, ears, and hands of the IoT ecosystem. They collect data from the environment, enable communication between physical and digital systems, and drive actionable insights. From smart thermostats in your home to industrial sensors in manufacturing plants, these components are the backbone of IoT applications.



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IoT Sensor Data Collection: The Sensing Layer

How IoT Sensors Work

01

Sensors convert physical phenomena into electrical signals.

02

Different sensors measure temperature, motion, light, chemical changes, etc.

03

Data is collected at fixed time intervals (acquisition frequency).

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Passive vs. Active Sensors

Types of Sensors Based on Power Needs

Passive Sensors	Active Sensors
No power source needed	Requires external power
Simply detect & measure	Emit signals & analyse responses
Example: Thermistor (Temperature Sensor)	Example: LiDAR (Proximity Sensor)

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Smart Sensors & Pre-Processing

Basic Sensors

- Send raw data to a processing unit.

Smart Sensors

- Perform pre-processing before transmission:
- Signal Conditioning (removes noise).
- Embedded Algorithms (analyse patterns).
- Digital Interfaces (prepare data for network transmission).

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What Are Actuators?

Sensors Gather Data, Actuators Perform Actions

Sensors measure changes (e.g., detecting heat)

Actuators respond (e.g., turning on an air conditioner)

Examples of Actuators:

💡 **Smart Lights:**	🚜 **Automated Irrigation:**	🔒 **Smart Locks:**
Turn on/off based on motion detection.	Adjusts water flow based on soil moisture sensors.	Unlocks doors based on RFID/NFC sensors.

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Acquisition Frequency in IoT Sensors

How Often Do Sensors Collect Data?

Acquisition Frequency is the rate at which sensors take measurements.

High-Frequency Sensors

Used for real-time monitoring (e.g., heart rate monitors, industrial sensors).

Low-Frequency Sensors

Used for occasional updates (e.g., weather monitoring, air quality sensors).

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Real-World Applications of IoT Sensors

Smart Cities	Traffic, air quality monitoring
Smart Agriculture	Soil moisture, crop health
Smart Homes	Temperature, motion, security sensors
Self-Driving Cars	Lidar, proximity sensors
Industrial IoT	Predictive maintenance, automation

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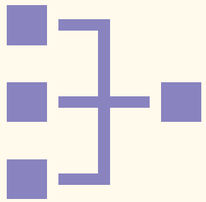
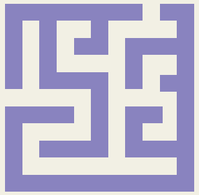
Why Are Security & Reliability Critical in IoT Sensors?



IoT sensors are widely used in critical systems (smart cities, healthcare, homes).

They face security threats, interoperability issues, and data management challenges.



Securing IoT devices is complex due to resource constraints & lack of universal standards.

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Challenges in IoT Sensor Deployments

What Makes IoT Sensor Systems Difficult to Manage?

- **Heterogeneity & Interoperability**: Different sensor manufacturers, lack of universal standards.
- **Scalability Issues**: Large-scale networks increase security risks & performance issues.
- **Limited Resources**: Low-power devices struggle to run strong security protocols.
- **Data Management& Environmental Complexity**: Huge data volumes make storage & processing difficult.
- **Mobility Factors**: Harsh environments & mobile networks cause reliability issues.
- **Energy Efficiency Concerns**: Wireless IoT devices need low-power solutions.
- **Real-Time Processing Demands**: Some IoT applications require instant data analysis.

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