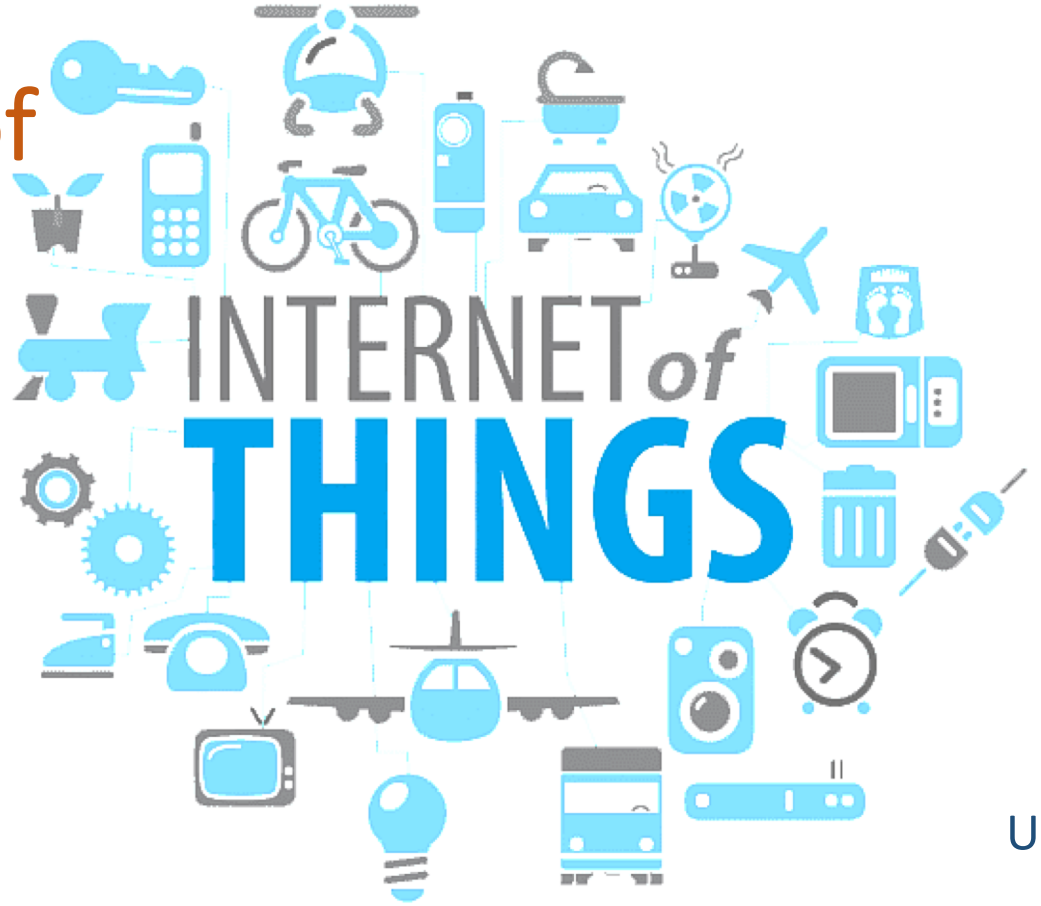
Architecture of



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Introduction to IoT Architecture

- The **IoT (Internet of Things) architecture** is typically organized into **layers,** each responsible for a specific set of functions that enable devices (“things”) to sense, communicate, process, and act upon data.

Goals of IoT Architecture

1. Connect billions of heterogeneous (different) devices.
2. Enable **communication** between sensors, gateways, and cloud services.
3. Ensure **scalability**, **security**, and **real-time processing**.
4. Provide **data-driven decision-making** through analytics.

Key Components of IoT Architecture

- **Sensors / Actuators**
  - Capture real-world data or perform actions.
- **Microcontrollers / Processors**
  - Process collected data (Arduino, Raspberry Pi).
- **Communication Technologies**
  - Wi-Fi, ZigBee, LoRa, 4G/5G, Bluetooth.
- **Protocols**
  - MQTT, CoAP, HTTP, TCP/IP.
- **Data Storage and Processing**
  - Cloud servers, Edge/Fog computing.
- **Applications**
  - Mobile or web platforms for visualization and control.

