Introduction to TinyML & Its Role in IoT Systems

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Introduction to
IOT

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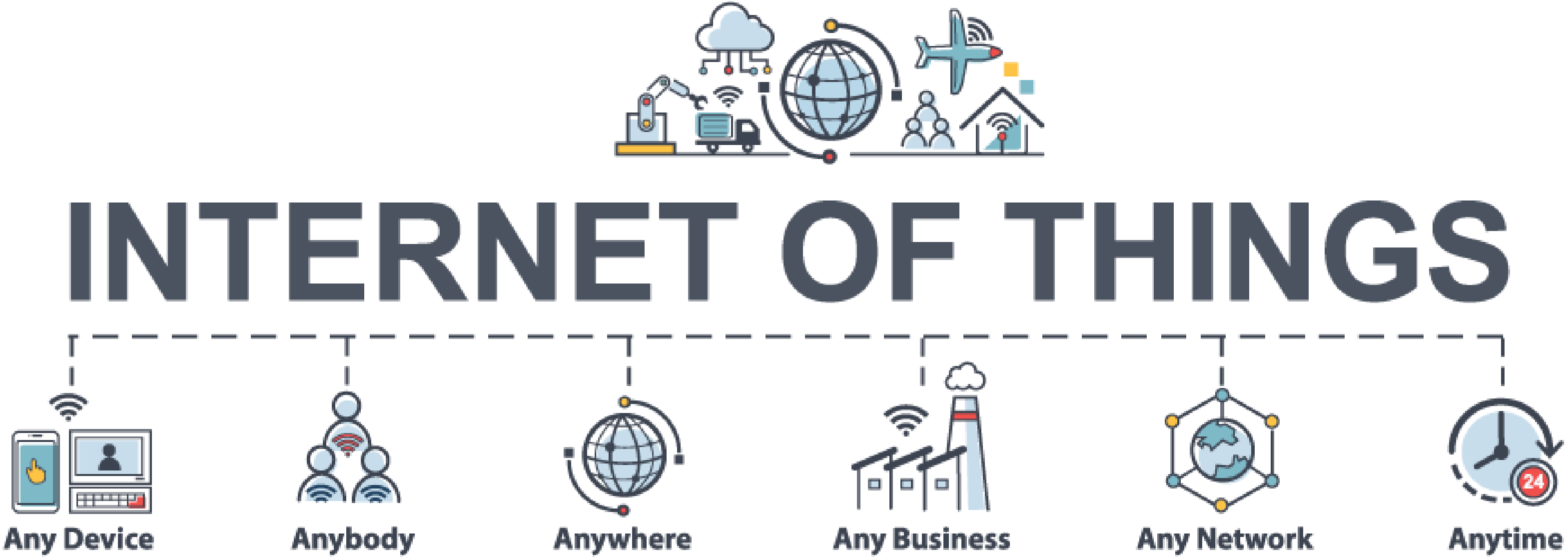
What is Internet of Things (IoT)?

- The **Internet of Things (IoT)** refers to a network of **physical objects or “things”** that are embedded with **sensors, actuators, processing units, and communication technologies**, enabling them to **collect, exchange, and act on data** over the internet without continuous human intervention.

- In a traditional system, devices operate independently and require manual control or monitoring. IoT transforms this approach by allowing devices to become **smart, connected, and autonomous**, capable of sensing their environment, processing information, and making decisions either locally or through cloud-based platforms.



