جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

أكاديمية كاوست
KAUST ACADEMY

Internet of Things (IoT)

DAY 5 Build your own device, then see where IoT lives

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KAUST Academy, KAUST

Salah Abdeljabar
salah.abdeljabar@kaust.edu.sa

🗺️ On Today's Agenda

1. 🎓 **The brief**: one sensor, one actuator, one service, starting from the template
2. 🔧 **Build**: your own device, in pairs
3. 🎤 **Demos**: three minutes per pair, in front of the room
4. **IoT is everywhere**: the sectors, from the home to the factory to the city
5. **Edge computing**: when the cloud is too far away
6. **Where to go next**: single-board computers, and choosing the right brain
7. **Benefits & concerns**: the promise and the price

A simple thing that fully works beats an ambitious thing that does not.

PROJECT 13 · CAPSTONE

Capstone: Build Your Own IoT Device

Combine the week into one device that senses, acts, and connects to the cloud, then demo it.

Builds on: everything so far. This is where the twelve separate projects stop being separate.

⏱️ ~60 min 📊 Advanced 🔖 Prerequisite: Projects 1-12

⬇ Download the starter sketch

The starter already connects to Wi-Fi and Ubidots. Follow the `TODO 1/2/3` markers to make it yours.

Project 13 · Capstone 🎓

Design and demo an IoT device of your own choosing, starter sketch and rubric included.

- Combine a sensor, an actuator, and a network service into one device
- Scope a build to the time available
- Start from a template and extend it, the way most embedded work begins
- Debug a multi-part system by testing one piece at a time

Key pins: your choice

Open the guide ↗

The Brief

In teams, combine the week into one small end-to-end device that does all three:

Sense
DHT11, PIR, LDR, pot

Act
LED, RGB, buzzer, relay, OLED

Connect
Ubidots and/or Telegram

Idea	Sense	Act	Cloud
Smart room monitor	DHT11 + LDR	OLED readings	Ubidots charts
Motion security node	PIR	Buzzer	Telegram alert
Comfort meter	DHT11	RGB green/yellow/red	Ubidots dashboard

One session to build, then a short demo. A simple thing that fully works beats an ambitious thing that does not.

Start From the Template: Three TODOs

The starter is Project 11 hollowed out. It compiles and publishes `0.0` as-is, so the **cloud half works before you wire a sensor**.

```
float readMySensor() {            // TODO 1: your sensor (ADC pin, DHT, ...)
  return 0.0;
}
ubidots.add(VAR_SENSOR, value);   // TODO 2: publish each value you care about
ubidots.publish(DEVICE_LABEL);

void callback(char *topic, byte *payload, unsigned int length) {
  digitalWrite(OUTPUT_PIN, v >= 0.5);   // TODO 3: decide what a command means
}
```

- The template already does Wi-Fi, the broker, reconnect, the non-blocking publish timer, and `ubidots.loop()`.
- A new sensor is **three edits**: the `#include`, the object, and the `begin()` in `setup()`. Forgetting the third is the usual bug.
- A command payload is a **number**, so it can be a brightness, a target, or an index, not just on/off.

Scope It, Then Demo It

Finish on time

- Wire and test **one part at a time**
- Confirm good values on Serial before adding the cloud
- `millis()`, never `delay()`, so Wi-Fi stays responsive
- Keep a known-working version before the next feature

The demo (about 3 min)

- What problem does it solve, and for whom?
- Show it live: trigger the sensor, watch it respond
- One thing that was harder than expected
- One thing you would add with another day

The Week in One Loop

Every project was one idea. The capstone is where they stop being separate:

- **Read the world, decide, act** (P1): everything since is a richer version of that loop
- **Digital or analog, counts or units** (P2, P3, P9): know which sensor you have
- `millis()`, **never** `delay()` (P4): what lets a device do two things at once
- **The board can serve a page** (P5 to 9): great locally, invisible from outside
- **Keep state honest** (P8), and **local output has its place** (P10)
- **Publish/subscribe reaches anywhere** (P11), and **an existing app can be the UI** (P12)

The habits matter as much as the APIs: check hardware started, guard bad readings, keep credentials private, and print enough on Serial to see what is happening. The next device is the same shape, with different parts.