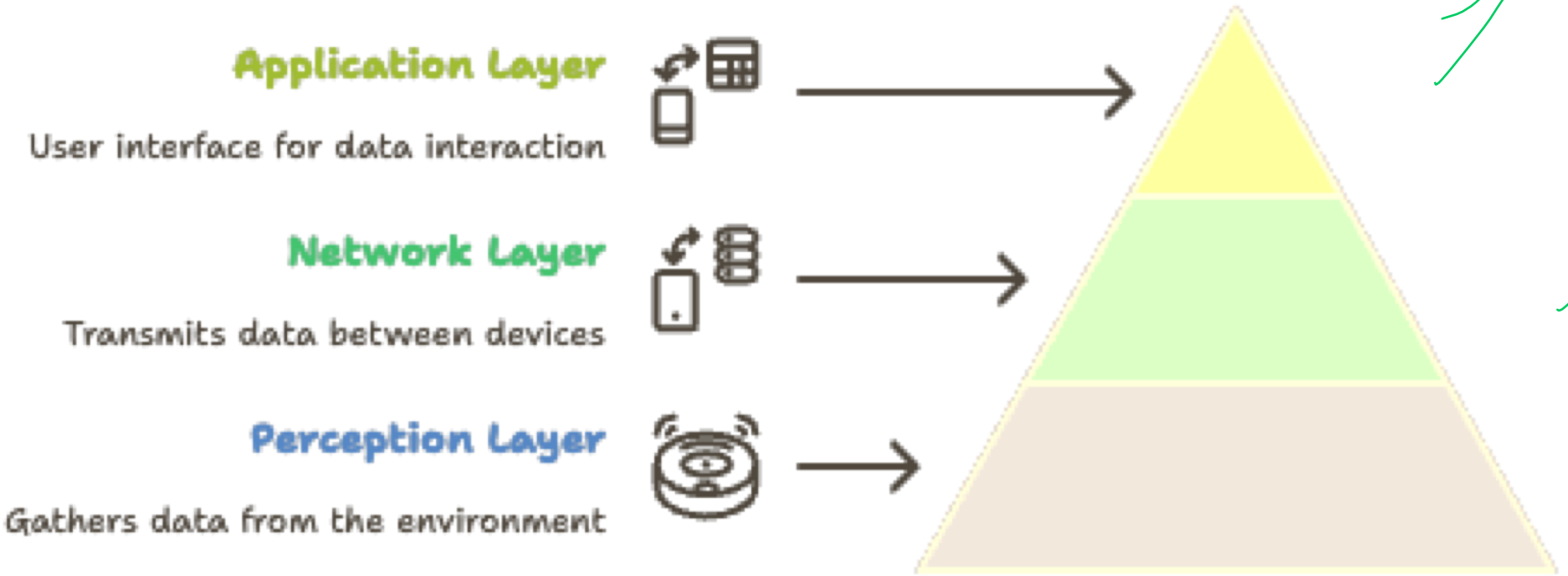
IoT Architectures models

- IoT systems can have different numbers of layers depending on complexity and function.
- Common models
  - **Three-Layer Architecture**
  - **Four-Layer Architecture**
  - **Five-Layer Architecture**

Three-Layer IoT Architecture (Cont.)

- The **three-layer architecture** is the **basic model** of IoT.
- It defines how IoT systems collect data, transfer it, and provide useful services to end-users.
- **Layers**
  1. **Perception Layer (Sensing Layer)**
  2. **Network Layer**
  3. **Application Layer**

Three-Layer IoT Architecture (Cont.)

