EEM602 Internet of Things

Lecture # 4 (week 4)

IoT Hardware Development Platforms

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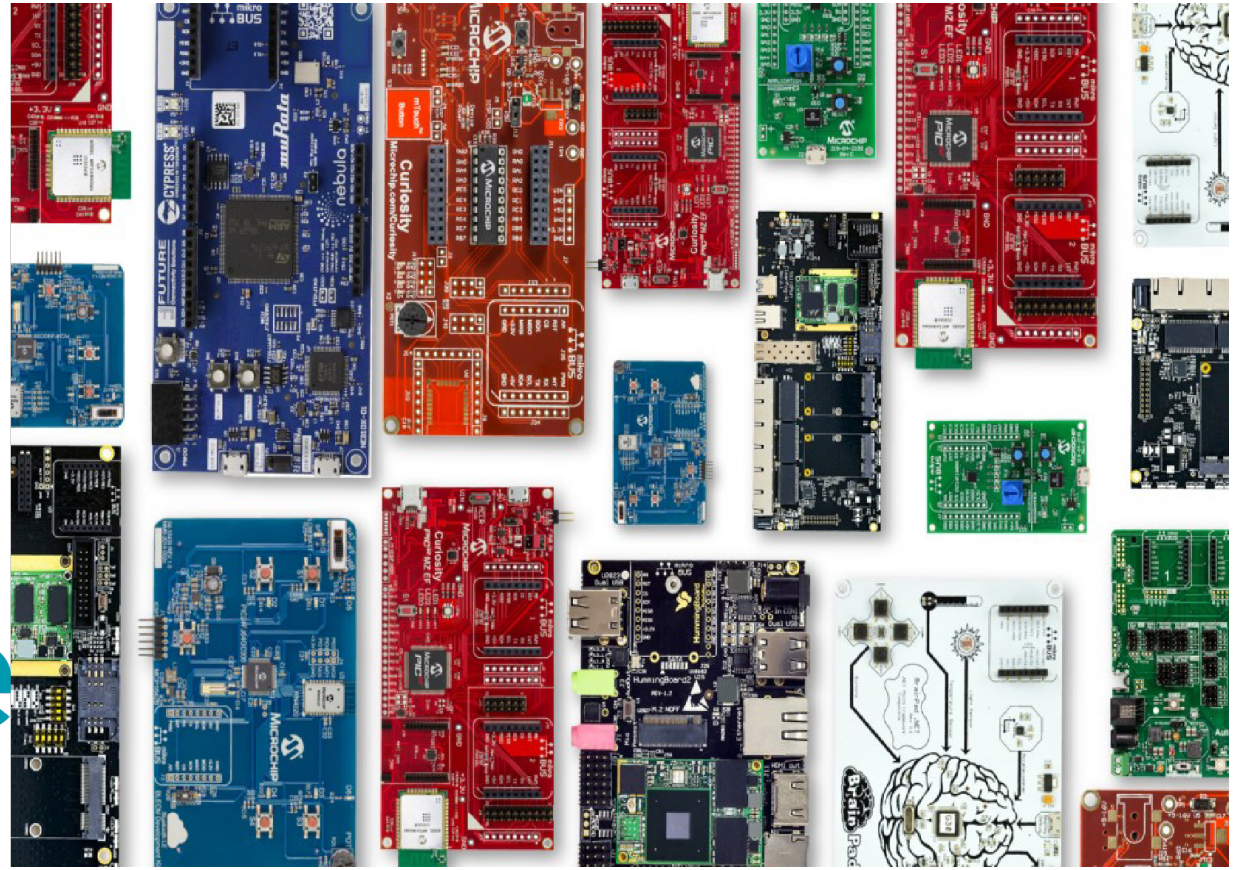
IoT Hardware Development Platforms

open source hardware



IoT hardware development platforms

- They are kits or development boards that combine microcontrollers and processors with wireless communication chips and other components in a ready-to-build and ready-to-program bundle.

- Include a variety of peripherals for connecting sensors and interfacing with other hardware components or devices for designing and prototyping IoT devices.

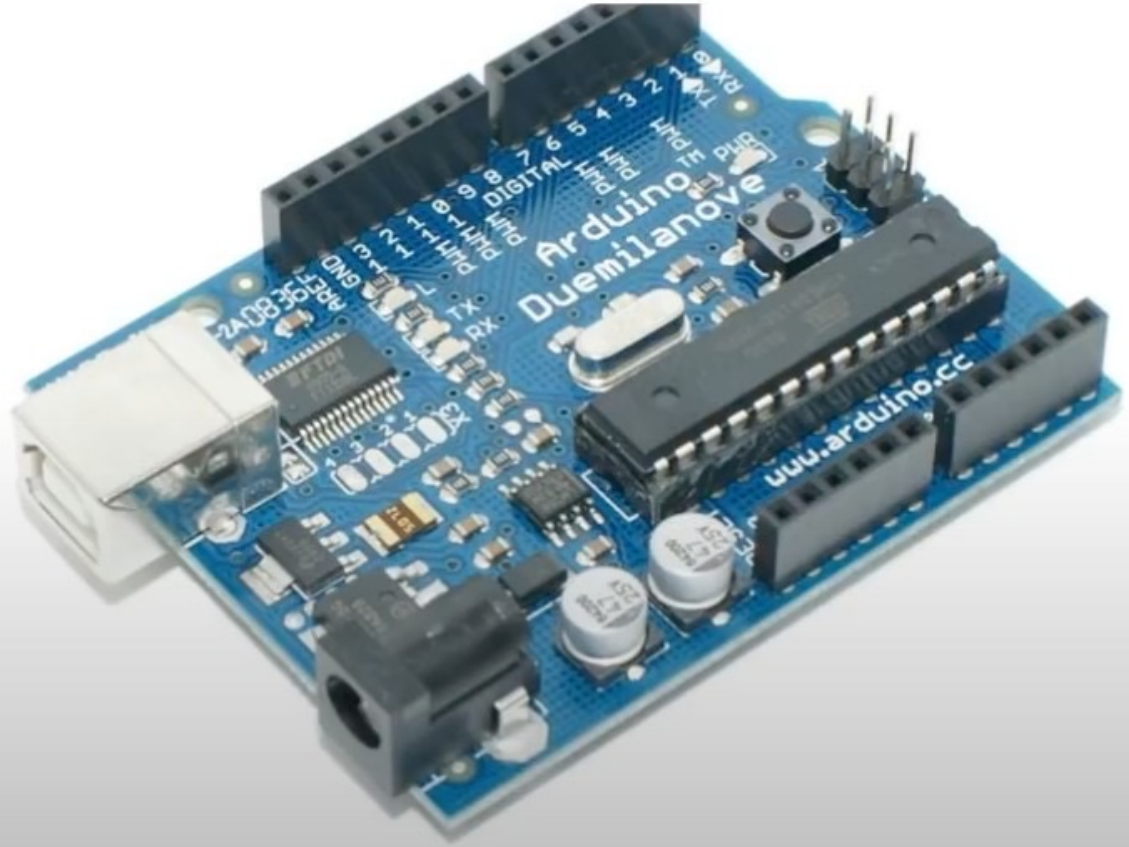
- IoT hardware development platforms are generally divided into two categories:

1. Microcontroller-based boards
   (e.g., Arduino boards, Adafruit Feather Bluefruit)

2. **Single- Board Computers (SBCs)**
   (e.g., Raspberry Pi, BeagleBone Black, and C.H.I.P).

Raspberry Pi and Arduino

HARDWARE



SOFTWARE AND NETWORKING SYST

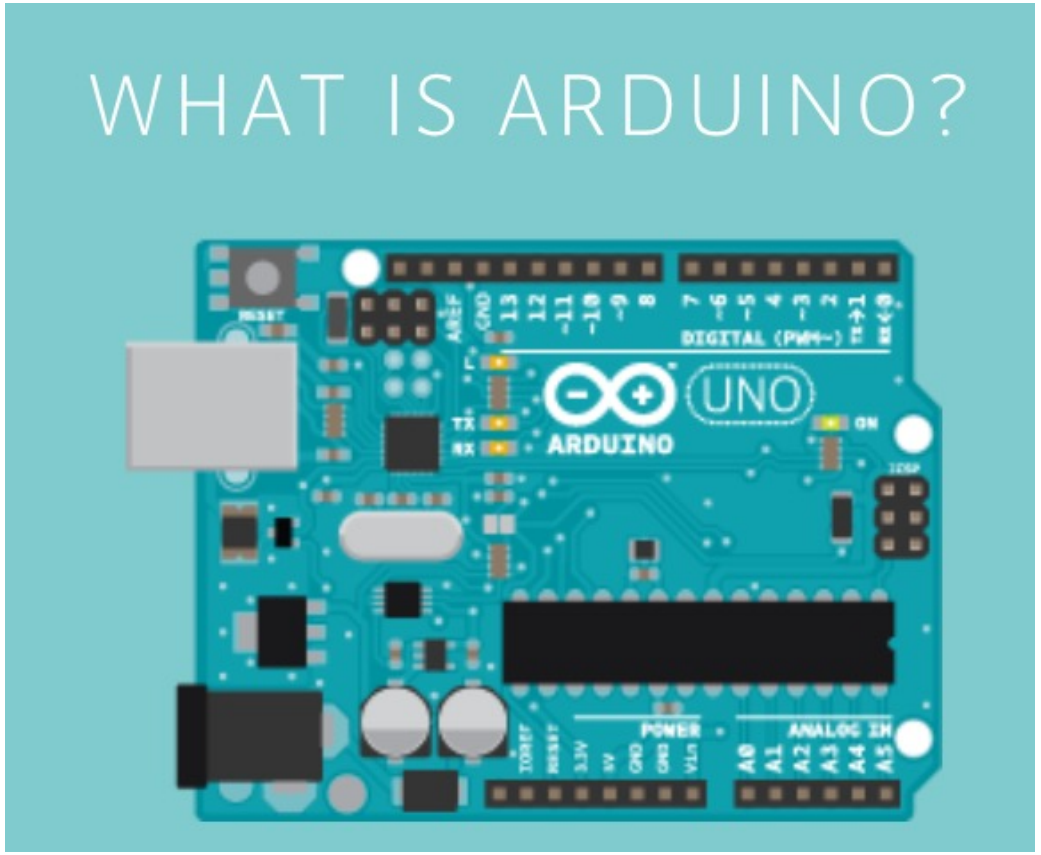
Arduino

Small programmable device

Easily connectable

Is open source

Has a simple to use software



Arduino is an open-source electronics platform based on easy-to-use hardware and software.

Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online.

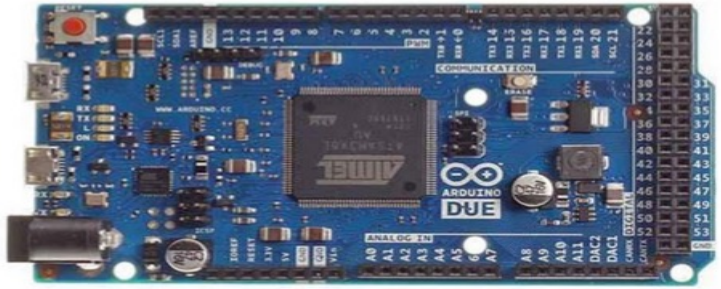
6.2.1 Key Features of Arduino Hardware Development Platforms

The Arduino (since 2007) is basically an open-source electronics prototyping platform that is made up of two essential parts:

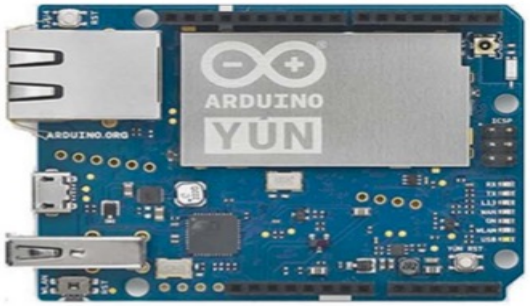
1. the hardware, which is the Arduino board
2. the software, the Integrated Development Environment (IDE).

(a) Arduino Uno

(b) Arduino Mega 2560



(c) Arduino Due



(d) Arduino Yún

(e) Arduino 101

(f) Arduino MKR1000

Figure 6.1 The selected Arduino boards. (Images CC-SA-BY from Arduino.cc.)

the *Uno* (released in 2010),
the *Mega 2560* (released in 2010),
the *Due* (released in 2012),
the *Yún* (released in 2013),
the *Arduino/Genuino 101* (release in 2015),
the *Arduino/Genuino MKR1000* (released in 2016).