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HISTORY OF IoT

Evolution from Connected Devices to Global Network

1982
Vending Machine
World's first internet-connected appliance, a Coke machine at Carnegie Mellon University.

1990
Toaster
John Romkey's smart toaster, controlled over the internet for the first time.

1999
IoT Term Coined
Kevin Ashton first used the phrase "Internet of Things" during a presentation at Procter & Gamble.

2000
LG Smart Fridge
LG introduced the world's first internet-enabled refrigerator, the "Internet Digital DIOS".

2004
Smart Watch
Early wearable tech like the Fossil Wrist PDA, integrating personal data and connectivity.

2009
Cars
Cars became increasingly connected with systems for navigation, diagnostics, and tracking.

2011
Smart TV
Smart TVs with integrated internet capabilities, apps, and streaming services became mainstream.

2014
Amazon Echo
Launch of the Echo smart speaker with the Alexa voice assistant, popularizing smart home control.

2015
Tesla Autopilot
Introduction of Tesla Autopilot, marking a significant step towards autonomous connected vehicles.

Basic Components of IoT

01 Devices & Sensors

Physical objects embedded with sensors or actuator

02 Connectivity

Networks such as Wi-Fi, Bluetooth, Zigbee, LoRa

03 Data Processing

Edge devices, gateways, or cloud platforms

04 User Interface (UI)

Applications, dashboards, or mobile apps

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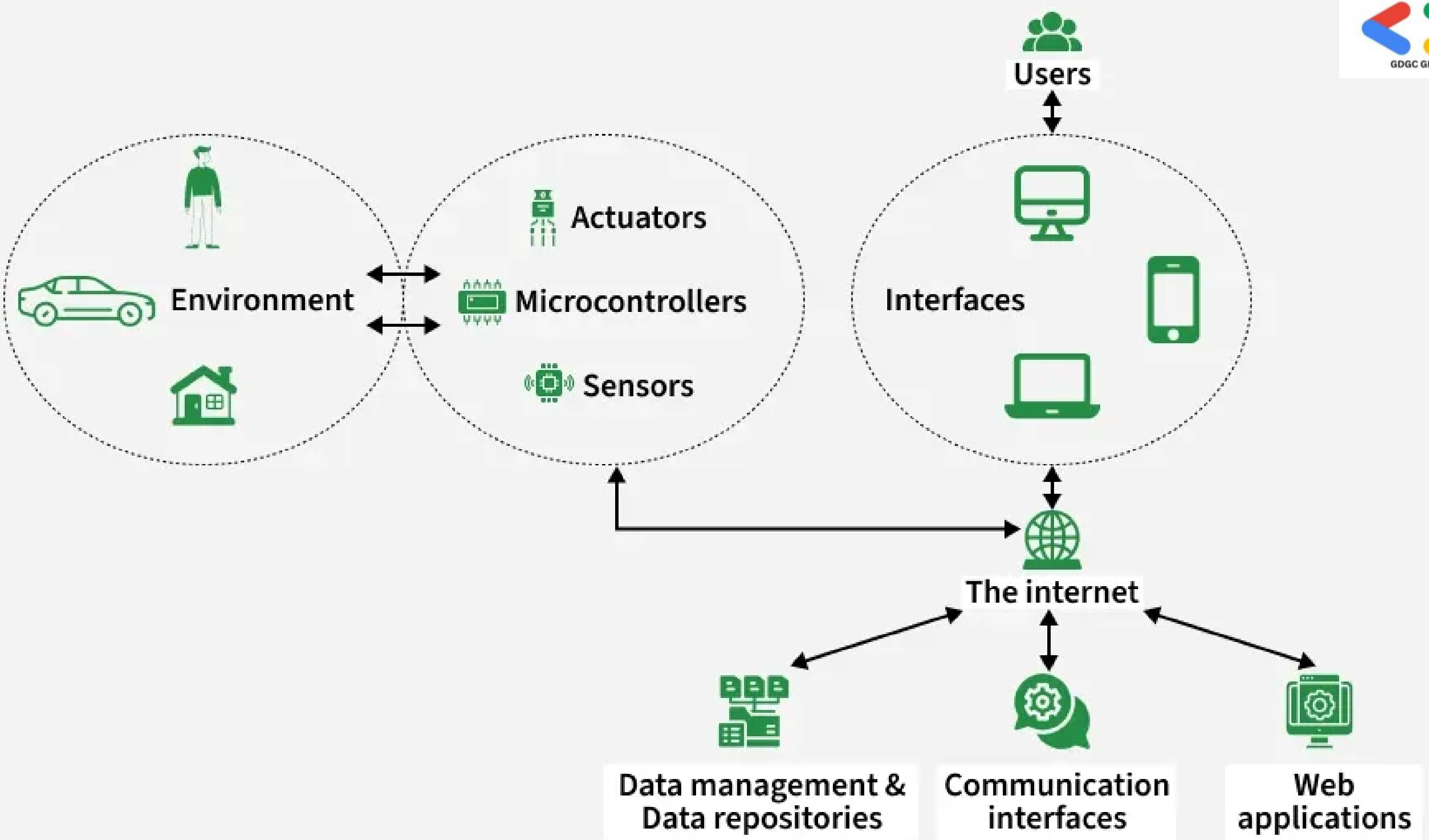

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IoT Advantages and Limitations

Advantages

- Minimizes the Human Work & Effort
- Saves Time and Effort
- Good For Personal Safety and Security
- Beneficial For the Healthcare Industry

Limitations

- Increased Privacy Concerns
- Increased Unemployment Rates
- Highly Dependent on the Internet
- Complex System For Maintenanace

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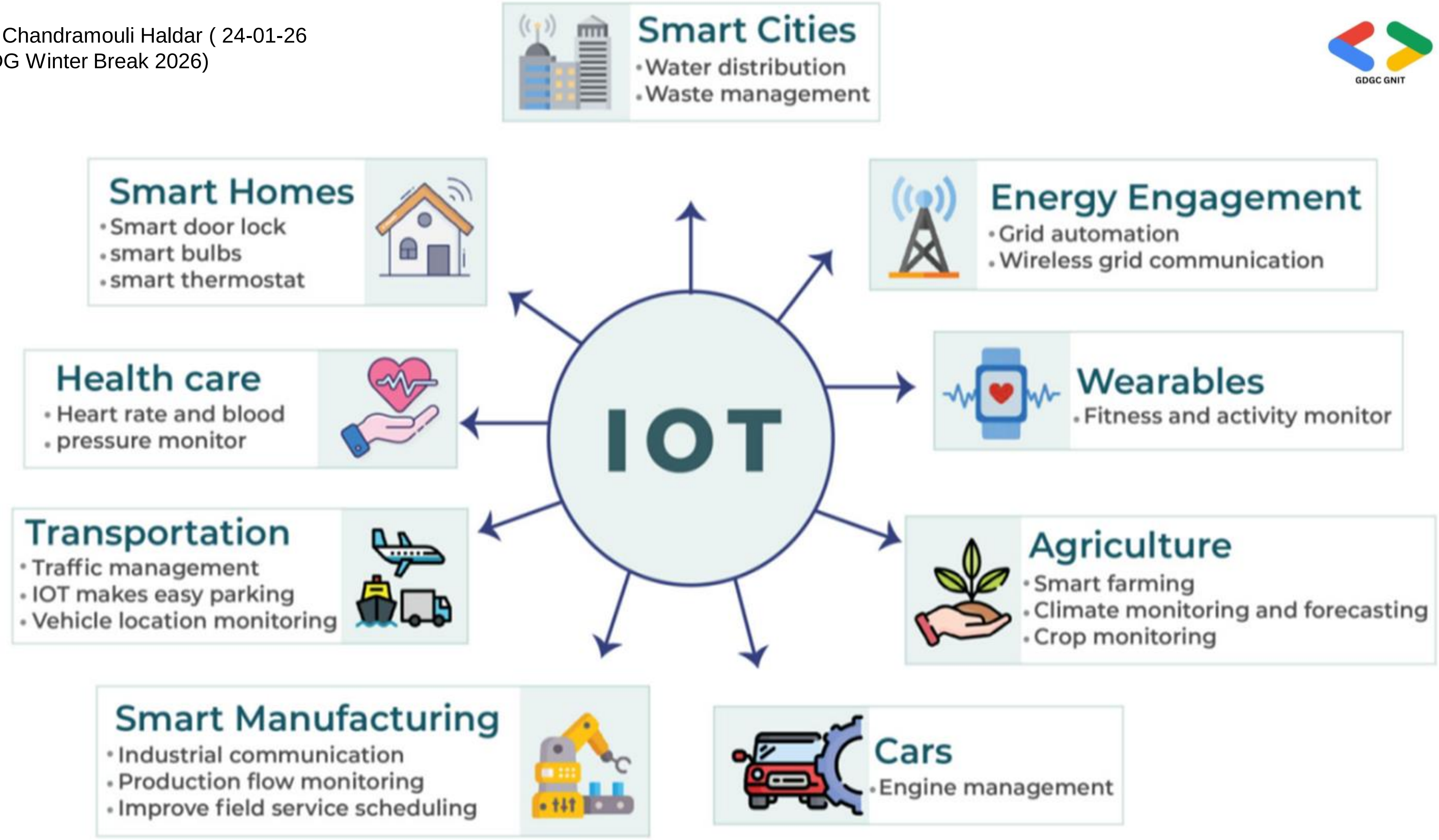