REFERENCE · GPIO PINOUT

ESP32 DEVKIT V1: GPIO Reference

A lookup table for the 30-pin ESP-WROOM-32 board: pick a pin without breaking booting or Wi-Fi.

> **Rule of thumb:** for a plain input or output, reach for a ✅ **safe** pin first: **GPIO 4, 13, 16, 17, 18, 19, 21, 22, 23, 25, 26, 27, 32, 33**.

Reference · GPIO Pinout

📌

The full ESP32 DEVKIT V1 pin table: safe pins, strapping pins, input-only pins, plus ADC, touch, DAC, and the default bus pins.

- Which GPIOs are safe to use freely
- Which pins must be left alone at boot (strapping pins)
- Which pins are input-only, and which carry ADC/DAC/touch
- Default I²C and SPI bus pins

Open the guide ↗

REFERENCE · COMPONENTS

Components Glossary

Every part in the kit: what it is, how to recognize it, whether direction matters, and where it's used.

> **Polarity key:** 🔴 **polarized**: direction matters, can be damaged if reversed · ○ **not polarized**: either way is fine.

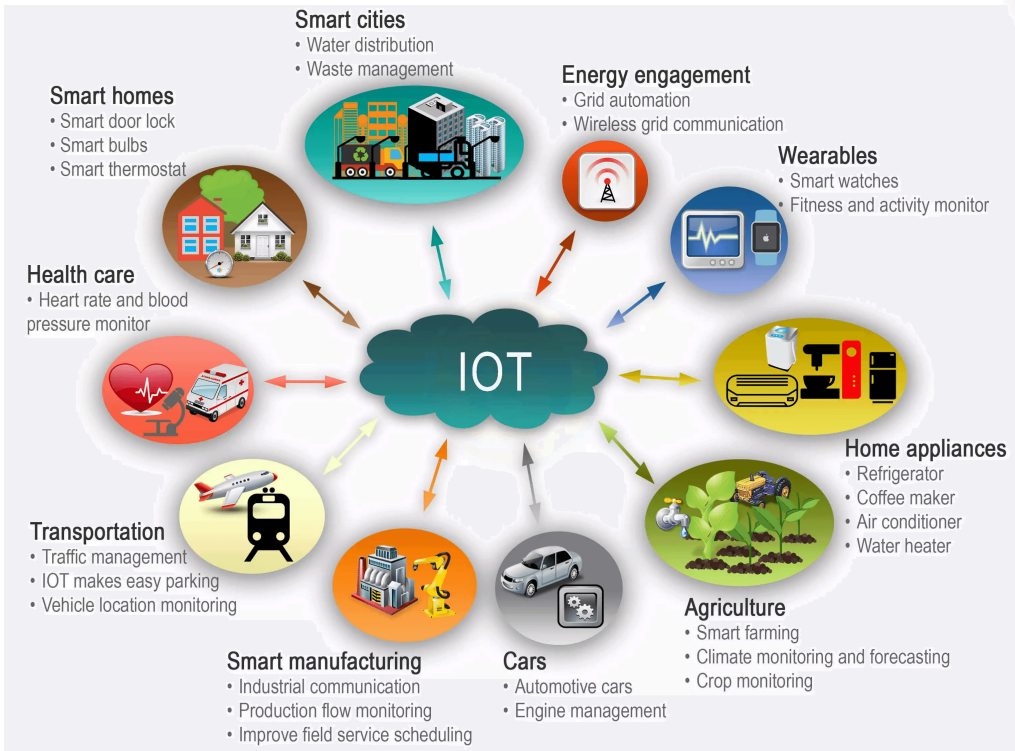
Reference · Components Glossary 🧩

Every part in the kit: how to identify it, whether it’s polarized, and which project uses it.

- A photo and description of each component in the kit
- Polarity called out where it matters
- A pointer to the project that first introduces each part

Open the guide ↗

IoT Is Everywhere 🌍



Source: Rejoicehub

Consumer IoT 

IoT devices you buy and use around the home

Consumer IoT

Devices consumers buy for everyday life: some incredibly useful, some questionable.