6.2.1.1 Processing and Memory/Storage Capacity

Table 6.1 Summary of processing and storage capacity of Arduino Boards.

	Microcontroller			Memory/storage		
Board name	**MCU chip**	**Processor bit**	**Clock speed**	**RAM**	**EEPROM (kb)**	**Flash memory (kb)**
Uno	ATmega328	8	16 MHz	2 KB	1	32
Mega 2560	ATmega2560	8	16 MHZ	8 KB	4	250
Due	AT91SAM3X8E	32	84 MHz	96 KB	–	512
Yún	ATmega32U4	8	16 MHz	2.5 KB	1	32
	AR9331	8	16 MHZ	64 MB, 2.5 KB	1	16
101	Intel Quark SE SoC	32	32 MHz	24 KB	–	196
MKR1000	ATSAMW25 SoC	32	48 MHz, 32.768 KHz	32 KB	–	256

6.2.1.2 Power Consumption, Size, and Cost of Arduino Boards

Table 6.2 Summary of power consumption, size, and cost of Arduino boards.

Board name	Average power consumption	Size (mm)	Cost ($)
Uno	250 mW	68.8 × 53.4	22.19
Mega2560	250 mW	101.5 × 53.3	38.83
Due	2.64 W	101.5 × 53.3	39.93
Yún	≥1 W	73 × 53	64.90
101	–	68.6 × 53.4	30.00
MKR1000	≥ 396 mW	65 × 25 × 6	34.38

6.2.1.3 Operating Systems and Programming Languages for Arduino Boards

Compared to standard computers, tablets, and smartphones, many IoT devices are resource constrained, especially in terms of memory footprint, and hence they cannot run High-Level Operating System (HLOS) such as Windows and Linux.

In addition, the diversity of MCU families and architectures (e.g., there are 8-bit, 16-bit, and 32-bit processors) is one of the greatest bottlenecks to the development of generic OSes for these devices.

The abovementioned diversity is also aggravating the restrictions on providing a more generic OS support for IoT heterogeneous hardware (Hahm et al., 2016).

In this section, OSes and programming languages for Arduino hardware platforms are discussed.

Owing to stringent resource restrictions, particularly low RAM, the *Yún* is the only Arduino board under consideration that supports an OS. The onboard Atheros AR9331 processor supports the OpenWrt Linux distribution.
Processes/threads in the other models of Arduino are managed in the program.

However, a number developers/people in the Arduino community have been exploring possibilities for developing portable OSes for many of the Arduino boards.

The Arduino programming language or Arduino Language (AL) is based on C/C++.

AL is composed of a set of C/C++ functions that users can easily call from their code (also known as sketch). While virtually all support libraries are subset of C standard library and not C++ standard library,

the Arduino IDE basically uses a simplified version of C++ language.

The IDE, which can be downloaded from the Arduino website, is used for writing and uploading the programs to the Arduino board.

Another alternative is to use the online IDE (Arduino Web Editor), which allows users to save their sketches in the Cloud. The sketch automatically generates function prototypes after which it is directly

Prototyping

Arduino IDE 1.8.13

The open-source Arduino Software (IDE) makes it easy to write code and upload it to the board. This software can be used with any Arduino board.

Refer to the **Getting Started** page for Installation instructions.

SOURCE CODE

Active development of the Arduino software is **hosted by GitHub**. See the instructions for **building the code**. Latest release source code archives are available **here**. The archives are PGP-signed so they can be verified using **this** gpg key.

DOWNLOAD OPTIONS

Windows Win 7 and newer
Windows ZIP file

Windows app Win 8.1 or 10 Get

Linux 32 bits
Linux 64 bits
Linux ARM 32 bits
Linux ARM 64 bits

Mac OS X 10.10 or newer

Release Notes
Checksums (sha512)

6.2.1.4 Connectivity and Flexibility/Customizability of Peripherals of the Arduino Boards

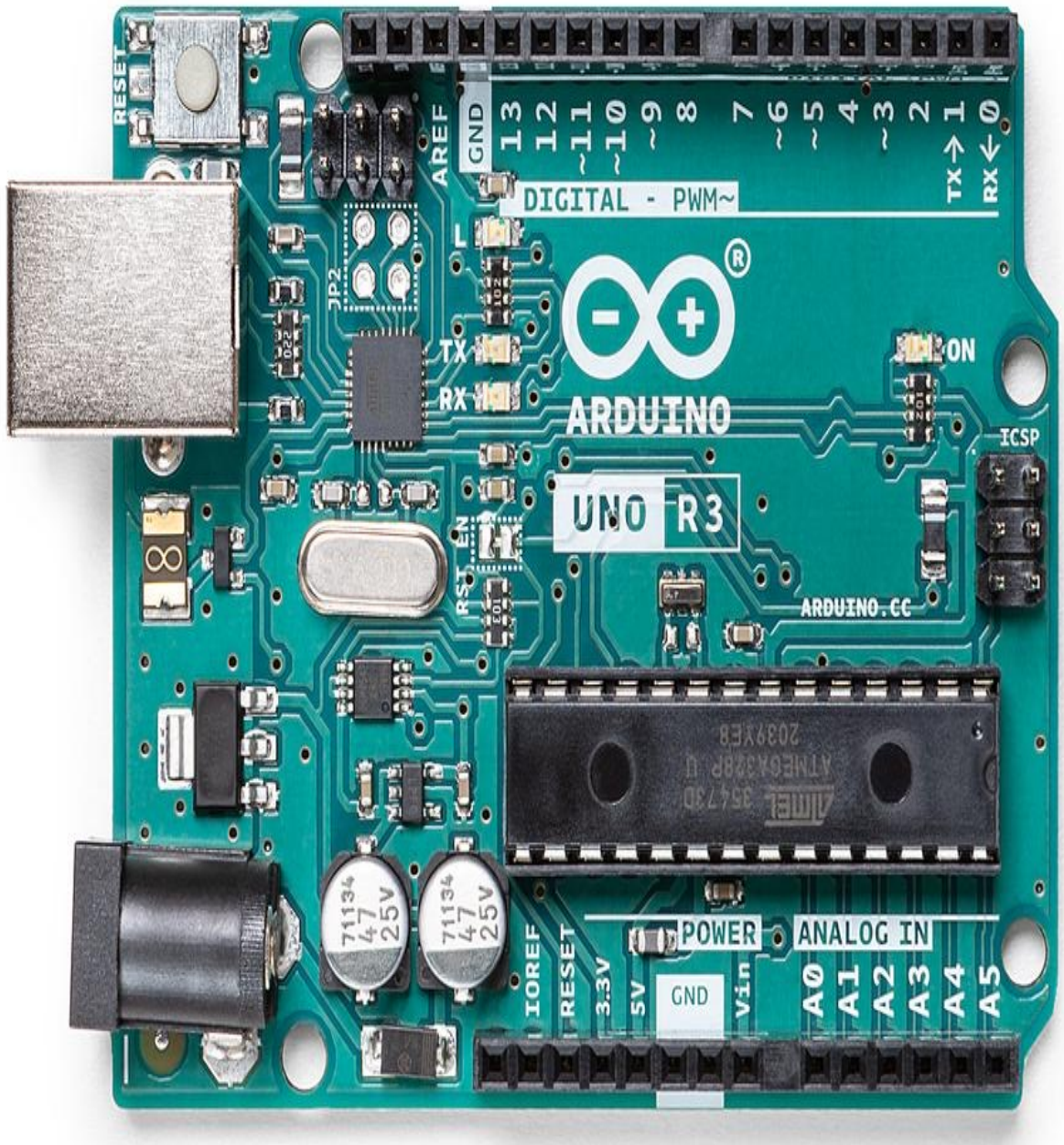
6.2.1.5 Onboard Sensors and Hardware Security Features of Arduino Boards

Table 6.3 Summary of connectivity and flexibility/customizability of peripherals of the Arduino boards.

Board name	Onboard connectivity	GPIO pins	Analog input	USB ports	ICSP header	Other hardware interfaces
Uno	–	14	6	1	1	SPI, UART, I2C/TWI
Mega2560	–	54	16	1	1	SPI, 4 UART, I2C/TWI
Due	–	54	12	2	1	SPI, 4 UART, I2C, 2 TWI
Yún	Ethernet, Wi-Fi	20	12	2	1	SPI, UART, I2C/TWI
101	BLE	14	6	1	1	SPI, UART, I2C/TWI
MKR1000	IEEE 802.11b/g/n	8	7	1	–	SPI, UART, I2C

Arduino Uno Rev3

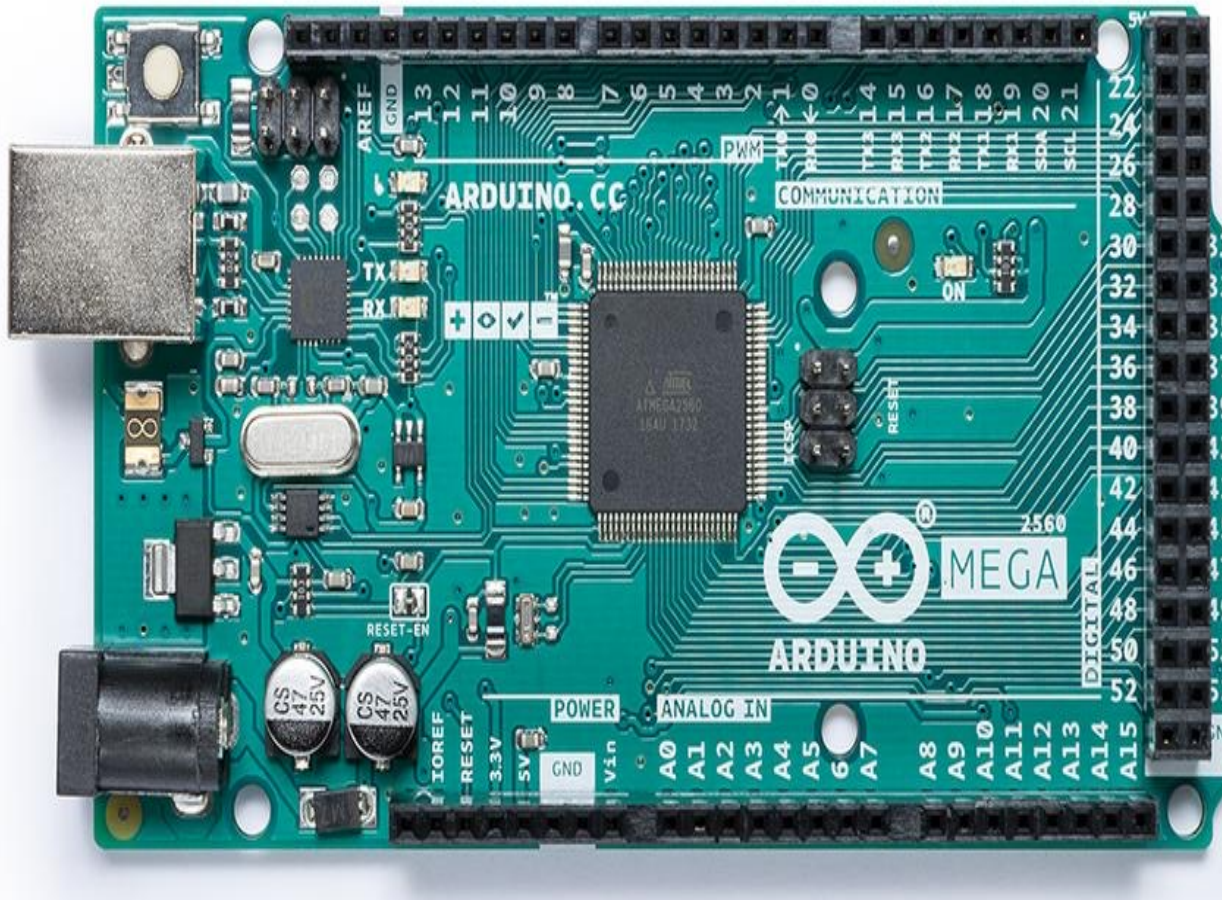
Arduino Uno is a microcontroller board based on the ATmega328P (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.. You can tinker with your Uno without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again.



€20,00

Arduino Mega 2560 Rev3

The **Arduino Mega 2560** is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega 2560 board is compatible with most shields designed for the Uno and the former boards Duemilanove or Diecimila.