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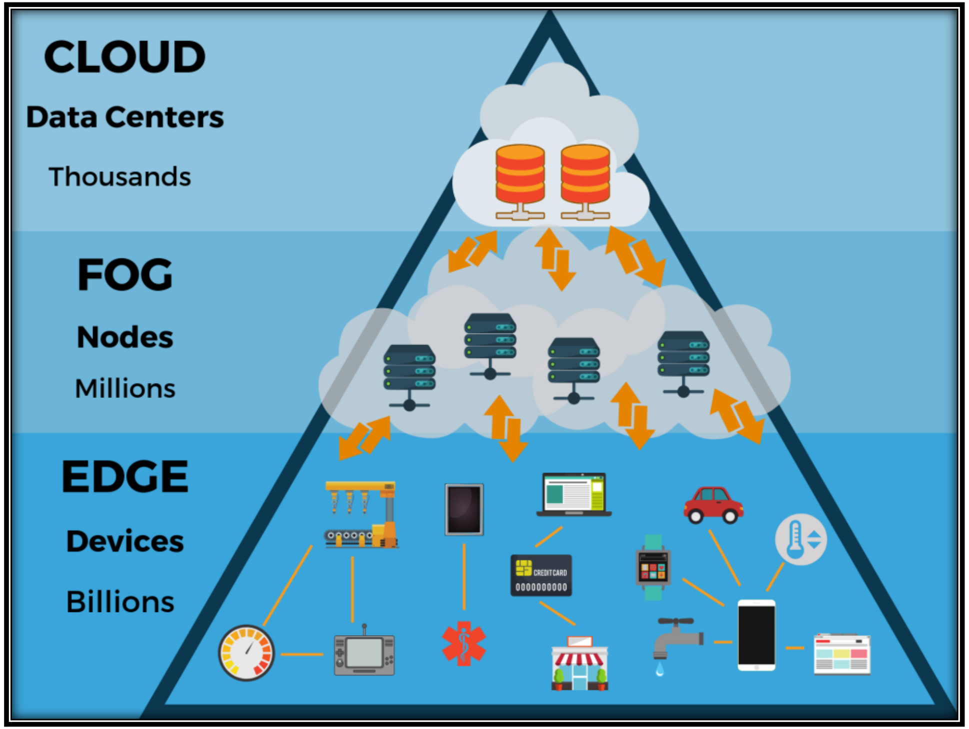
Edge Computing