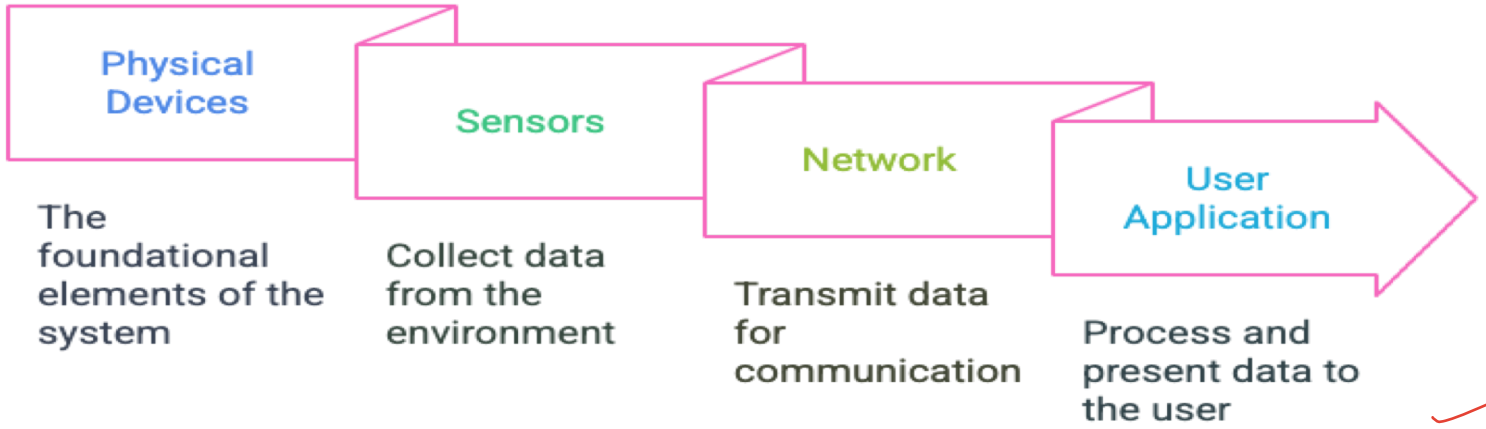


Three-Layer IoT Architecture (Cont.)

1. **Perception Layer (Sensing Layer)**
   - Detects and collects physical data (temperature, motion, humidity).
   - Devices: Sensors, RFID tags, GPS, cameras.
2. **Network Layer**
   - Transfers data from sensors to servers/cloud.
   - Technologies: Wi-Fi, Bluetooth, ZigBee, 4G/5G, LoRaWAN.
3. **Application Layer**
   - Delivers services to users.
   - Technologies: Mobile apps, dashboards
   - Examples: Smart homes, healthcare, smart cities.