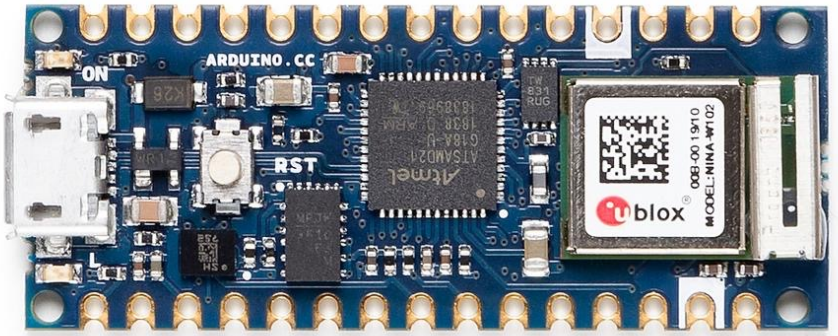


€35,00

Arduino Nano 33 IoT

The Arduino Nano 33 IoT is the easiest and cheapest point of entry to enhance existing devices (and creating new ones) to be part of the IoT and designing pico-network applications.

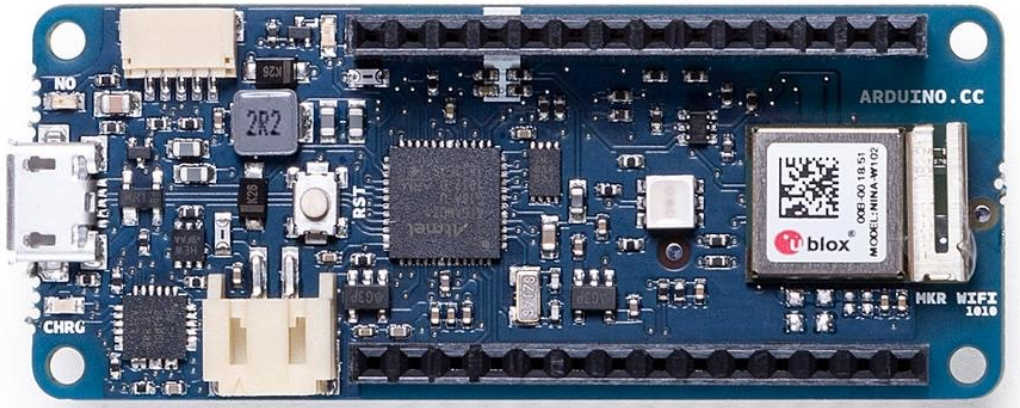
Whether you are looking at building a sensor network connected to your office or home router, or if you want to create a BLE device sending data to a cellphone, the Nano 33 IoT is your one-stop-solution for many of the basic IoT application scenarios.



€16,00

Arduino MKR WiFi 1010

The Arduino MKR WiFi 1010 is the easiest point of entry to basic IoT and pico-network application design.



The board's main processor is a low power Arm® Cortex®-M0 32-bit SAMD21, like in the other boards within the Arduino MKR family.

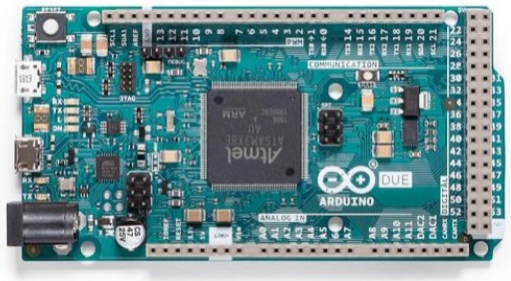
The WiFi and Bluetooth® connectivity is performed with a module from u-blox, the NINA-W10, a low power chipset operating in the 2.4GHz range.

On top of those, secure communication is ensured through the Microchip® ECC508 crypto chip. Besides that, you can find a battery charger, and a directionable RGB LED on-board.

Arduino Nano Every - Pack

The Nano Every is Arduino's 5V compatible board in the smallest available form factor: 45x18mm! The Arduino Nano is the preferred board for many projects requiring a small and easy to use microcontroller board. One example is low cost robotics, where the Nano is broadly used. If you are in the s...

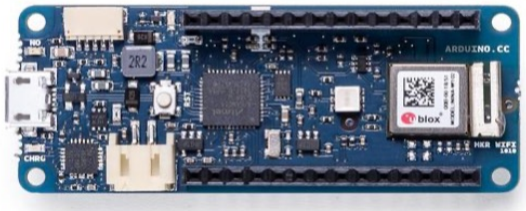
View full details



Arduino Due

The Arduino Due is a microcontroller board based on the Atmel SAM3X8E ARM Cortex-M3 CPU. It is the first Arduino board based on a 32-bit ARM core microcontroller. It has 54 digital input/output pins (of which 12 can be used as PWM outputs), 12 analog inputs, 4 UARTs (hardware serial ports), a 84 ...

View full details



Arduino MKR WiFi 1010

The Arduino MKR WiFi 1010 is the easiest point of entry to basic IoT and pico-network application design. Whether you are looking at building a sensor network connected to your office or home router, or if you want to create a BLE device sending data to a cellphone, the MKR WiFi 1010 is your one-...

View full details

Arduino Student Kit

€54,00

Learn the basics of programming, coding and electronics, including current, voltage and digital logic. No prior knowledge or experience is necessary as the kit guides you through step by step. You'll get all the hardware and software you need for one person, making it ideal to use for remote tea...

QUICK SHOP

ADD TO CART

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Arduino Sensor Kit - Base

€24,70

The Arduino Sensor Kit is made for Makers who have just started using Arduino to explore the vast space of electronics and programming. This kit teaches how to connect and program basic Grove modules that includes both sensors and actuators. Grove is an open-source, modulated, and ready-to-use ...

QUICK SHOP

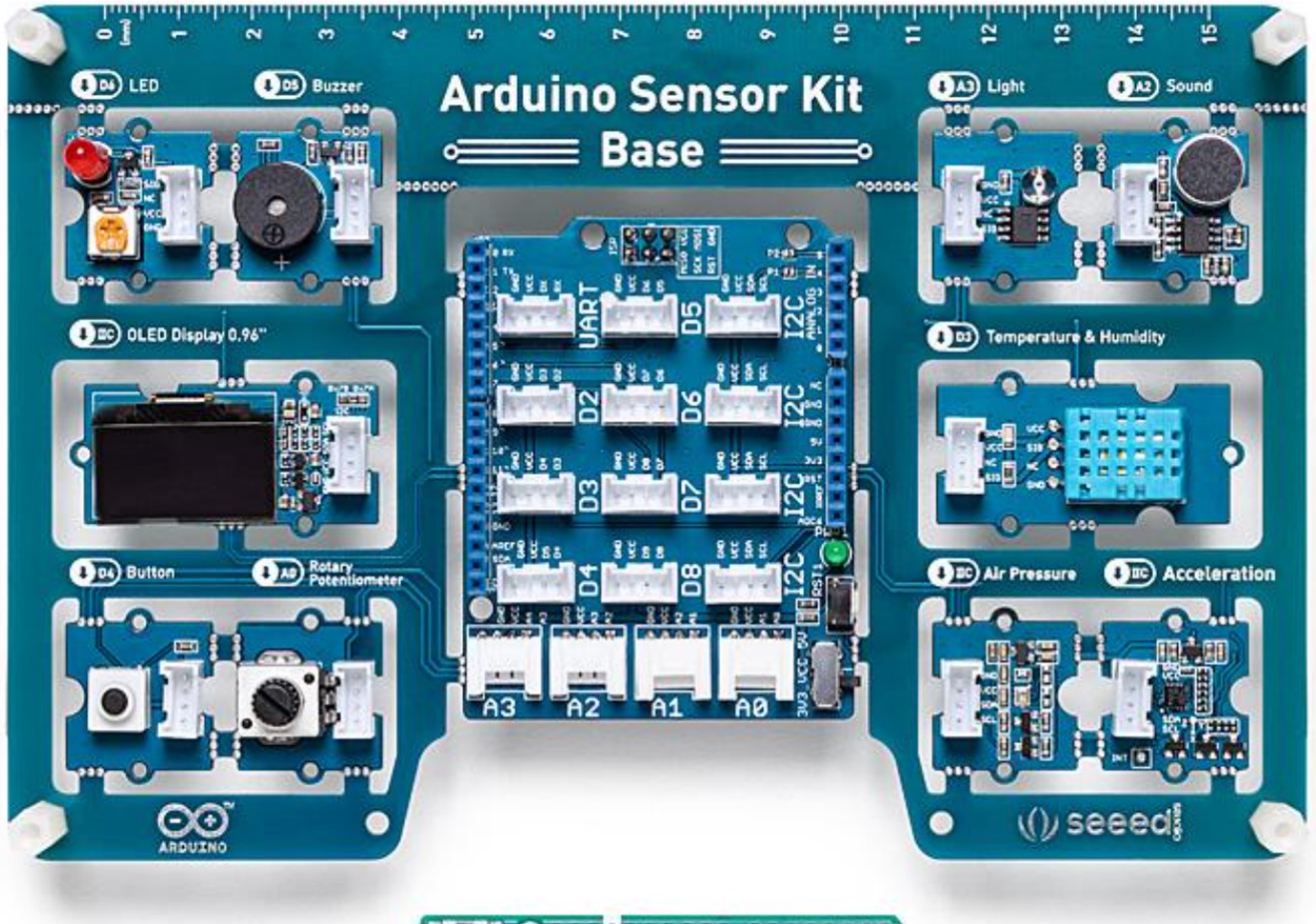
ADD TO CART

View full details

The Arduino Sensor Kit

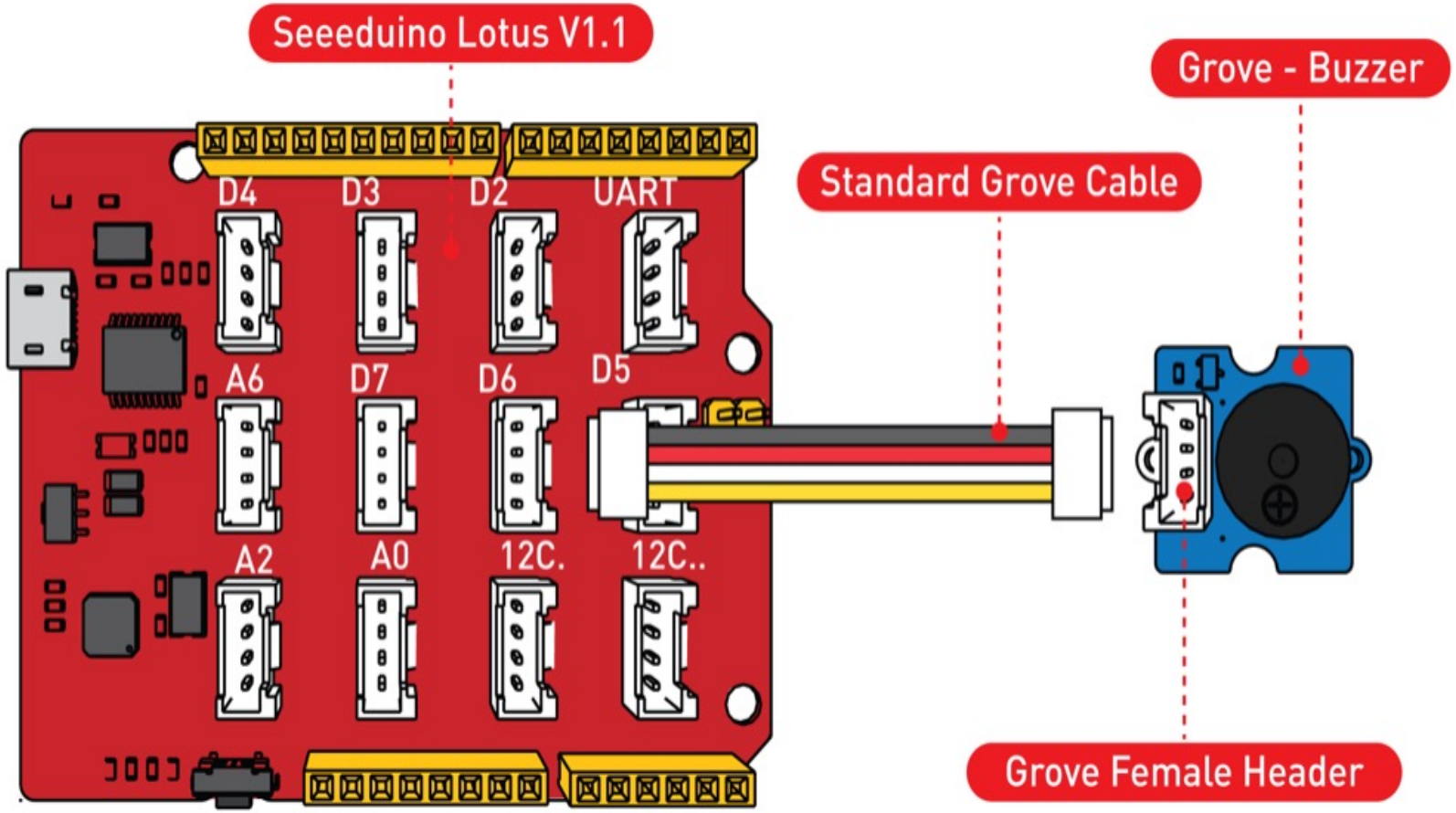
is made for Makers who have just started using Arduino to explore the vast space of electronics and programming. This kit teaches how to connect and program basic Grove modules that includes both sensors and actuators along with the Arduino Uno.