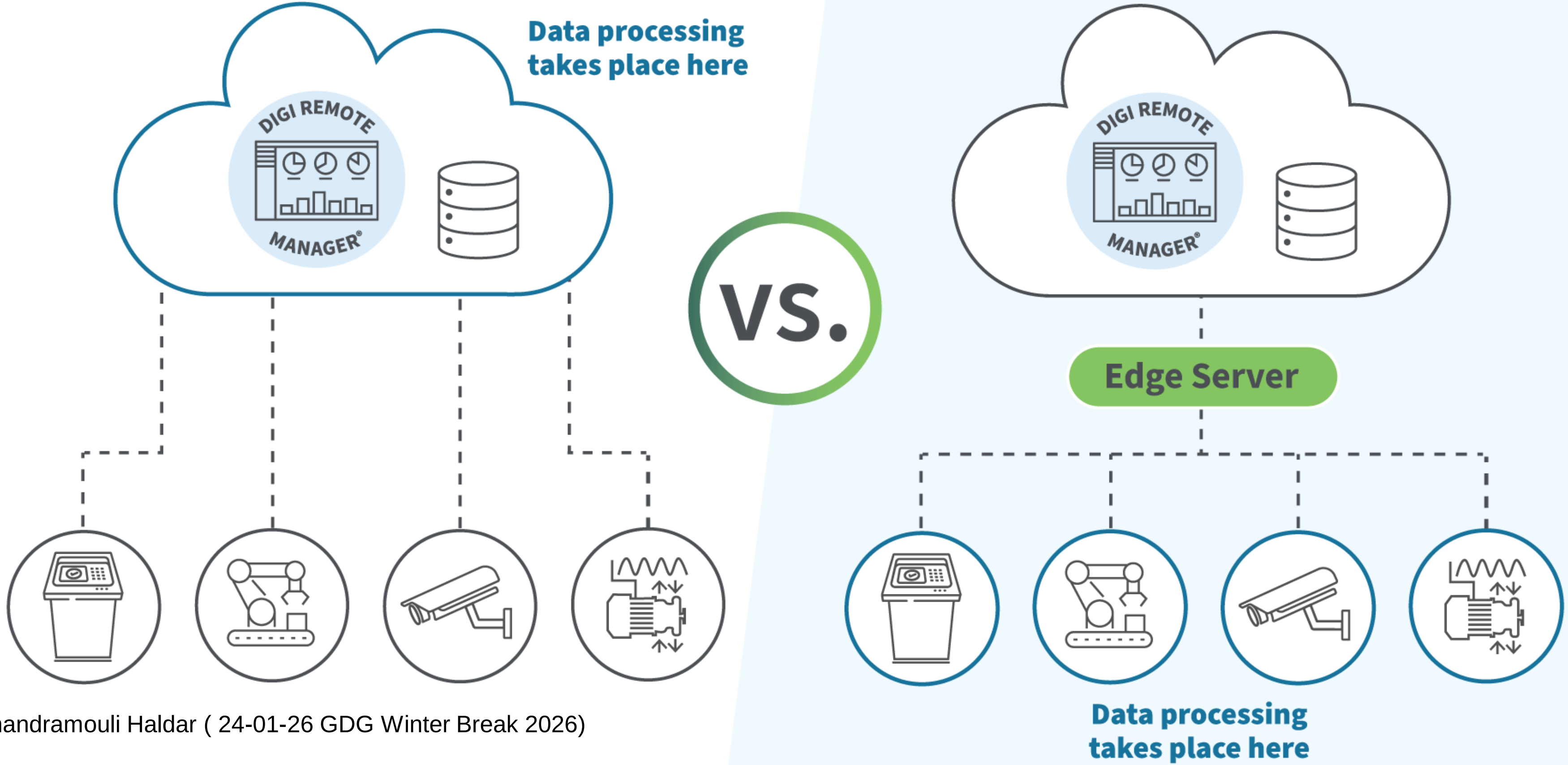


It is a distributed computing model that brings computation and data storage closer to the sources of data.

More broadly, it refers to any design that pushes computation physically closer to a user, so as to reduce the latency compared to when an application runs on a centralized data center.

TRADITIONAL
Cloud Computing

MODERN
Edge Computing



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Pros and Cons of Edge Computing

Pros

- Low latency
- Reduced bandwidth
- Improved data security and privacy
- Offline functionality
- Decentralized infrastructure

Cons

- Limited resources
- Higher upfront costs
- Security management challenges
- Software compatibility issues
- Limited scalability

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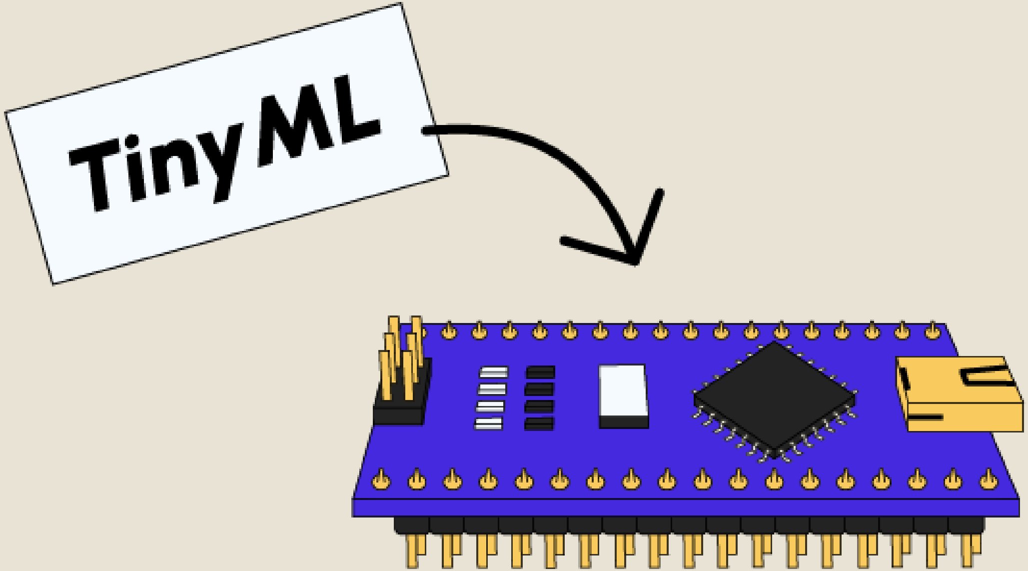