Three-Layer IoT Architecture

- **Data flow**

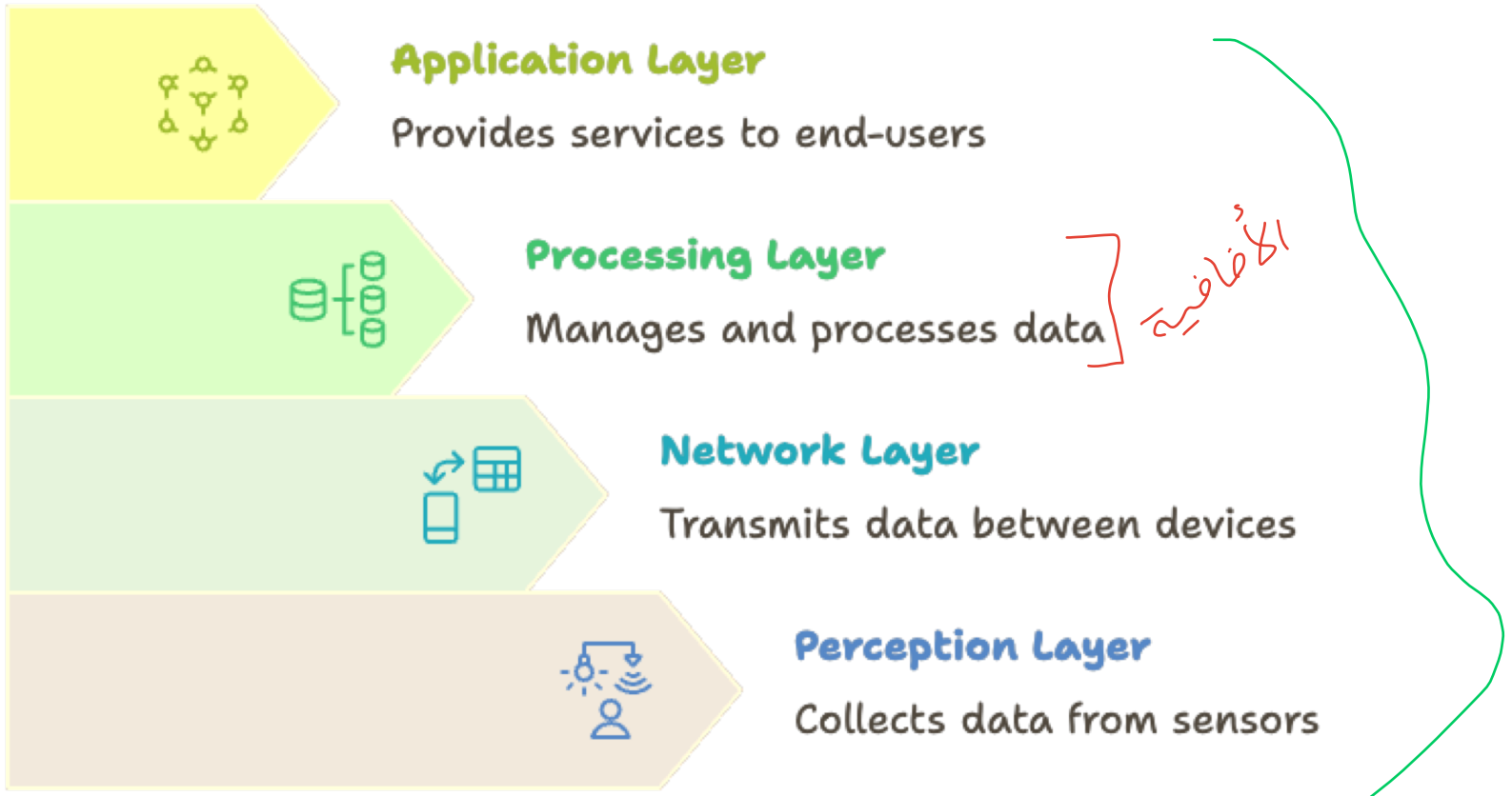


- **Example**
  - Smart thermostat measures temperature → sends data via Wi-Fi → mobile app displays room temperature and allows control.

Four-Layer IoT Architecture (Cont.)

- The **Four-Layer IoT architecture** is a more **refined model** than the basic three-layer structure.
- It introduces a **Processing Layer**, which manages and analyzes data before it reaches the user.
- **Layers**
  1. **Perception Layer (Sensing layer)**
  2. **Network Layer**
  3. **Processing Layer**
  4. **Application Layer**

Four-Layer IoT Architecture (Cont.)



Four-Layer IoT Architecture (Cont.)

1- Perception Layer (Sensing layer)

- Collects data from the physical environment.
- Detects changes such as temperature, light, motion, or location.
- Converts physical signals to digital data.
- Devices: Sensors, RFID tags, cameras, GPS, actuators

Four-Layer IoT Architecture (Cont.)

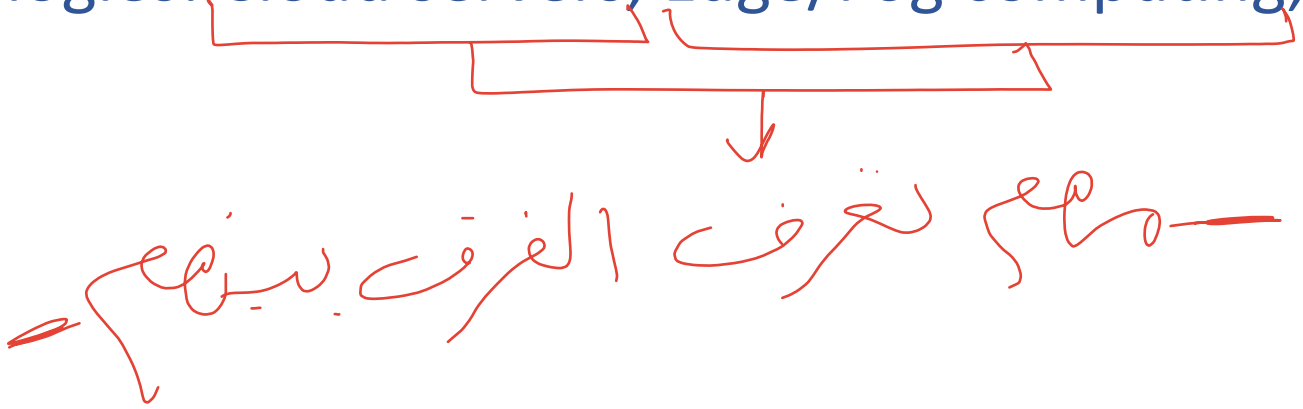
2- Network Layer

- Transmits sensed data securely to other devices, gateways, or servers.
- Uses communication technologies and network protocols.
- Technologies: Wi-Fi, Bluetooth, ZigBee, 4G/5G, LoRaWAN, Ethernet

Four-Layer IoT Architecture (Cont.)