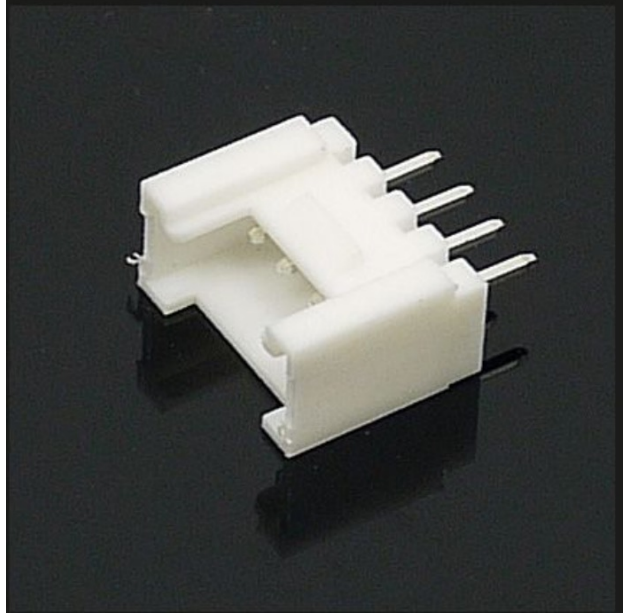
All of the modules use a Grove connector, which connects each of the components to a Base Shield in just a few seconds. The Base Shield can then be mounted on to an Arduino UNO board and can be programmed using the Arduino IDE. Instructions for connecting and programming the different modules are also included in this kit.

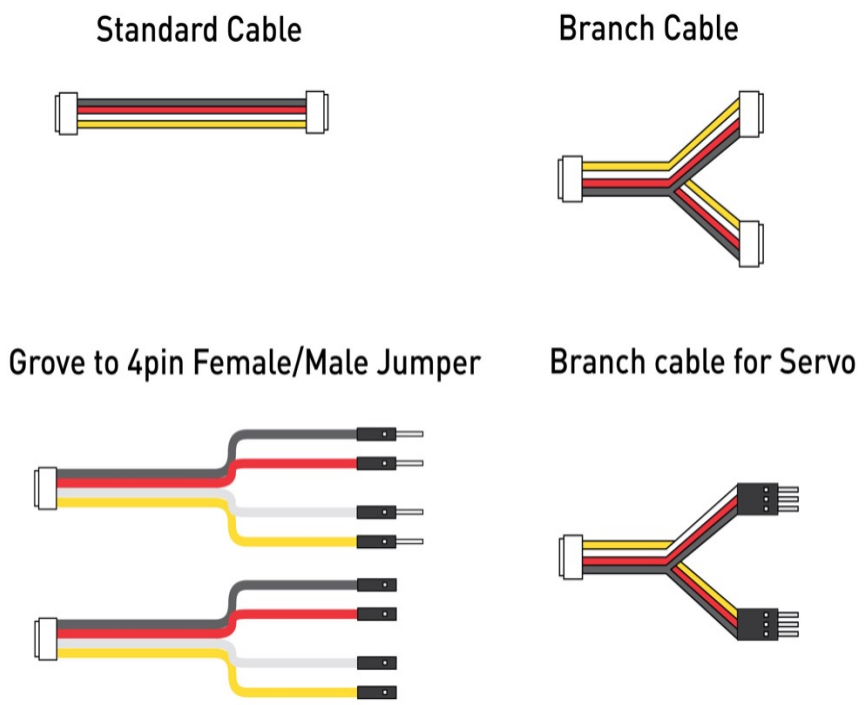


Grove connector

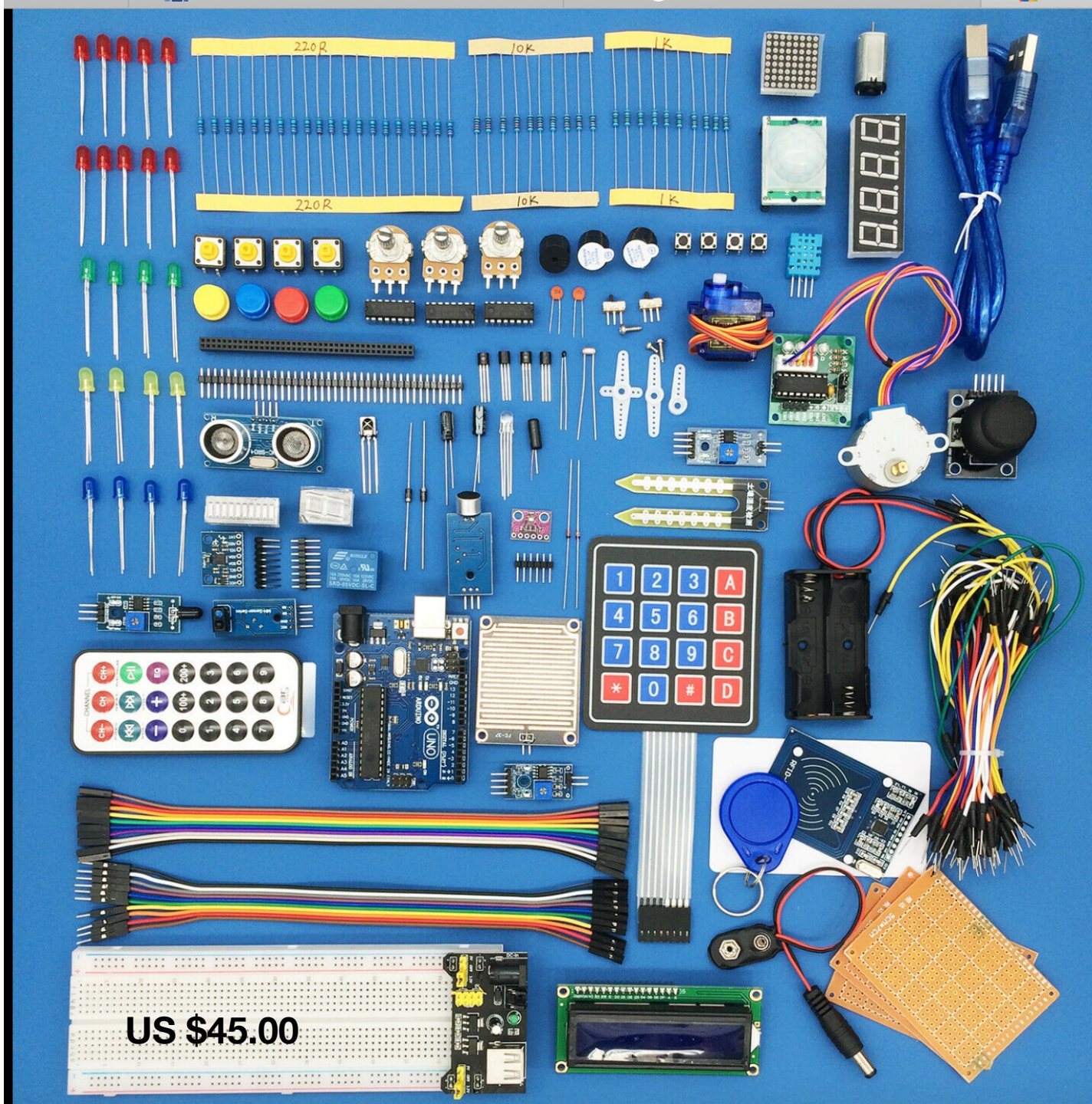
The Grove Female Header allows you to solder it into your exciting modules with a 4-pin connection and use the Grove cable along with the connector to connect your modules to various other development boards offered by Seeed.







Ultimate Starter Kit with UNO R3 Breadboard 1602LCD Servo Motor LED for Arduino



EXPERT ARDUINO BASIC ELECTRONICS ULTIMATE KIT

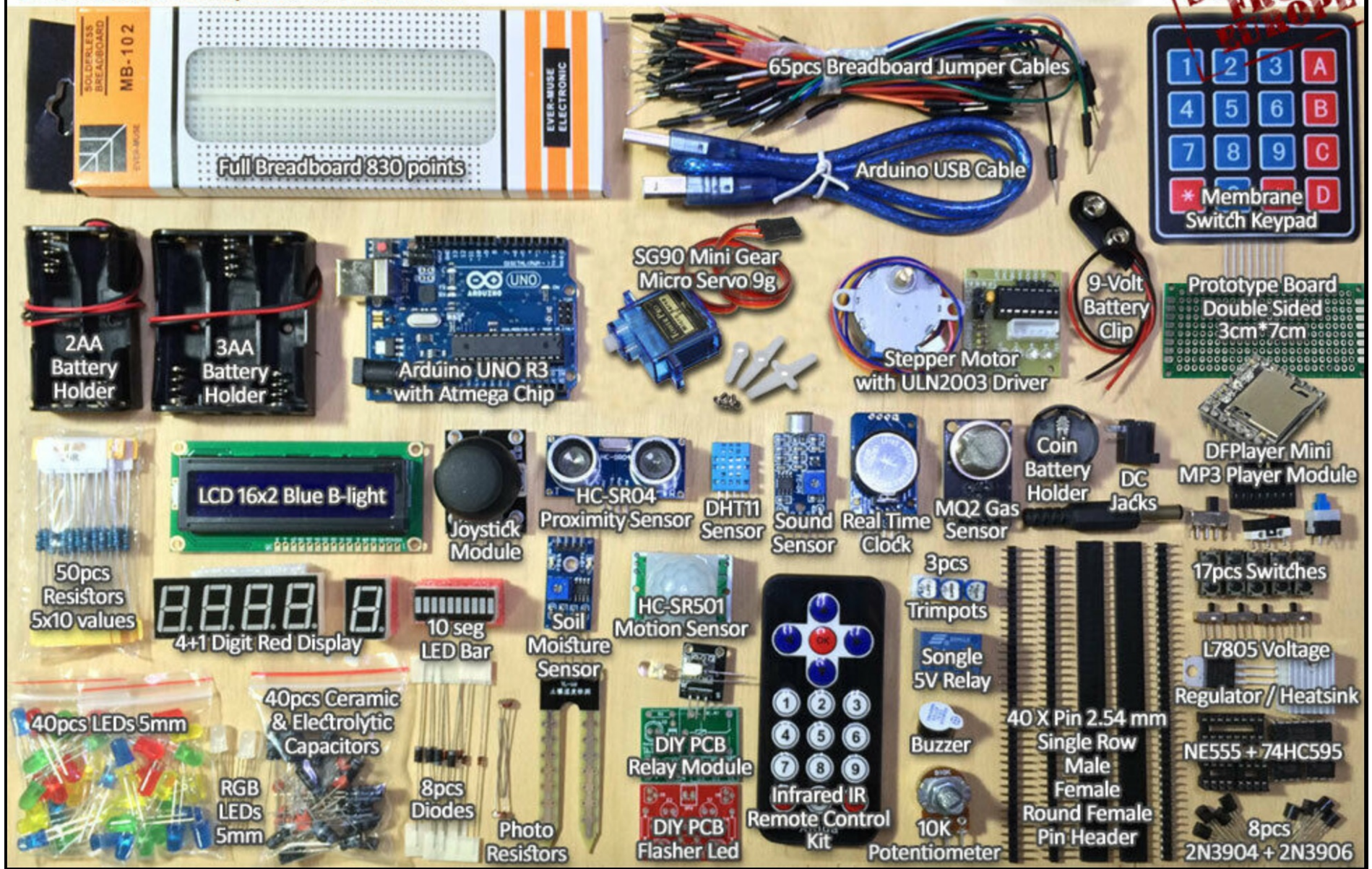
with Arduino UNO, Breadboard 830, Resistors, Jumpers, Sensors, DIY kits

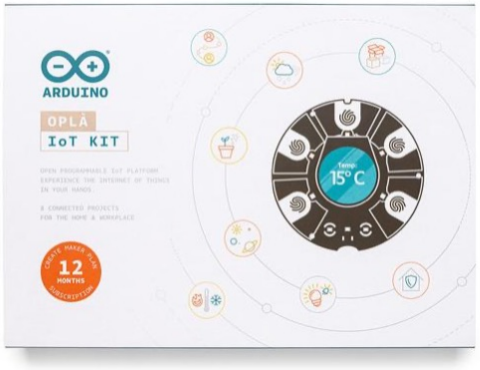
Every basic component for all the Arduino experiments you can find anywhere online...