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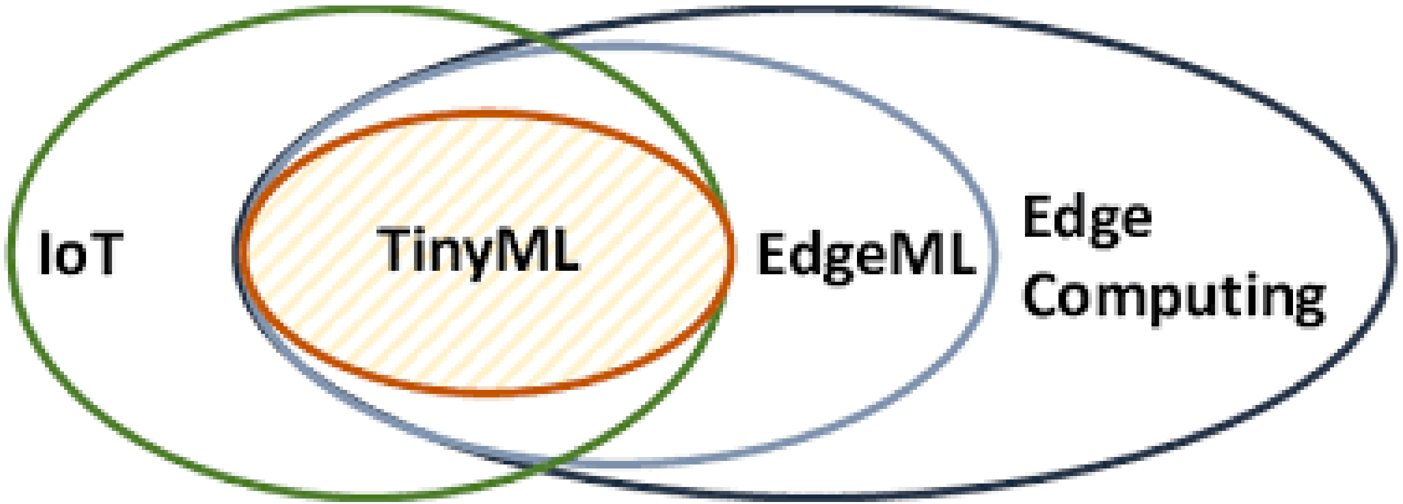
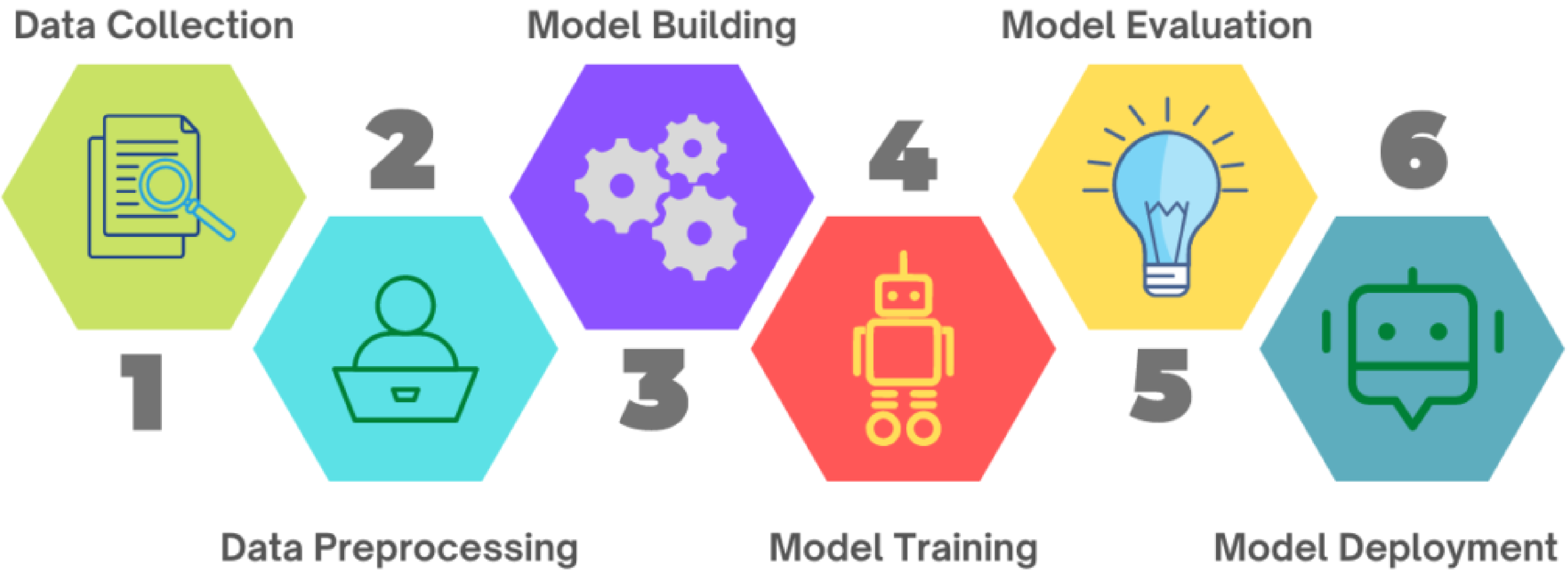

IoT
TinyML
EdgeML
Edge
Computing

What is TinyML?

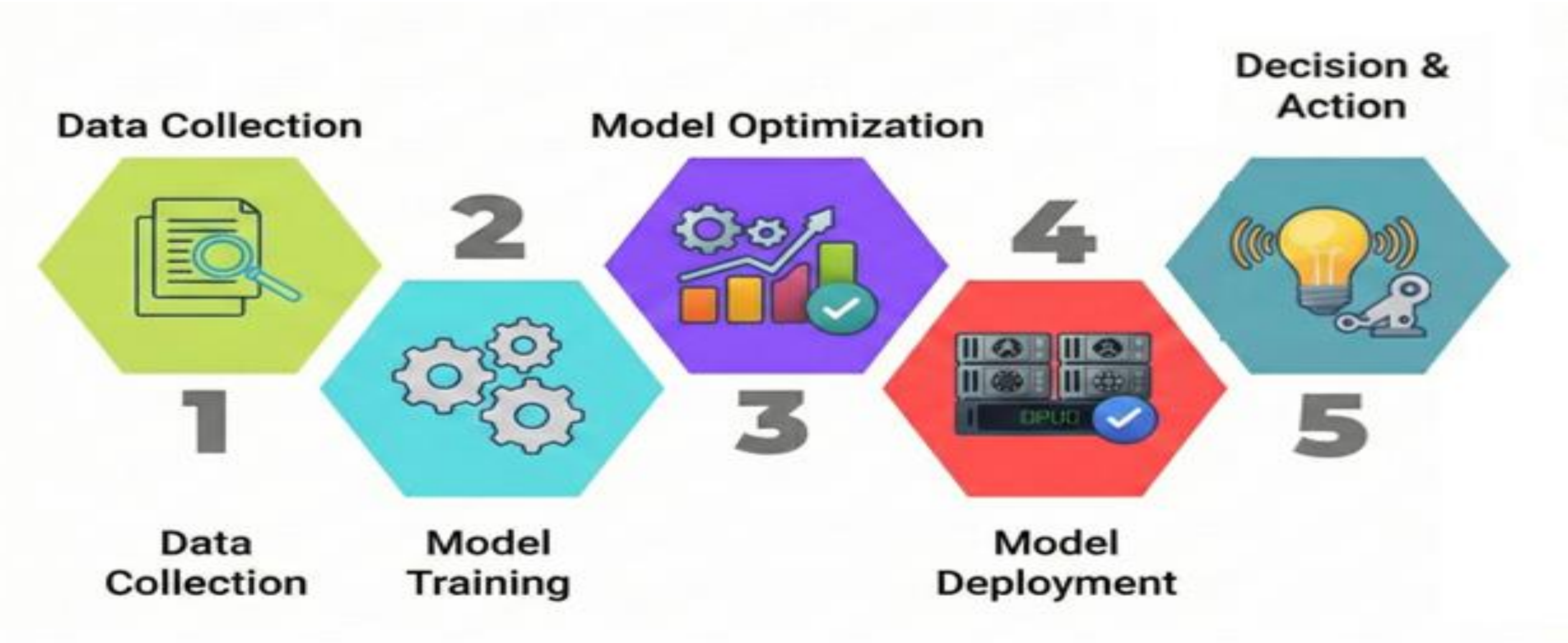
- **TinyML** stands for **Tiny Machine Learning**
- It enables **machine learning models to run on microcontrollers** and tiny embedded devices
- Works with **very low power**, memory, and computation
- Performs **on-device inference** (no cloud or internet required)
- Ideal for **IoT and battery-powered systems**
- Used for tasks like **sensor-based detection, classification, and simple predictions**