3- **Processing Layer**

- Stores, processes, and analyzes the received data.
- Makes decisions or runs algorithms (AI, machine learning, cloud computing).
- Technologies: Cloud servers, Edge/Fog computing, Databases



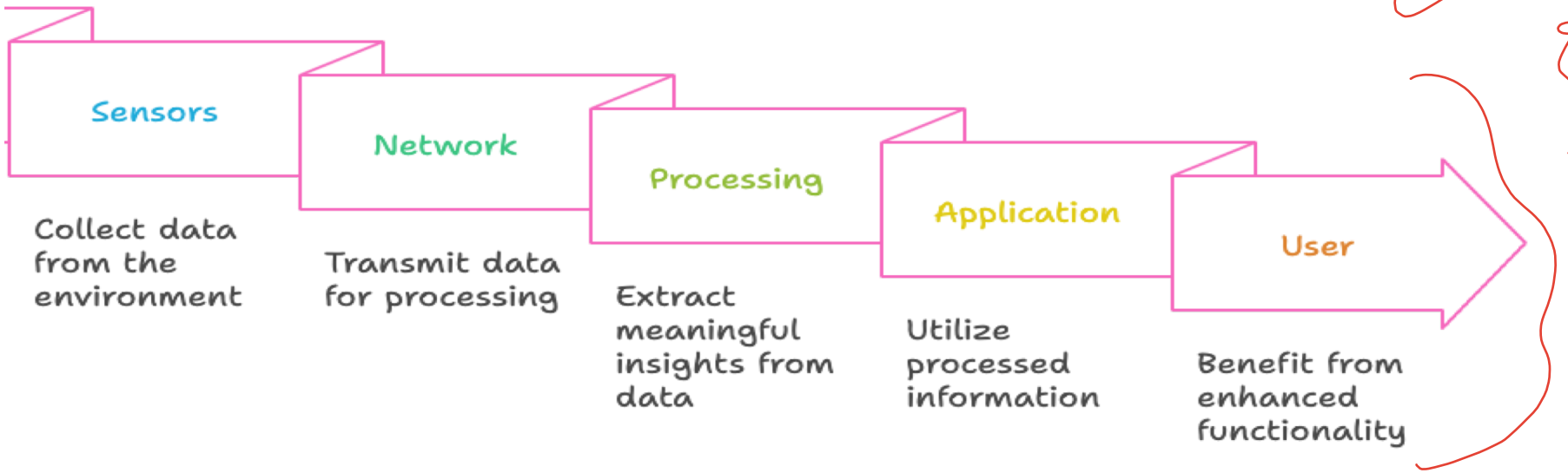
Four-Layer IoT Architecture (Cont.)

4- **Application Layer**

- Provides IoT-based services and interfaces to end-users.
- Converts analyzed data into meaningful applications.
- Examples: Smart homes, Smart cities, Healthcare monitoring, Industrial automation