🛋️ Around the home

- Smart speakers & assistants
- Smart heating & thermostats
- Robotic vacuum cleaners
- Smart appliances & plugs

⌚ On the person

- Fitness & health trackers
- Wearables & smart watches
- Video doorbells & security cameras

> **Important**
>
> Consumer IoT empowers the **1 billion people with a disability**: voice-controlled ovens, robot vacuums, and self-monitored health conditions.

Commercial IoT 

IoT in the workplace, retail, and transport

Commercial IoT

Using IoT across offices, factories, retail, and logistics.

🏢 Buildings & retail

- Occupancy sensors for lighting/heating
- Factory safety: hard hats, noise levels
- Cold-storage temperature monitoring
- Smart shelves that signal restocking

🚚 Transport & logistics

- Vehicle location tracking
- Road-user mileage charging
- Driver hours & break compliance
- Depot arrival notifications

> ⓘ **Note**
>
> The goal: **cut cost and carbon**, improve **safety**, and keep operations running smoothly.

Infrastructure IoT 

Smarter cities, power, and environment

Infrastructure IoT

Monitoring and managing the infrastructure people use every day.

🏙️ Smart cities

- Pollution monitoring
- Traffic & smart parking
- Public transport management

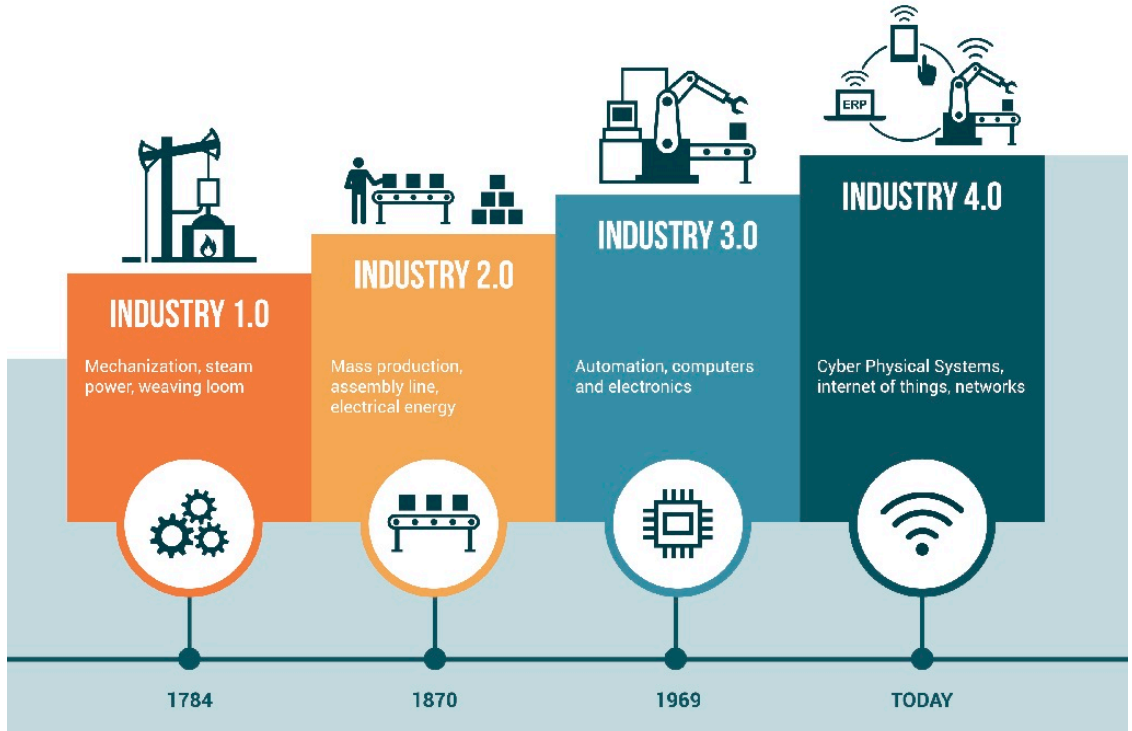
⚡ Utilities

- Smart power grids
- Home-level usage analytics
- Water & environmental monitoring

Real example: Copenhagen

Air pollution is measured across the city and used to suggest the **cleanest cycling and jogging routes**.