Including DIY project "Relay Breakout Module 1 Channel" and "2 Led Flasher"
2 PCBs to solder all components with instructions

280 pcs included

FAST SHIPPING FROM EUROPE





Arduino Oplà IoT Kit

€99,00

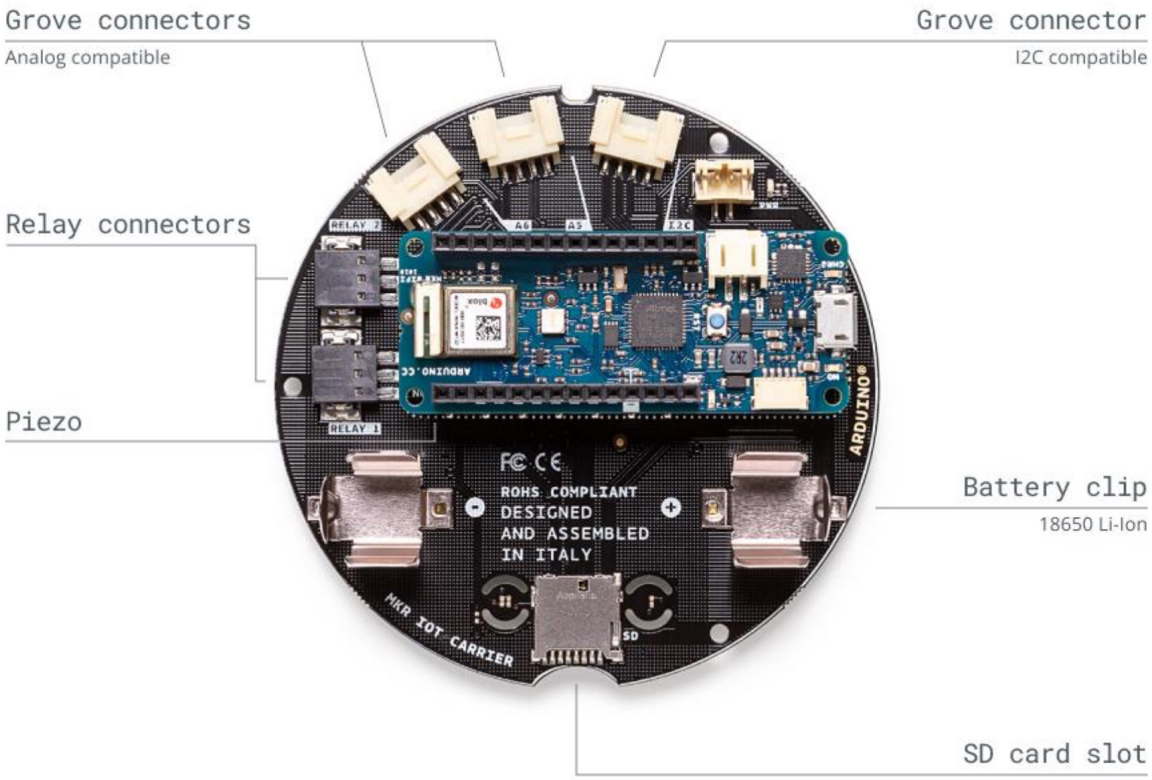
The Oplà IoT Kit allows you to add connectivity to devices around the home or workplace. It comes complete with a set of 8 Internet of Things self assemble projects ready to show you how to turn everyday appliances into 'smart appliances' and build custom connected devices that can be controlle...

QUICK SHOP

ADD TO CART

View full details

https://store.arduino.cc/collections/kits/products/arduino-opla-iot-kit



Watch this video

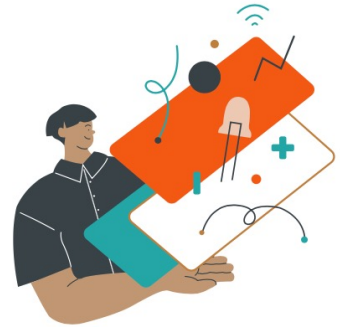
https://www.youtube.com/watch?v=livKtMZQMS8&t=12s

Arduino Cloud IoT

Configure, program and connect your devices - all through the Arduino IoT Cloud service.

QUICKSTART GUIDE → ARDUINO IOT CLOUD ↗

https://docs.arduino.cc/cloud/iot-cloud



Create your first Thing

A Thing is a connected device that can communicate with the cloud. You can make your Things interact with other Things or anything else in the physical world.

CREATE THING

Explore, get inspired, start building

Import, use, and customize ready-made templates for your IoT projects

Home Security Alarm

Build a basic alarm system and explore different trigger signals.

Oplà IoT Kit

Personal Weather Station

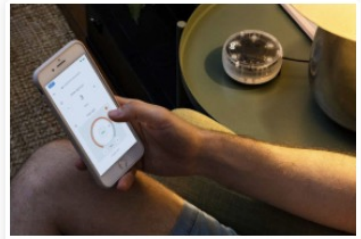
Gather temperature, moisture and humidity data from your surroundings.

Oplà IoT Kit

Inventory Control

Keep track of your inventories and update them remotely in real time.

Oplà IoT Kit



Remote Controlled Lights

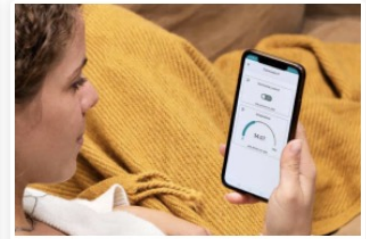
Test different light colours, patterns and outputs through the Arduino IoT Cloud.

Oplà IoT Kit

Smart Garden

Create an urban farming application and monitor your house plants.

Oplà IoT Kit



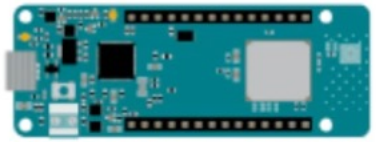
Thermostat Control

Create a basic thermostat device that can monitor and control temperature.

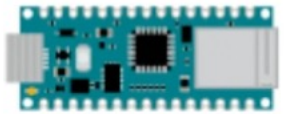
Oplà IoT Kit

Compatible Devices

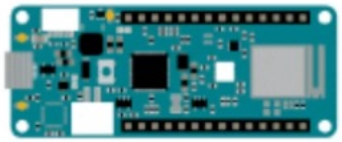
MKR Family



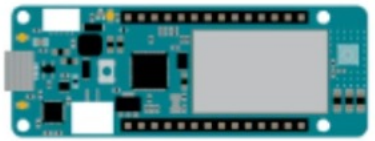
MKR WAN 1300



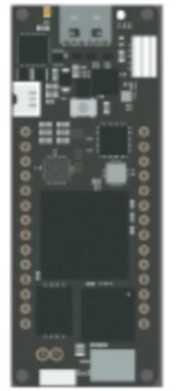
Nano 33 IoT



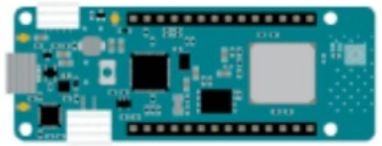
MKR WiFi 1010



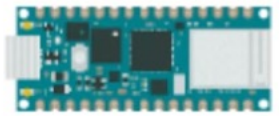
MKR GSM 1400



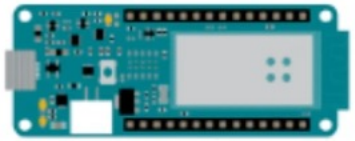
PORTENTA H7



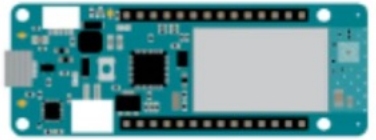
MKR WAN 1310



Nano RP2040 Connect



MKR 1000 WiFi

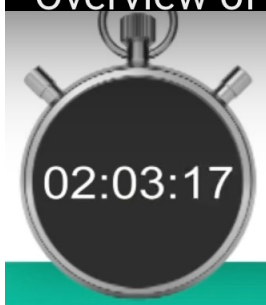


MKR NB 1500

ARDUINOPRO

https://www.youtube.com/watch?v=y2z1qsgHsAw

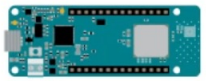
Overview of Arduino IoT Cloud (2021) | Learn Technology in 5 Minutes

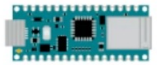


Compatible Devices

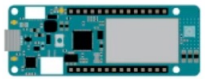
LEARN TECHNOLOGY IN 5 MINUTES BY MAKERDEMY

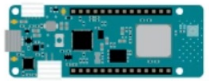
MKR Family

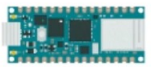

MKR WAN 1300

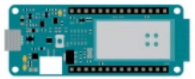

Nano 33 IoT

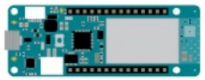

MKR WiFi 1010


MKR GSM 1400


MKR WAN 1310


Nano RP2040 Connect

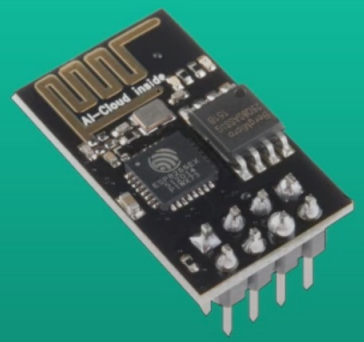

MKR 1000 WiFi


MKR NB 1500


PORTENTA H7

ARDUINOPRO

3rd-Party Compatible Devices



ESP8266

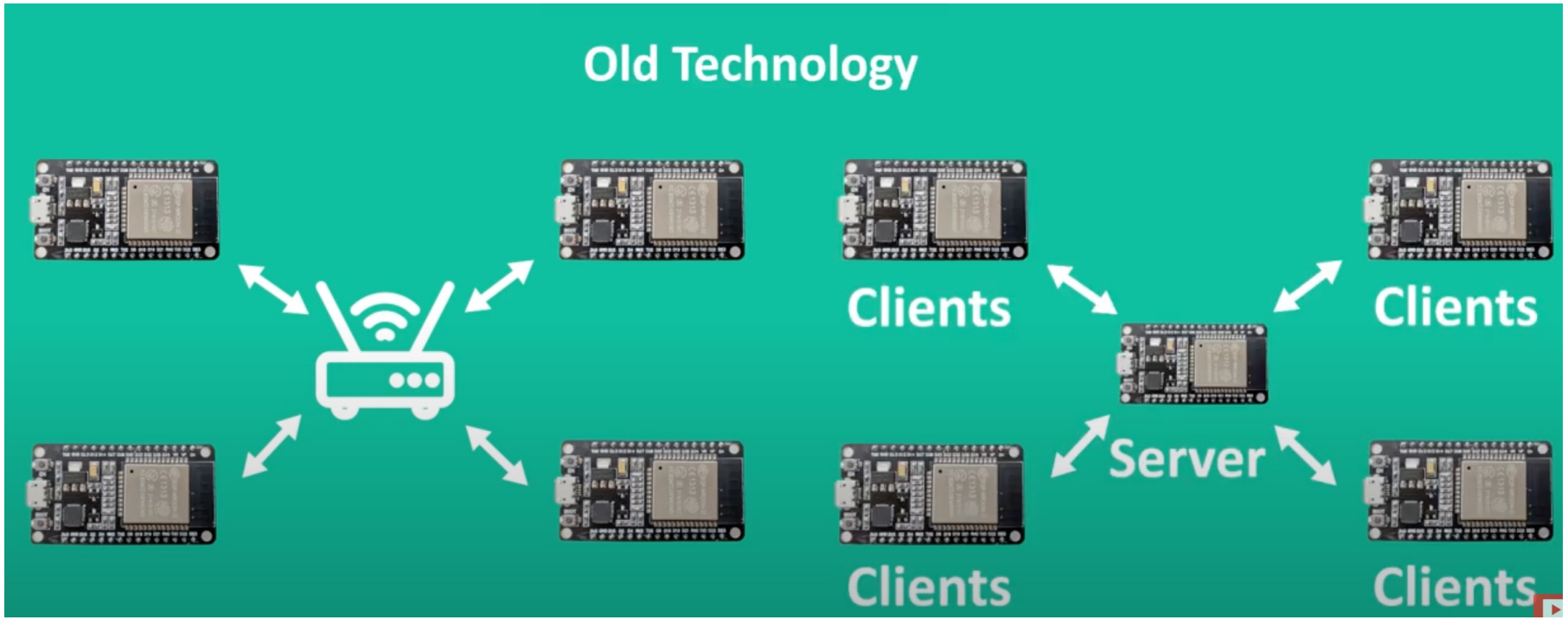
LoRaWAN

ESP32

Play (k)

Subscribe

2:32 / 5:23


Old Technology
Clients
Clients
Server
Clients
Clients


Latest Technology
ESP NOW
ESP32
Peer-to-Peer
ESP8266

Arduino IoT Cloud Plans

LEARN TECHNOLOGY IN 5 MINUTES BY MAKERDEMY

MONTHLY YEARLY

FREE

Everything you need to learn Arduino, build your first IoT project and control it from your phone.