Four-Layer IoT Architecture

- **Data flow**

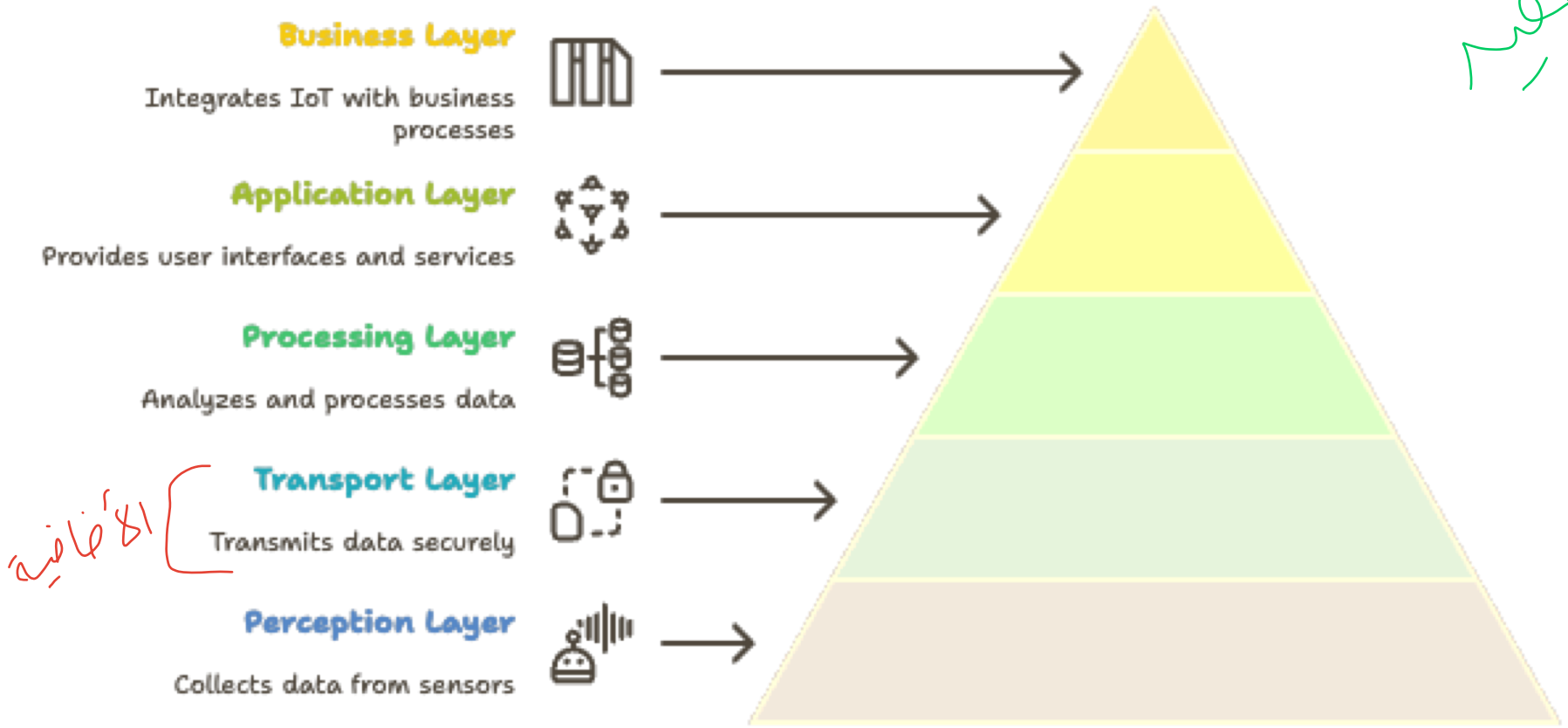


- **Example**
  - Smart parking system detects free slots → transmits data via 4G/5G → cloud analyzes availability → mobile app shows open parking spots.

Five-Layer IoT Architecture (Cont.)

- The **Five-Layer IoT Architecture** is the most **comprehensive model**, commonly used for **large-scale and complex IoT systems**.
- **Layers**
  1. **Perception Layer**
  2. **Transport Layer**
  3. **Processing Layer**
  4. **Application Layer**
  5. **Business Layer**

Five-Layer IoT Architecture (Cont.)



Five-Layer IoT Architecture (Cont.)

1. Perception Layer

- Sensing and collecting data.
- Detects physical parameters using sensors, RFID, cameras, GPS.
- Converts physical signals into digital data.
- **Example**
  - Temperature sensors in a smart building measure room conditions.

Five-Layer IoT Architecture (Cont.)

2. Transport Layer

- Transfers data from devices to processing servers.
- Ensures reliable and secure communication.
- Technologies and protocols: 5G, LoRaWAN, TCP/IP, and MQTT.
- **Example**
  - Smart meters send electricity usage data via LoRaWAN to cloud servers.

Five-Layer IoT Architecture (Cont.)

3- Processing Layer

- Stores and analyzes incoming data using cloud computing, edge computing, and big data analytics.
- Supports AI and machine learning for intelligent decision-making.
- Manages device interoperability and data aggregation.
- **Example**
  - Cloud server analyzes energy consumption for optimization.

Five-Layer IoT Architecture (Cont.)