Industry 4.0 and Industrial IoT (IIoT)



Source: Aberdeen

From Factories to Farms

🏭 Factories

Monitor machinery with many sensors:

- Temperature, vibration, rotation speed
- Auto-stop when outside tolerances
- Predictive maintenance: AI predicts failures *before* they happen

🌱 Digital agriculture

Feeding a growing planet:

- Soil-moisture → automated watering
- Growing degree days to predict harvest
- Drones, satellites & AI for crop health

Why IIoT Matters

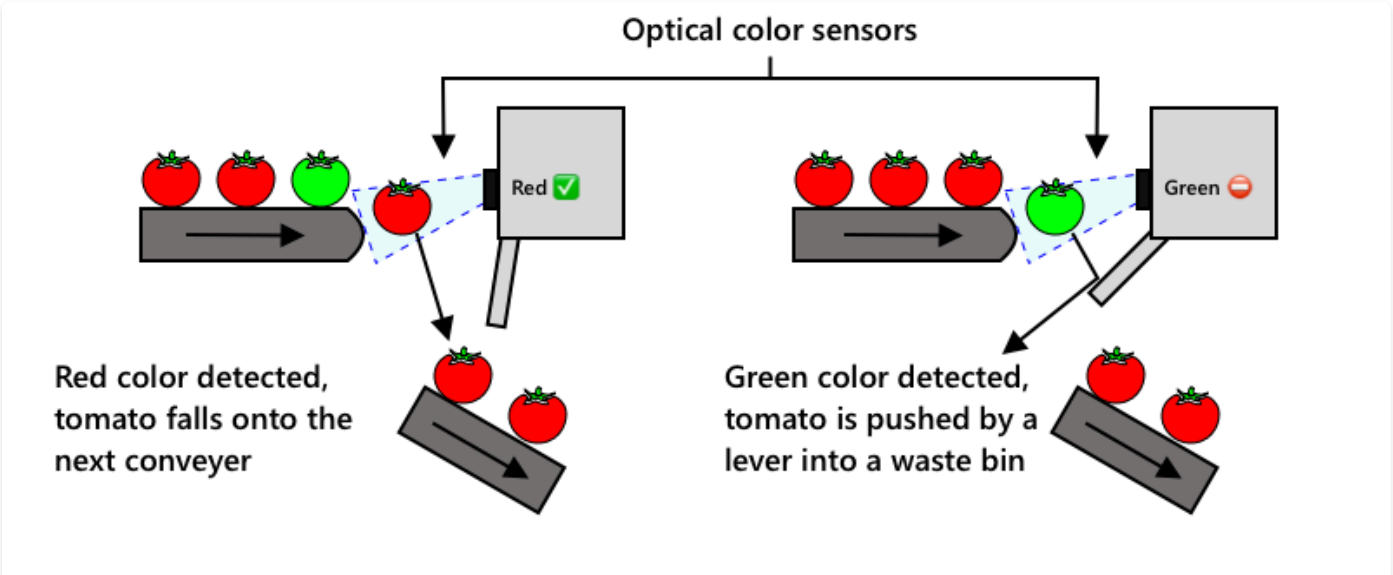
Important

Digital agriculture can help the **2 billion people** in 500 million households living on subsistence farming, starting with sensors that cost just a few dollars.

Think

What other IoT devices could help farmers grow more with less?

One Machine, End to End 🍅



Sense 👁️ An optical color sensor reads each tomato as it passes.

Decide 🧠 Red passes, green does not. The rule runs on the machine, in milliseconds.

Act 🦾 A lever pushes the rejects into a waste bin.

A whole IoT loop with no cloud in sight: at conveyor speed, the round trip would cost more than it's worth.