- 2 Things
- Unlimited dashboards
- 100 Mb to store sketches
- 1 day data retention
- 200s/day of compilation time

ENTRY

Get unlimited storage, scale up your IoT projects and get access to advanced features.

- 10 Things
- Unlimited dashboards
- Unlimited storage for sketches
- 15 days data retention
- Unlimited compilation time
- APIs
- Over the Air Updates

MAKER

BEST VALUE

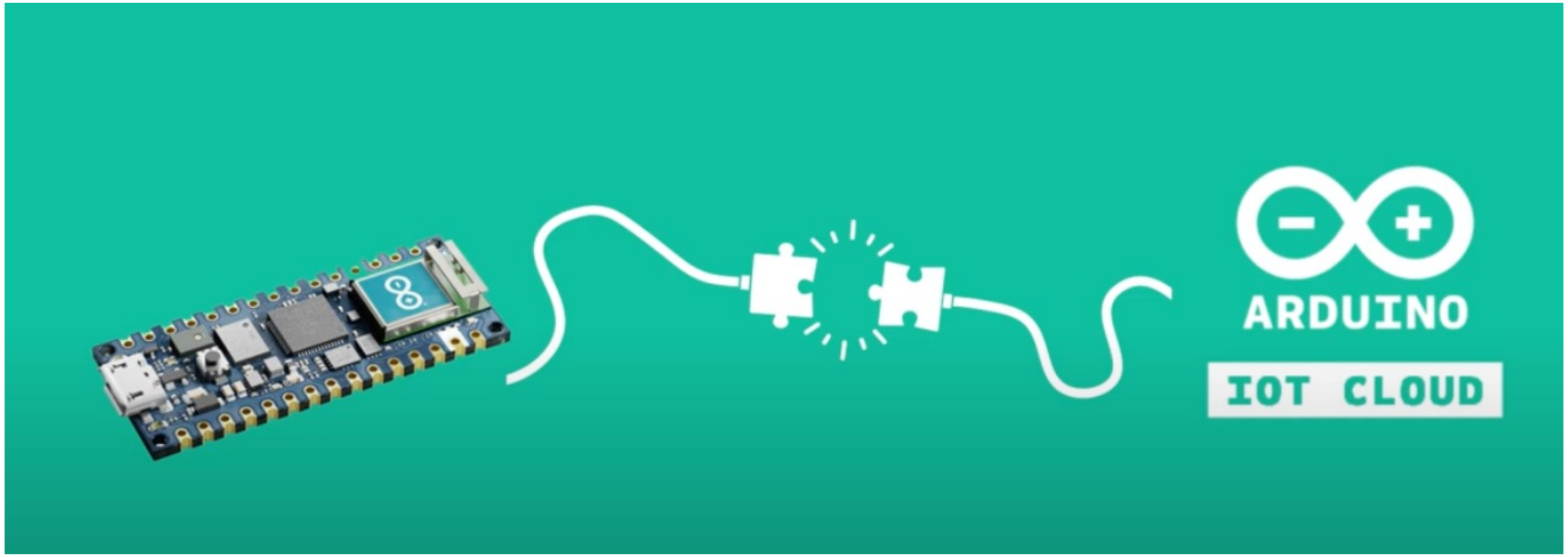
For makers that are getting serious and need a reliable and sophisticated IoT platform to run their projects.

- 25 Things
- Unlimited dashboards
- Unlimited storage for sketches
- 3 months data retention
- Unlimited compilation time
- APIs
- Over the Air Updates
- Dashboard sharing

MAKER PLUS

The option for makers with ambitions, that need to manage a small fleet of connected devices.

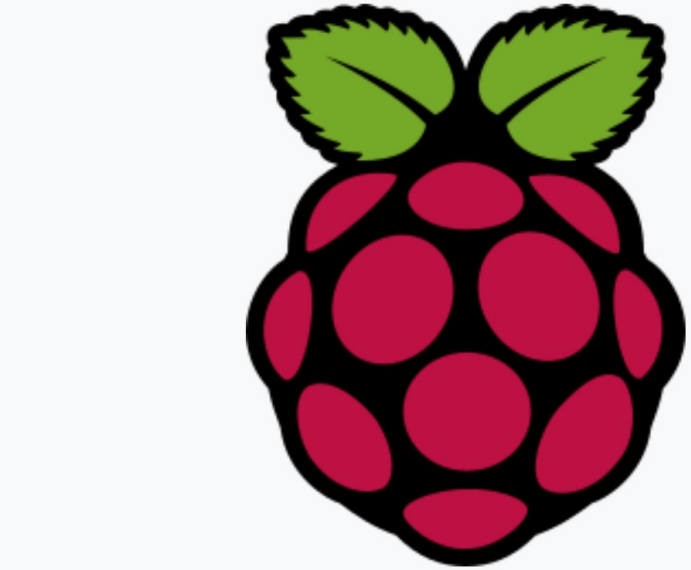
- 100 Things
- Unlimited dashboards
- Unlimited storage for sketches
- 1 year data retention
- Unlimited compilation time
- APIs
- Over the Air Updates
- Dashboard sharing

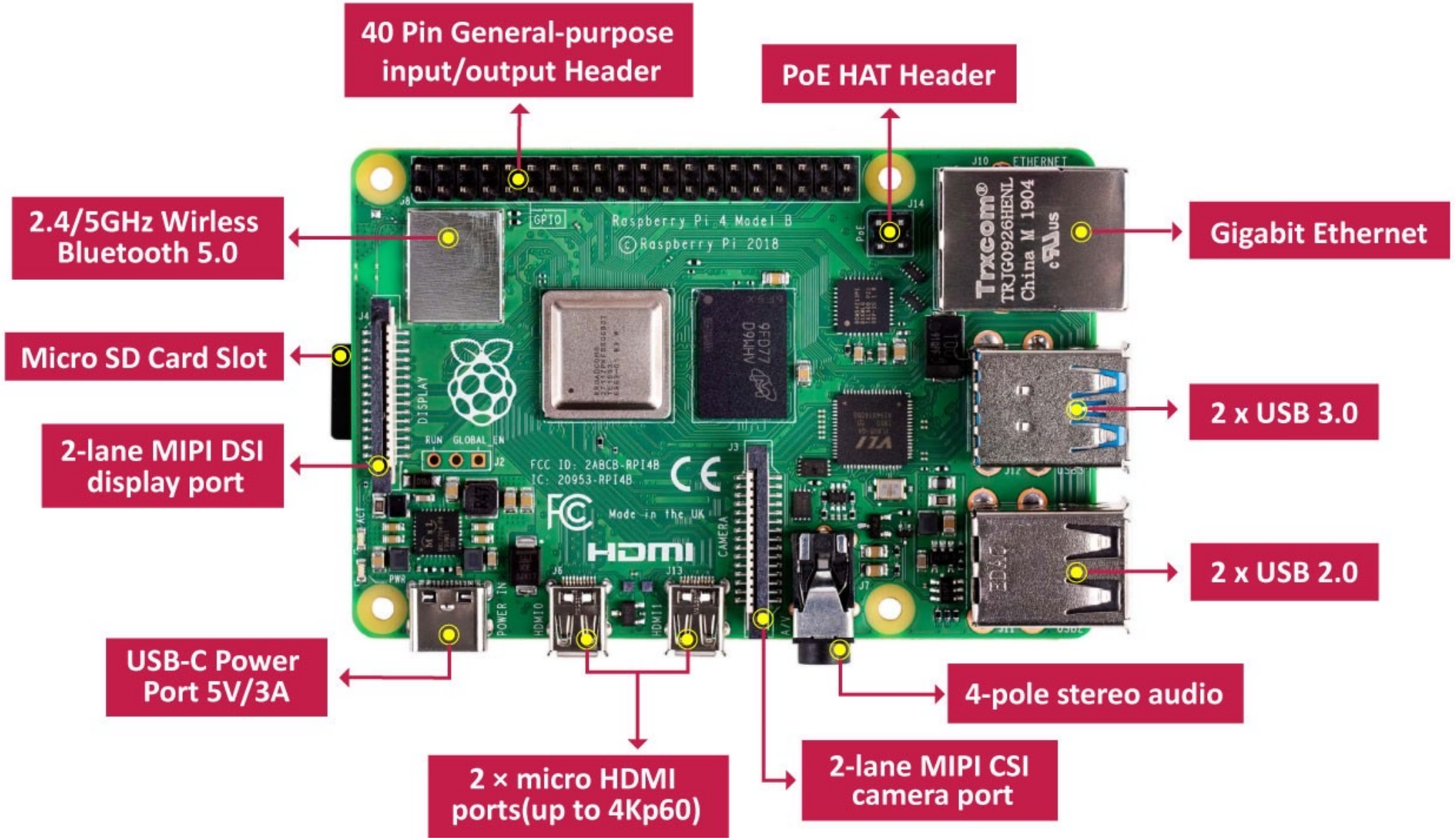


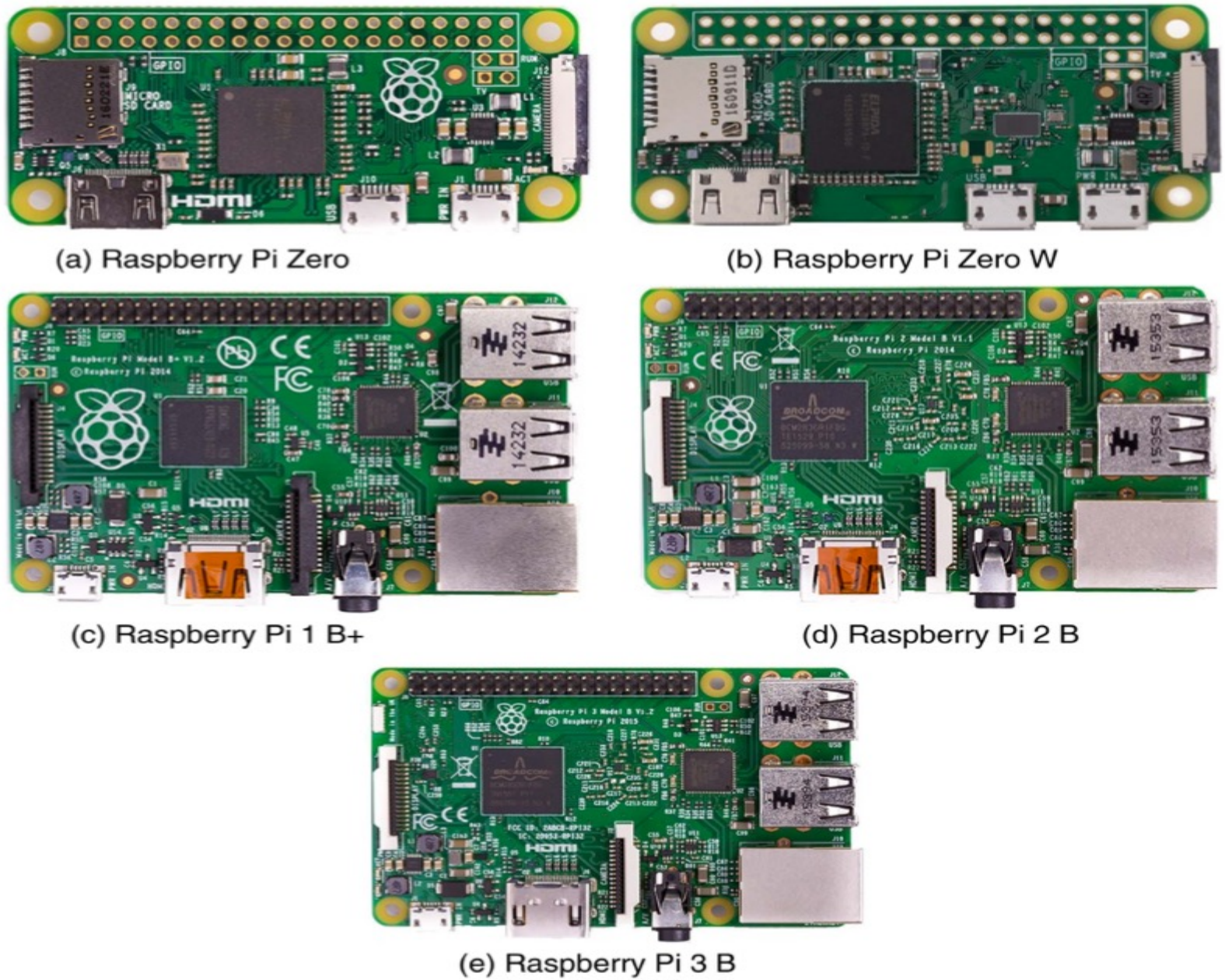
https://www.youtube.com/watch?v=fMaMerwXndI