➢ In short: **TinyML brings intelligence directly to small, low-power devices.**

Traditional ML Workflow



TinyML Workflow



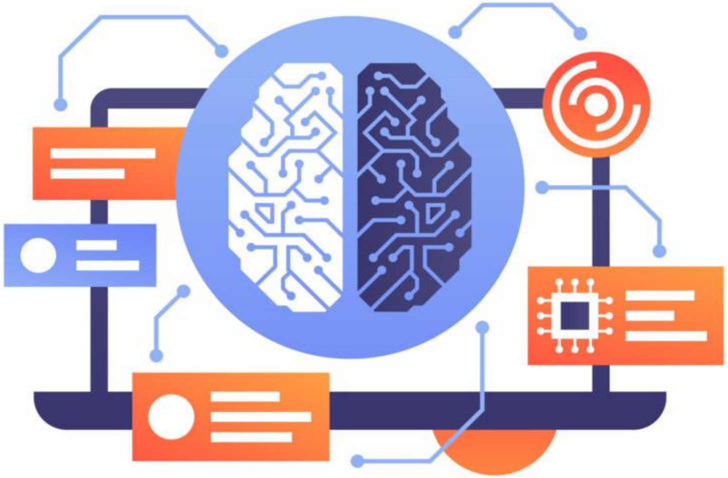
Step 1: Data Collection & Cleaning

- **We collect data from the real world like sensors (Temp, Humidity, etc.)**
- **Create a Dataset by combining data from multiple sources if needed.**
- **Then Clean the Data by Remove duplicates, Handle missing values**
- **Then Split the data into Train and Validation and Move forward to Model Training**

Step 2: Model Training

- The training data is given to the computer
- We decide an algorithm to train the model such as:
  - CNN (Convolutional Neural Network)
  - KNN (K-Nearest Neighbor)

- The model learns patterns from the data
- Training is done on a PC or Cloud system
- After training, a model is created



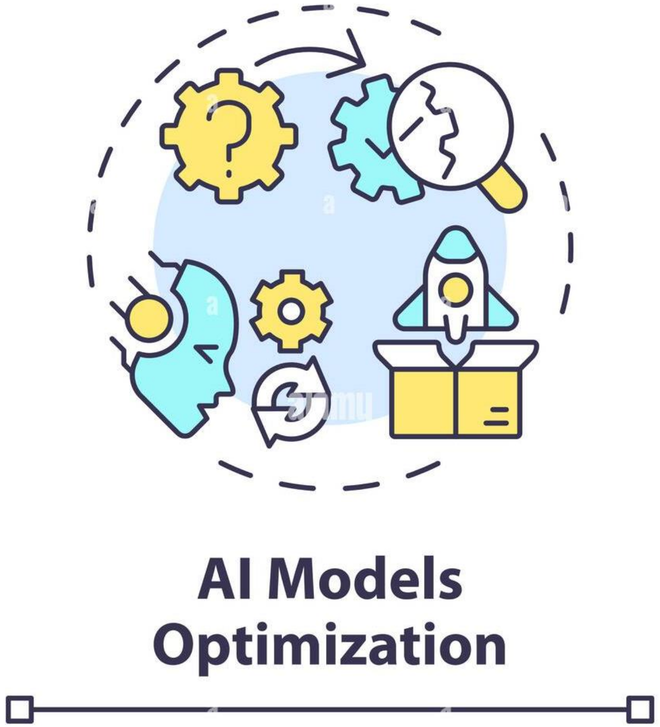
Step 3: Model Optimization

- **The trained model is too large for small devices**

- **So, the model is optimized to reduce size and power usage**
- **Optimization techniques used:**

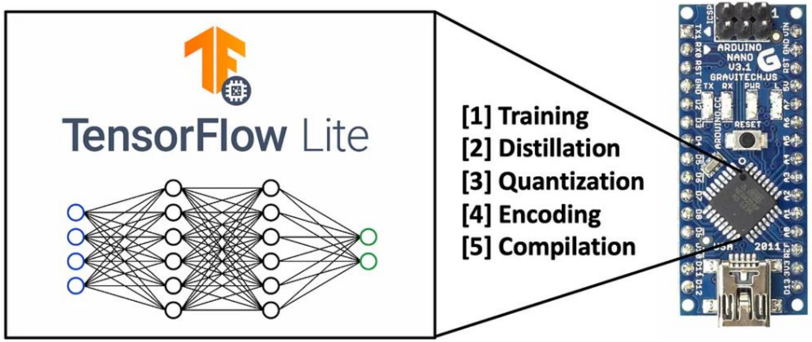
➢ **Quantization – reduces numerical precision**
➢ **Pruning – removes unnecessary connections**
➢ **Tuning – improves performance within limits**