4- Application Layer

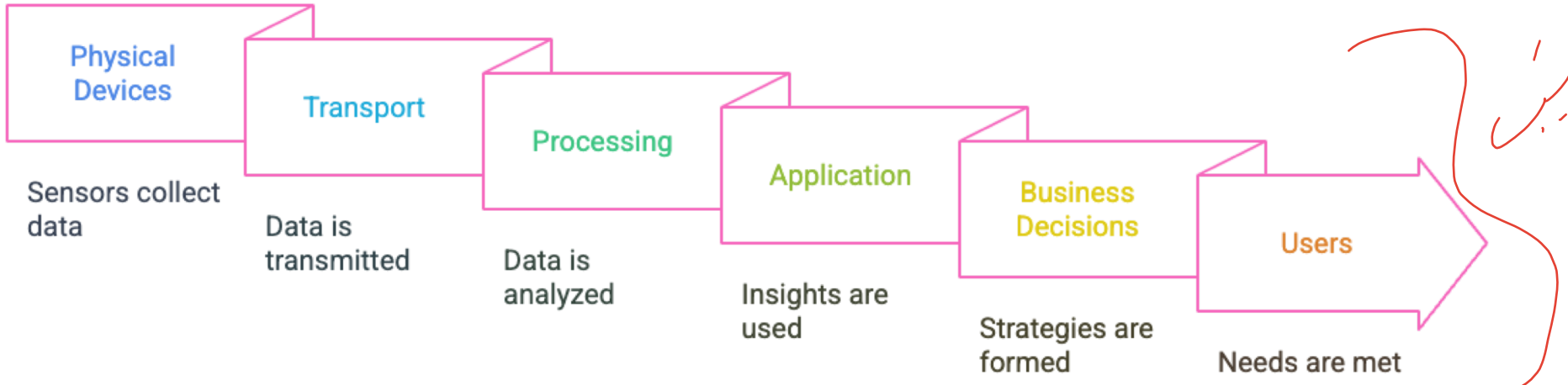
- This layer provides **specific IoT services and applications** tailored for users or businesses.
- It converts **processed data into actionable insights or automated control**.
  - Provides dashboards, mobile apps, or web platforms.
  - Executes control actions (e.g., turning devices ON/OFF automatically).
  - Sends notifications or warnings based on data analysis.
  - Adjusts functionality according to industry needs.
- **Examples**
  - Smart Home, Healthcare, Smart City, Industrial IoT (IIoT), Agriculture.

Five-Layer IoT Architecture (Cont.)

- **5. Business Layer**
  - Manage **business models, system policies, and strategies**.
  - Handles **privacy, security, and data governance**.
  - Integrates IoT data into decision-making for organizations or governments.
  - Technologies: Dashboards, AI reports
  - **Example**
    - Smart city authorities use energy consumption data to plan infrastructure investments.

Five-Layer IoT Architecture

- **Data flow**



- **Example**
  - Smart city air quality sensors → data sent via LoRaWAN → cloud analyzes pollution → city dashboard displays info → authorities plan pollution control measures.

Comparison of IoT architectures

Feature	3-Layer Architecture	4-Layer Architecture	5-Layer Architecture
Layers	Perception, Network, Application	Perception, Network, Processing, Application	Perception, Transport, Processing, Application, Business
Complexity	Simple	Moderate	Complex
Data Processing	Minimal	Moderate (processing layer added)	Advanced (processing and business layer)
Scalability	Medium	High	Very High
Use Case	Small IoT systems (home automation)	Medium-scale IoT (smart agriculture, smart cities)	Large-scale IoT (smart cities, industry, healthcare)
Advantages	Easy to implement	Better data management	Full control, business decision support, high scalability

Comparison of data flow IoT architectures

Architecture	Data Flow
3-Layer	Sensors → Network → Application → User
4-Layer	Sensors → Network → Processing → Application → User
5-Layer	Sensors → Transport → Processing → Application → Business/User

Other advanced Architectures

Architecture	Description / Focus	Use Case
6-Layer Model	Adds middleware and management layers for interoperability and security	Industrial IoT
Fog/Edge Computing Model	Processes data near devices to reduce latency	Smart traffic, real-time monitoring
SOA-Based Model	Uses web services for modular communication	Cloud IoT systems
AIoT (AI + IoT)	Integrates Artificial Intelligence for smart decision-making	Autonomous vehicles, predictive maintenance