Raspberry Pi

- A series of small single-board computers (SBCs)
- Developed in the United Kingdom by the Raspberry Pi Foundation in association with Broadcom.
- The Raspberry Pi project originally leaned towards the promotion of teaching basic computer science in schools and in developing countries.
- As of May 2021, more than forty million boards have been sold.[1]




40 Pin General-purpose input/output Header
PoE HAT Header
2.4/5GHz Wirless Bluetooth 5.0
Gigabit Ethernet
Micro SD Card Slot
2 x USB 3.0
2-lane MIPI DSI display port
2 x USB 2.0
USB-C Power Port 5V/3A
4-pole stereo audio
2 × micro HDMI ports(up to 4Kp60)
2-lane MIPI CSI camera port
Raspberry Pi 4 Model B
© Raspberry Pi 2018
FCC ID: 2ABCB-RPI4B
IC: 20953-RPI4B
Made in the UK
ETHERNET
GPIO
DISPLAY
CAMERA
POWER IN
HDMI0
HDMI1
RUN
GLOBAL EN
PWR
ACT



(a) Raspberry Pi Zero

(b) Raspberry Pi Zero W

(c) Raspberry Pi 1 B+

(d) Raspberry Pi 2 B

(e) Raspberry Pi 3 B

Figure 6.2 The selected Raspberry Pi models. (*Source:* Raspberrypi.org2017.)

Table 6.4 Summary of processing speed and memory/storage capacity of Raspberry Pi hardware platforms.

	Broadcom SoC				Memory/storage	
Raspberry Pi	SoC	CPU core	Processor architecture	Clock speed	RAM	Storage
Zero	BCM2835	ARM1176JZF-S	–	1 GHz	512 MB	Micro SD
Zero W	BCM2835	ARM1176JZF-S	–	1 GHz	512 MB	Micro SD
1 B+	BCM2835	ARM1176JZF-S	–	700 MHz	512 MB	Micro SD
2 B	BCM2836	Quad-core ARM Cortex-A7	32	900 MHz	1 GB	Micro SD
3 B	BCM2837	Quad-core ARM Cortex-A53	64	1.2 GHz	1 GB	Micro SD

Table 6.6 Summary of connectivity and flexibility/customizability of the peripherals of the Raspberry Pi.

Raspberry Pi	Onboard connectivity	GPIO pins	USB ports	Display ports/ interfaces	Camera port	Other hardware interfaces
Zero	–	40	1 mini	Mini-HDMI	CSI	UART, SPI, I2C
Zero W	Wi-Fi, Bluetooth 4.1, BLE	40	1 mini	Mini-HDMI	CSI	UART, SPI, I2C
1 B+	Ethernet	40	4	HDMI, DSI, 3.5 mm Video Jack	CSI	UART, SPI, I2C
2 B	Ethernet	40	4	HDMI, DSI, 3.5 mm Video Jack	CSI	UART, SPI, I2C
3 B	Ethernet, Wi-Fi, Bluetooth 4.1, BLE	40	4	HDMI, DSI, 3.5 mm Video Jack	CSI	UART, SPI, I2C

The Raspberry Pi 3

Raspberry Pi 3 is the third generation of Raspberry Pi and it packs quite a formidable punch in its credit card-sized package. Most notably, in addition to the standard features of the Raspberry Pi (such as four USB 2.0 ports and built-in Ethernet), it has:

- A 1.2GHz 64-bit quad-core ARMv8 CPU
- 802.11n Wireless LAN
- Bluetooth 4.1 Low Energy (BLE)

The powerful CPU coupled with Wireless LAN and Bluetooth 4.1 radio makes it an ideal candidate for IoT projects, because multiple sensors can be connected to it simultaneously. In addition, the Raspberry Pi has a 40-pin GPIO (General Purpose I/O) connector for interfacing with external sensors.

Products

Raspberry Pi 400 Personal Computer Kit

Raspberry Pi 400 is your complete personal computer, built into a compact keyboard. Featuring a quad-core 64-bit processor, 4GB of RAM, wireless networking, dual-display output, and 4K video playback, as well as a 40-pin GPIO header, it's the most powerful and easy-to-use Raspberry Pi computer yet.

More info >

Raspberry Pi Pico

The new, flexible $4 microcontroller board from Raspberry Pi

More info >

Raspberry Pi 4 Model B

Your tiny, dual-display, desktop computer

More info >

https://www.raspberrypi.com/products/

Raspberry Pi 4 Model B

The Raspberry Pi 4 B, introduced in 2019

- Released in June 2019
- with a 1.5 GHz 64-bit quad core ARM Cortex-A72 processor,

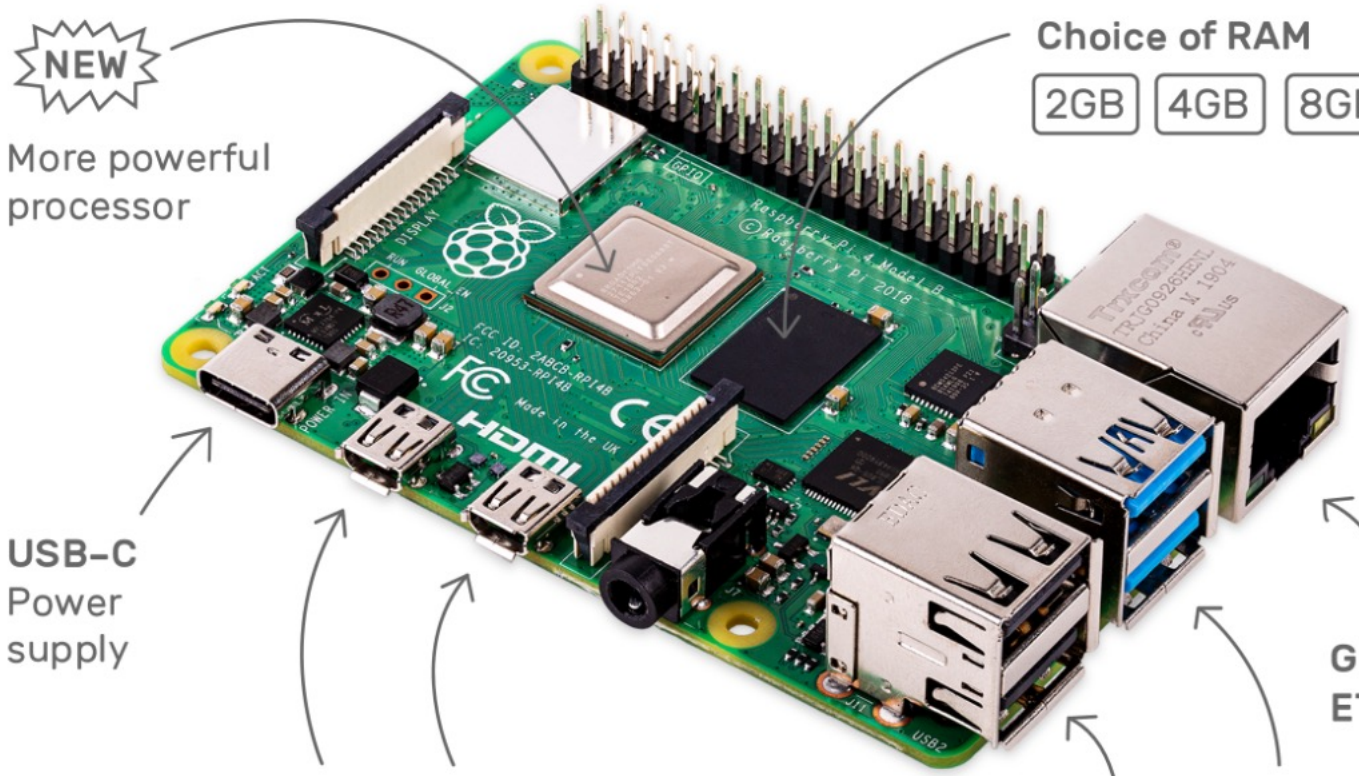
- On-board 802.11ac Wi-Fi, Bluetooth 5, full gigabit Ethernet (throughput not limited),

- Two USB 2.0 ports, two USB 3.0 ports, 2-8 GB of RAM, and dual-monitor support via a pair of micro HDMI (HDMI Type D) ports for up to 4K resolution.

- The Pi 4 is also powered via a USB-C port, enabling additional power to be provided to downstream peripherals, when used with an appropriate PSU.

Raspberry Pi 4

Your tiny, dual-display, desktop computer
...and robot brains, smart home hub, media centre, networked AI core, factory controller, and much more



Raspberry Pi 400

Your complete personal computer, built into a **compact keyboard**

was released in November 2020.

It features a custom board that is derived from the existing Raspberry Pi 4, specifically remodelled with a keyboard attached.

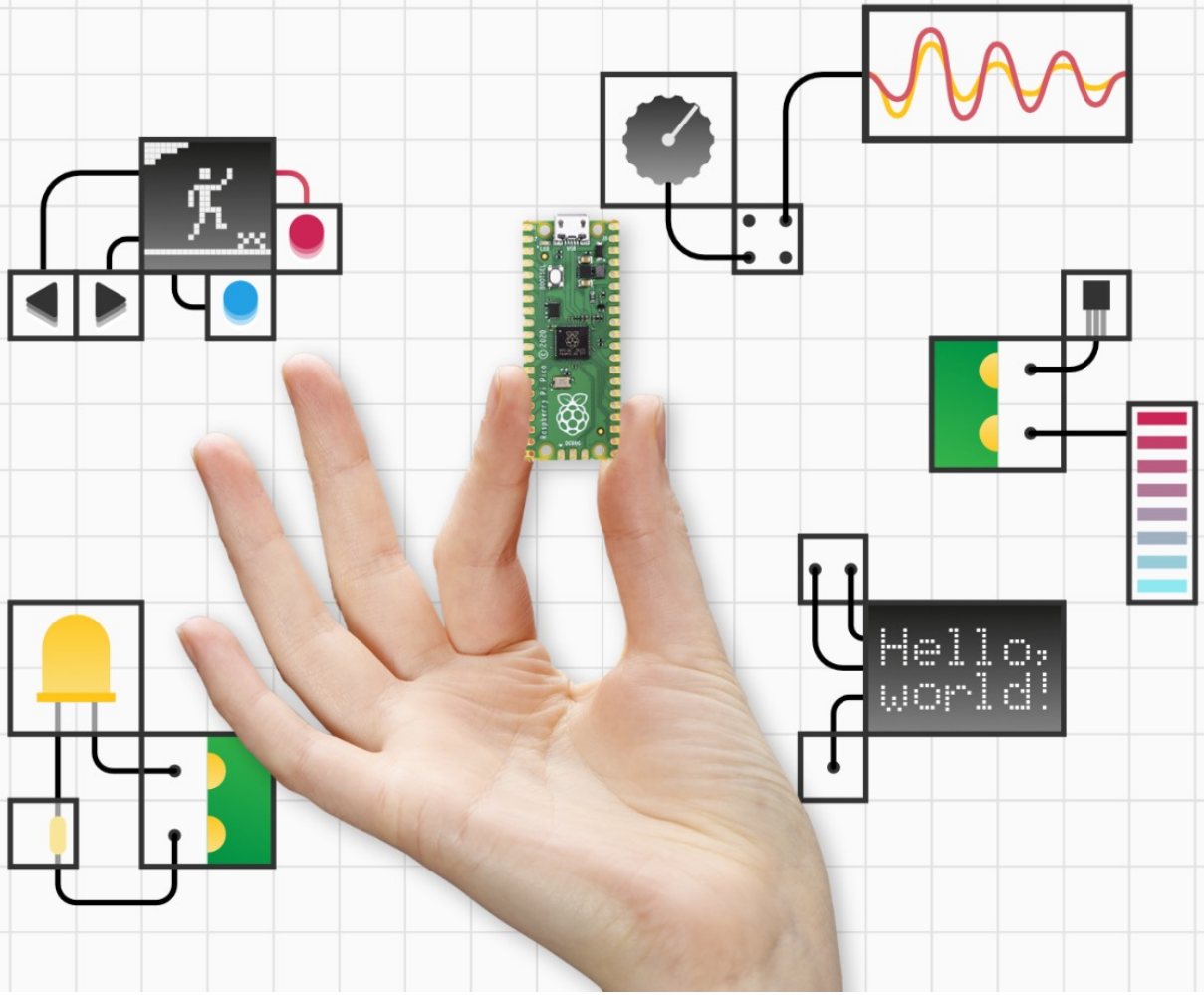
the Raspberry Pi 400's Broadcom BCM2711C0 processor to be clocked at 1.8 GHz