- **Optimized model is ready for deployment**



Step 4: Model Deployment

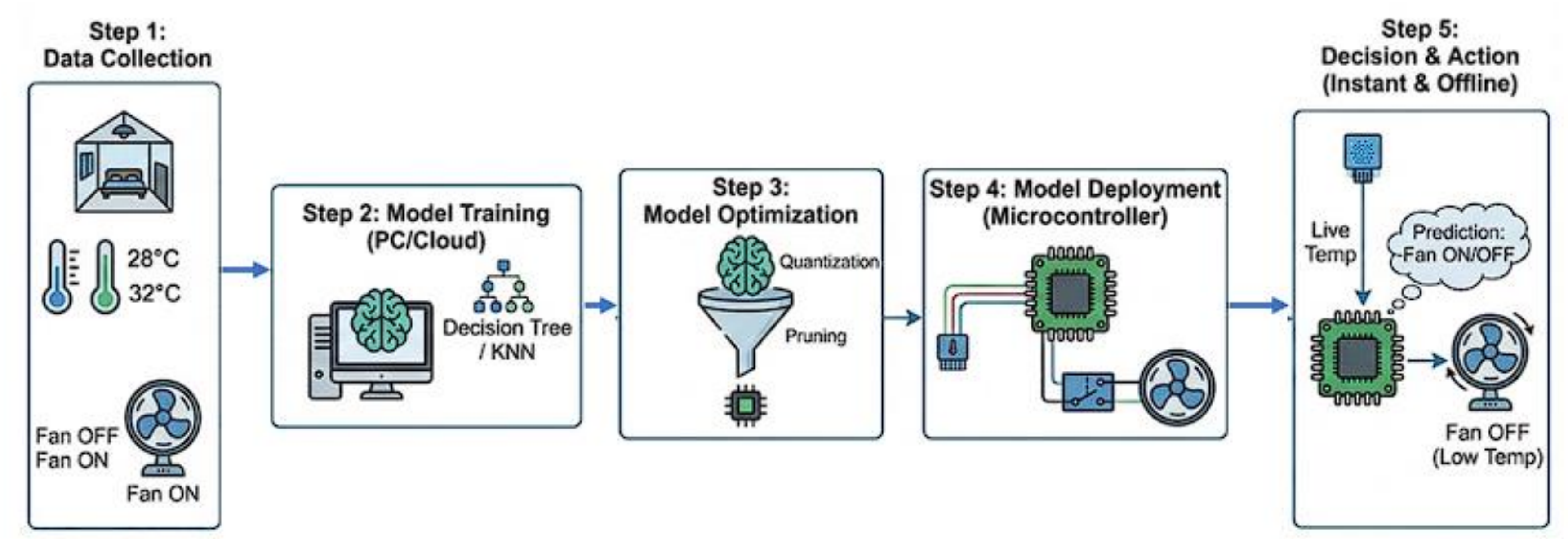
- **The optimized model is transferred to the target system**
- **Model can be deployed on Edge devices like (Microcontroller or Microprocessor)**
- **The model is integrated with the application**
- **System is now ready to perform inference**



Step 5: Decision & Action

- New real-time data is given to the model
- The model predicts or classifies the input data
- Based on the output:
    - ➢ Alerts are generated
    - ➢ Devices are turned ON/OFF
    - ➢ Signals are sent to other systems
- The system takes action automatically

Example: with Home Automation



TinyML Advantages & Challenges

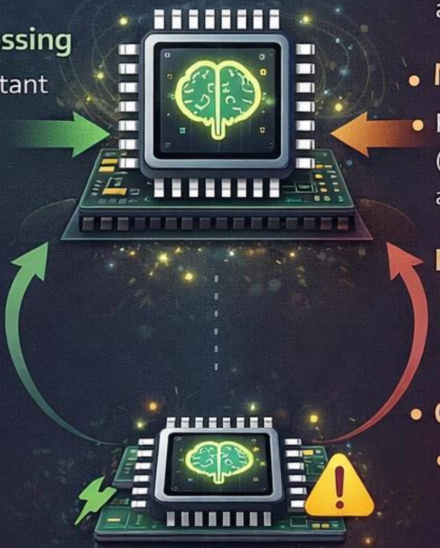
Advantages

Low Power & Energy Efficiency
- Runs on microcontrollers with minimal power, ideal for battery-operated or remote sensors.

Low Latency & Real-time Processing
- Processes data locally, providing instant responses crucial for industrial automation, medical monitoring, etc.

Enhanced Privacy & Security
- Sensitive data stays on the device, reducing risks from cloud transfers.

Offline Capability
- Functions without contant internet connectivity, perfect for remote areas.



Disadvantages & Challenges

Resource Constraints
- Limited memory and processing power on microcontrollers restrict model size and complexity.

Model Complexity vs.Accuracy Trade-off
- Requires highly optimized, lightweight models (like MobileNet), which might sacrifice some accuracy.

Hardware Diversity
- Wide range of device capabilities makes consistent performance hard to achieve.

Optimization Overhead
- Requires specialized techniques (quantization, pruning) to squeez models, adding development complexity.