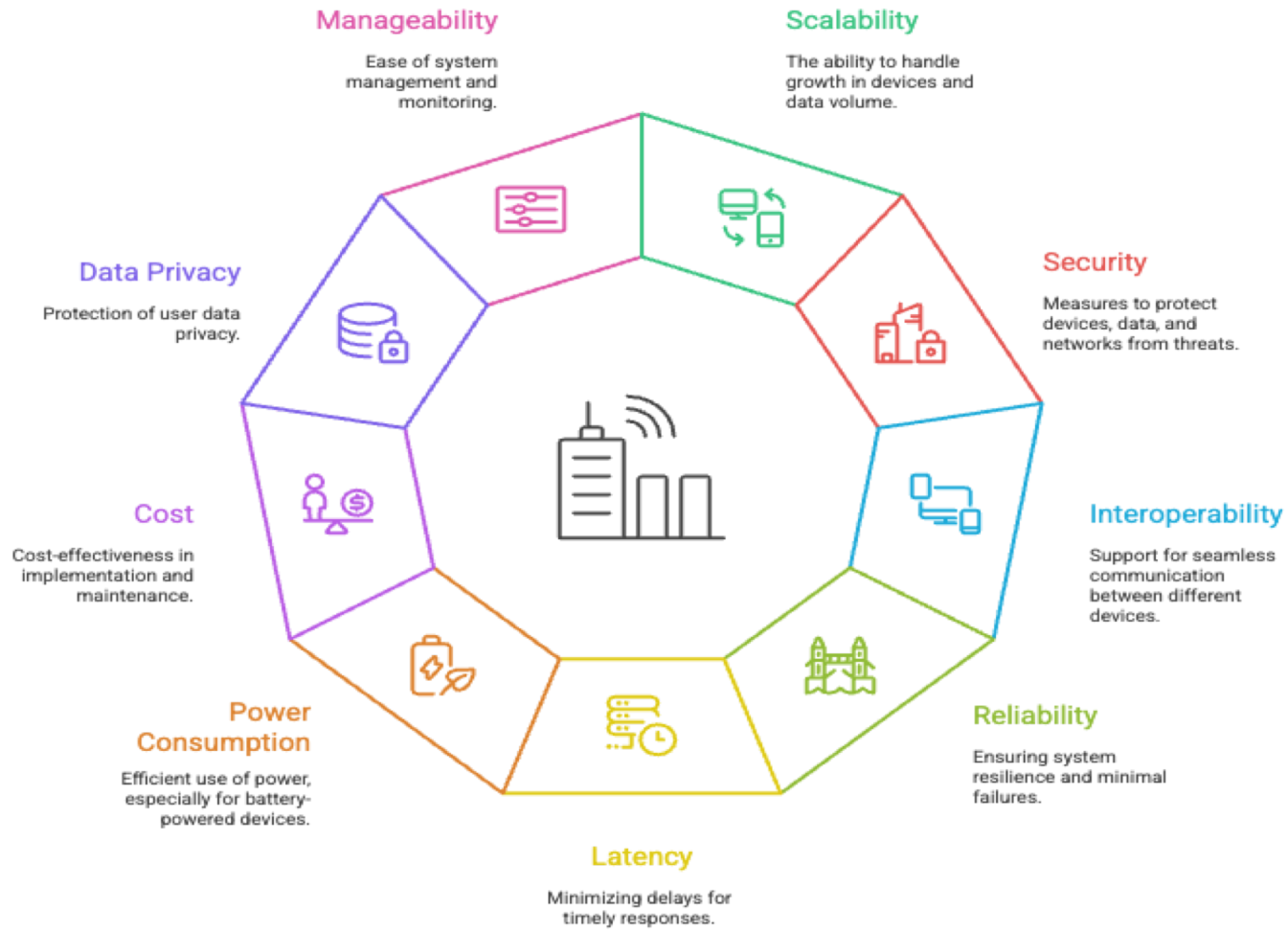
Designing an IoT Architecture (Cont.)

- Designing an effective IoT architecture requires careful consideration of several **factors**:
  1. **Scalability**
     - handles a growing number of devices and data volumes.
  2. **Security**
     - protect devices, data, and the network from threats.
  3. **Interoperability**
     - support interoperability between different devices and systems.
  4. **Reliability**
     - reliable and resilient to failures.

Designing an IoT Architecture (Cont.)

5. **Latency**
   - minimize latency to ensure timely responses.
6. **Power Consumption**
   - critical factor for battery-powered devices.
7. **Cost**
   - cost-effective to implement and maintain.
8. **Data Privacy**
   - protects the privacy of user data.
9. **Manageability**
   - easy to manage and monitor.

Designing an IoT Architecture



Summary

- IoT architecture organizes how data moves from devices to users.
- IoT Architecture **Models**
  - **Three-Layer:** Basic sensing, transmission, application.
  - **Four-Layer:** Adds data processing layer.
  - **Five-Layer:** Adds transport and business layers for complex IoT systems.
  - **6-Layer / SOA-based / Fog / AIoT:** Adds intelligence, security, local processing
- Proper architecture choice depends on system scale and complexity.


Thank you!