Edge Computing 

Process data locally instead of always calling the cloud

What is the Edge?

Even though the **I** in IoT is "Internet," devices don’t always have to use it. **Edge devices** are gateways on your **local network** that process data without a round-trip to the cloud.

⚡ Speed

Handle lots of data or a slow connection without waiting on the Internet.

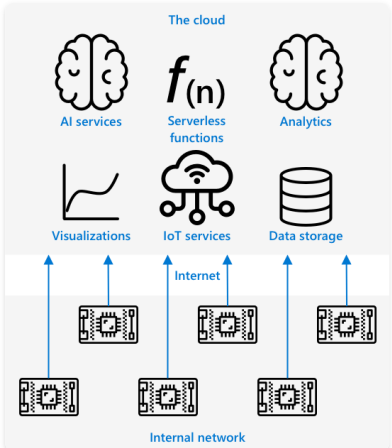
📴 Offline

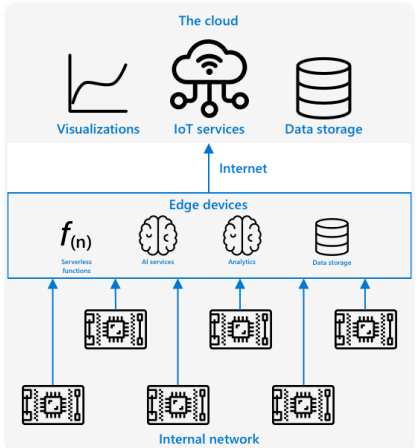
Keep working with no connectivity: on a ship, or in a disaster area.

🔒 Privacy

Sensitive data stays on the local device.

Without the Edge vs With the Edge





Without: every device crosses the Internet for every decision.

With: an edge device runs the same services on your network.

The cloud stack (functions, AI, storage) moves next to the devices. Only what matters goes up.

Edge in Action

A smart speaker listens for its **wake word** locally, only sending your speech to the cloud *after* it wakes.

Important

Everything said **before** the wake word (and **after** it stops listening) never leaves the device, keeping it private.

Single-Board Computers (SBCs) 💻

A full computer on a single board

MCU or SBC?

💻 Single-Board Computer

A complete computer on one board, running a **full operating system**.

- Runs **Linux**, coded in **Python**
- More power, memory & complexity
- Connect monitors, keyboards, USB
- e.g. **Raspberry Pi**

🧠 Microcontroller

A chip built to do **one specific task**.

- Runs **C/C++**, no full OS
- Tiny power draw, low cost
- Real-time, single-purpose
- e.g. **ESP32**

Side by Side

	🧠 Microcontroller	💻 Single-Board Computer
Cost	Cents to a few dollars	Tens of dollars
Power	Months on a battery	Usually mains-powered
Software	C/C++, no full OS	Linux + Python, full OS
Complexity	Single dedicated task	Many apps at once
Timing	Deterministic, real-time	OS-scheduled

Which Do I Pick?

Reach for an MCU

Battery-powered, **dedicated**, **real-time** tasks: a sensor node, a nightlight, a wearable.

Reach for an SBC

Complex logic, **multiple peripherals**, a **rich UI**, or **on-device AI**.

Tip

Many real products use **both**: an SBC coordinating several MCUs.

Benefits & Concerns ⚖️

The promise and the price of connecting everything

Weighing IoT

✅ Benefits

- Convenience & automation
- Efficiency: save cost & energy
- Safety & accessibility
- Data-driven insights

⚠️ Concerns

- **Privacy**: who sees your data?
- **Security** vulnerabilities
- Dependence on **connectivity**
- Interoperability between brands

Security Deserves Attention 🔒

> **Caution**
> There's an old joke: *"the **S** in IoT stands for Security."* There is no S. A device is only as secure as the cloud service behind it.

- Real attacks: the **Stuxnet** worm, hacked **baby monitors**
- Weak passwords and open connections are common entry points
- Good design treats privacy and security as first-class requirements

Thank you!

For spending the day building the Internet of Things with us.

Questions? Ask now, or write to me any time.

Slides, labs, and resources

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