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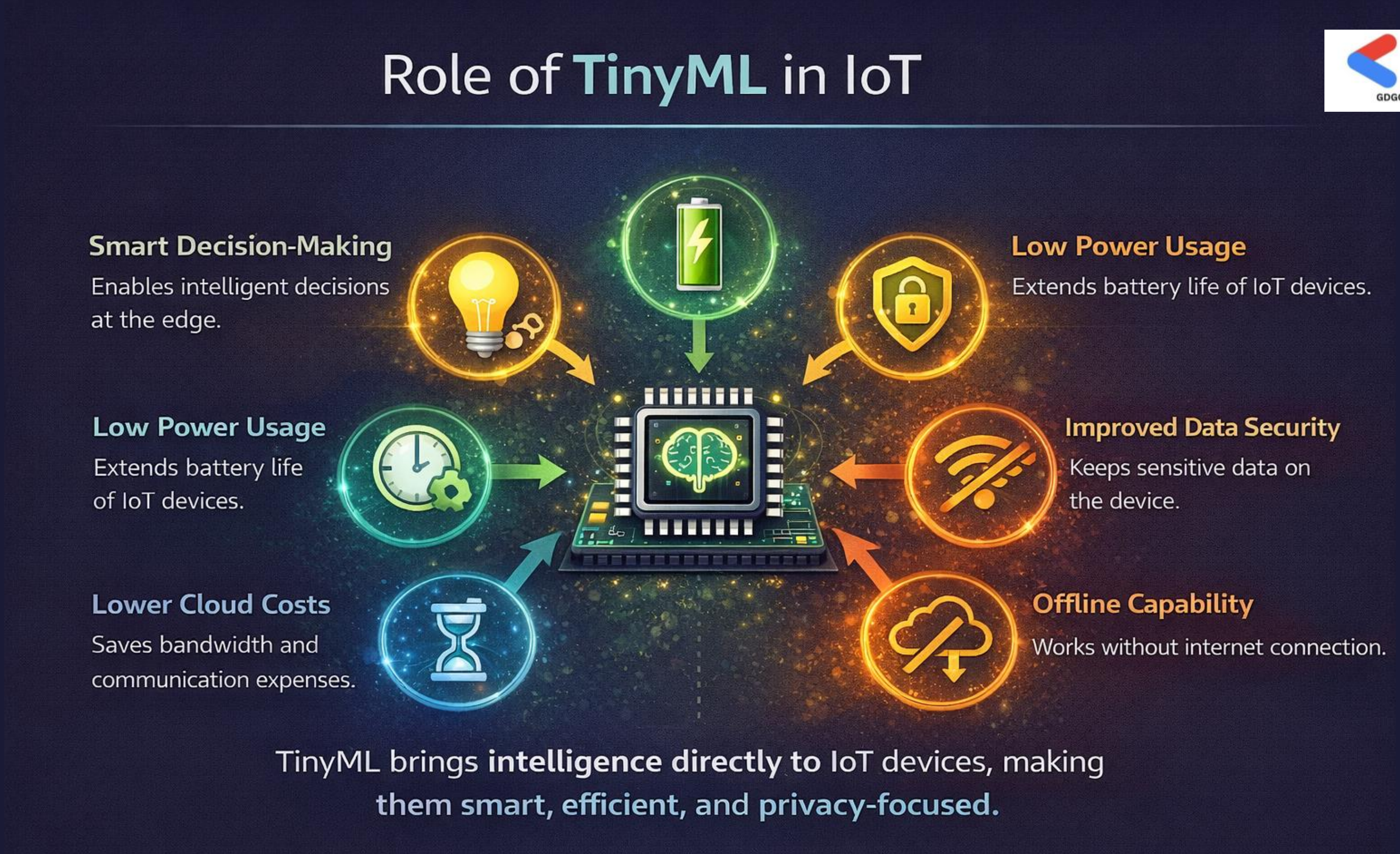

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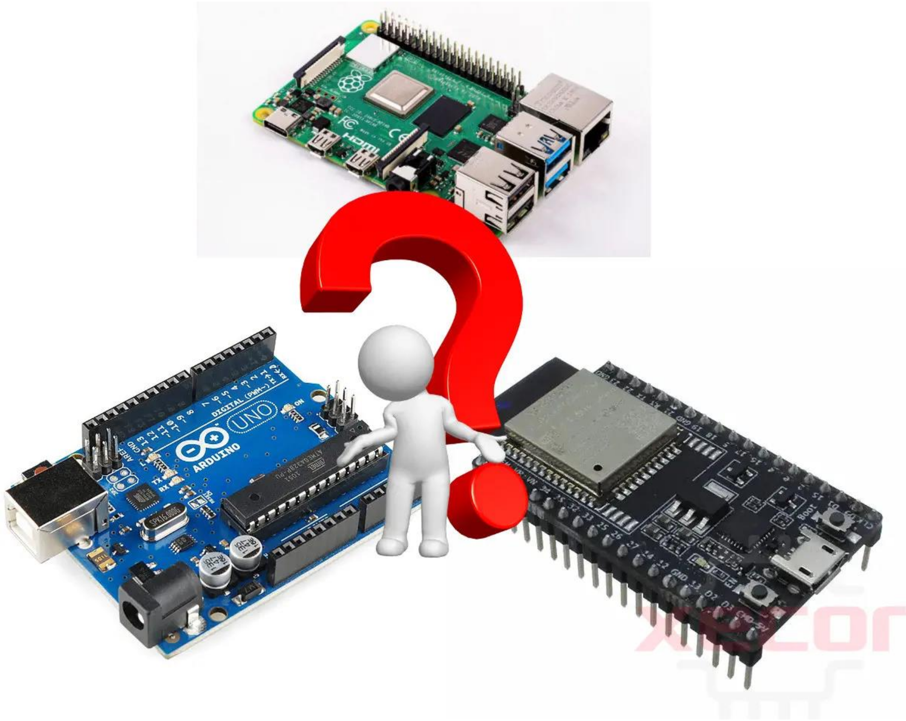
How to Get Started with TinyML ?



Step 1: Choose the Right Hardware

Step 2: Select the Software Tools

Step 3: Collect Sensor Data

Step 4: Train the ML Model

Step 5: Deploy the Model to Device

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Projects

Project 1

Project 2

Project 3

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Thank You!

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