The keyboard-computer features 4 GB of LPDDR4 RAM.

Raspberry Pi Pico

The new flexible $4 microcontroller board from Raspberry Pi

Raspberry Pi Pico is a tiny, fast, and versatile board built using RP2040, a brand new microcontroller chip designed by Raspberry Pi in the UK.



Raspberry Pi Pico

- **Raspberry Pi Pico** was released in January 2021 with a retail price of $4.
- It was Raspberry Pi's first board based upon a single microcontroller chip;
- The **RP2040**, which was designed by Raspberry Pi in the UK.
- The Pico has 264 KB of RAM and 2 MB of flash memory.
- It is programmable in MicroPython, CircuitPython, and C.
- It has partnered with Vilros, Adafruit, Pimoroni, Arduino and SparkFun to build Accessories for Raspberry Pi Pico and variety of other boards using RP2040 Silicon Platform.
- Rather than perform the role of general purpose computer (like the others in the range) it is designed for physical computing, similar in concept to an Arduino.[42]

Upto 133 MHz	16 MHz
SRAM - 264 KB	SRAM - 2KB

21 mm × 51 mm form factor

RP2040 microcontroller chip designed by Raspberry Pi in the UK

Dual-core Arm Cortex-M0+ processor, flexible clock running up to 133 MHz

264KB on-chip SRAM

2MB on-board QSPI Flash

26 multifunction GPIO pins, including 3 analogue inputs

2 × UART, 2 × SPI controllers, 2 × I2C controllers, 16 × PWM channels

1 × USB 1.1 controller and PHY, with host and device support

8 × Programmable I/O (PIO) state machines for custom peripheral support

Supported input power 1.8–5.5V DC

Operating temperature -20°C to +85°C

Castellated module allows soldering direct to carrier boards

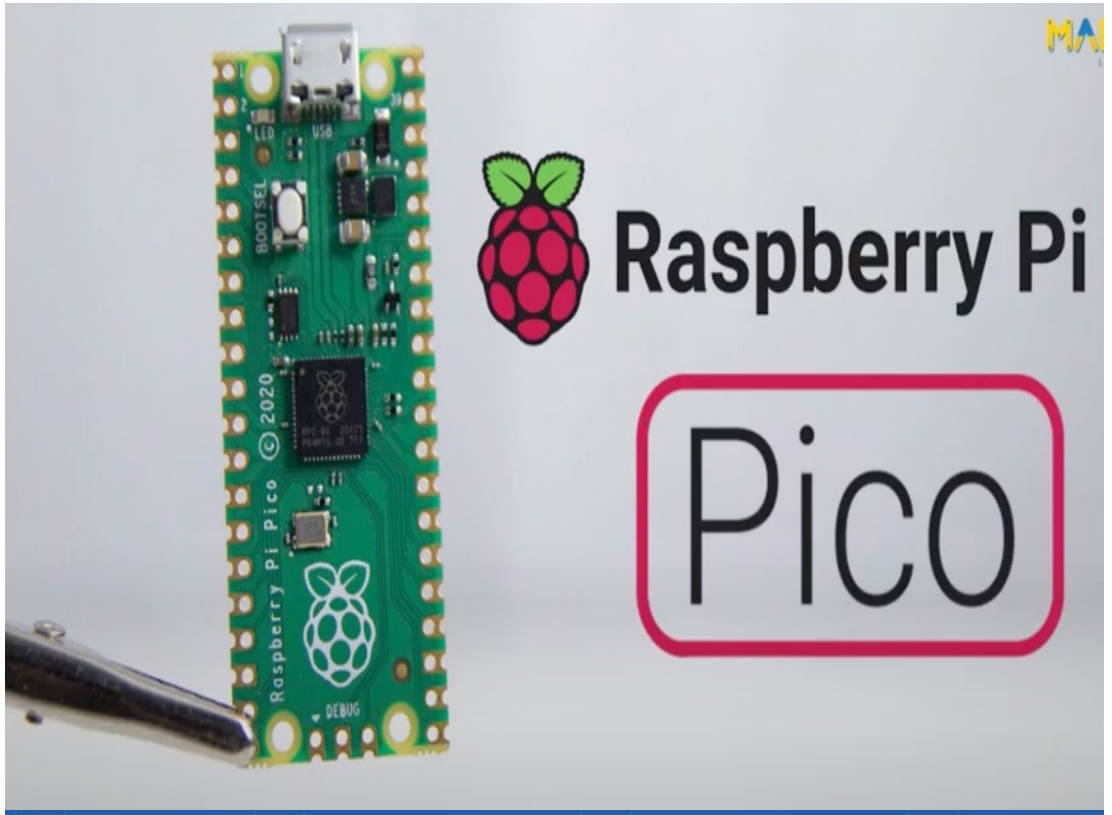
Drag-and-drop programming using mass storage over USB

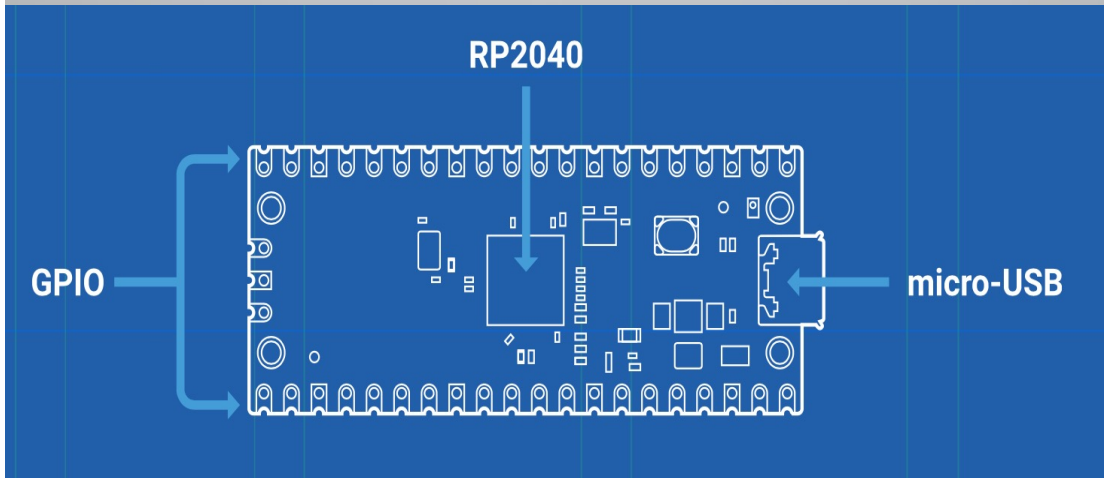
Low-power sleep and dormant modes

Accurate on-chip clock

Temperature sensor

Accelerated integer and floating-point libraries on-chip

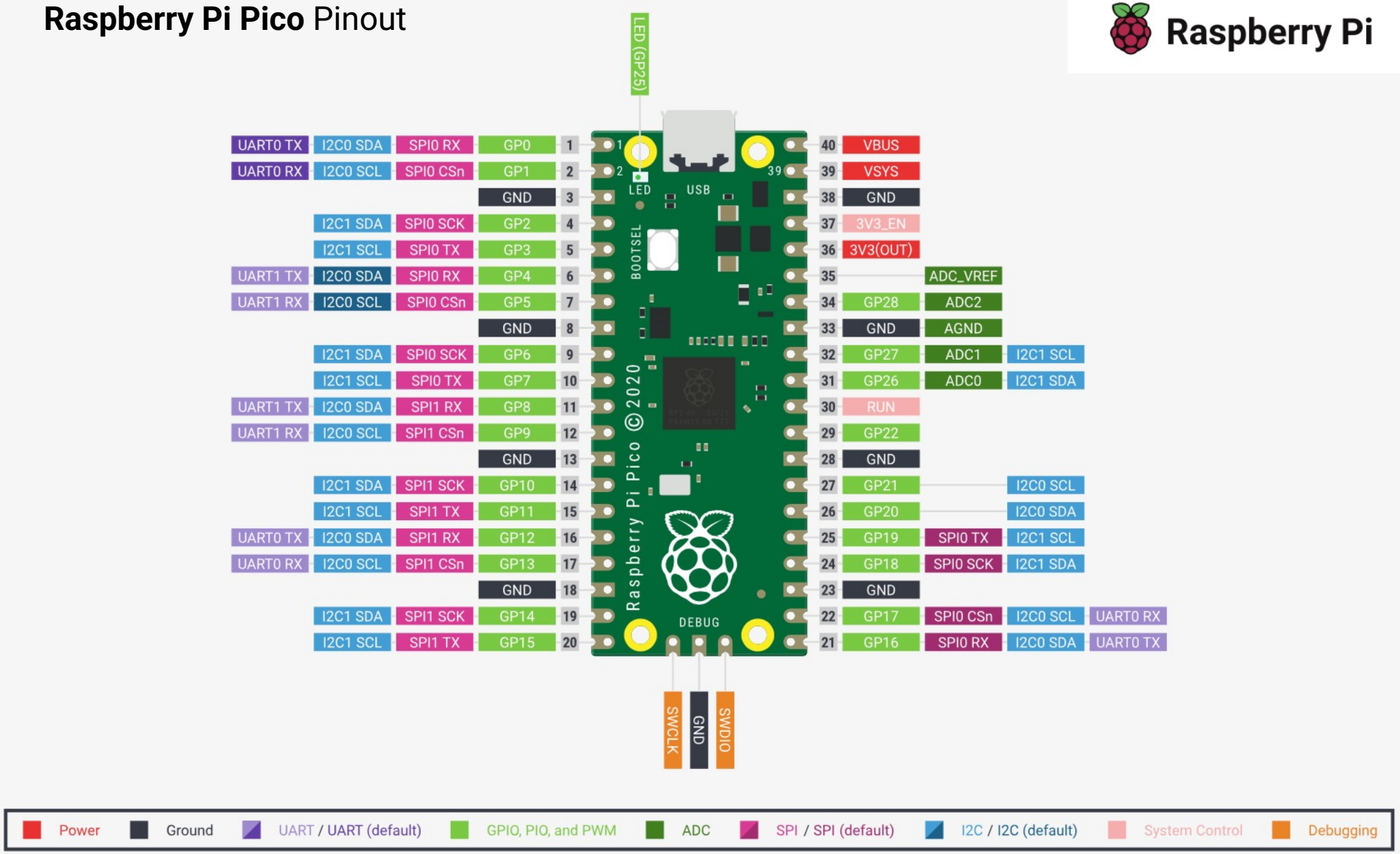




https://www.raspberrypi.com/documentation/microcontrollers/raspberry-pi-pico.html

Raspberry Pi Pico Pinout

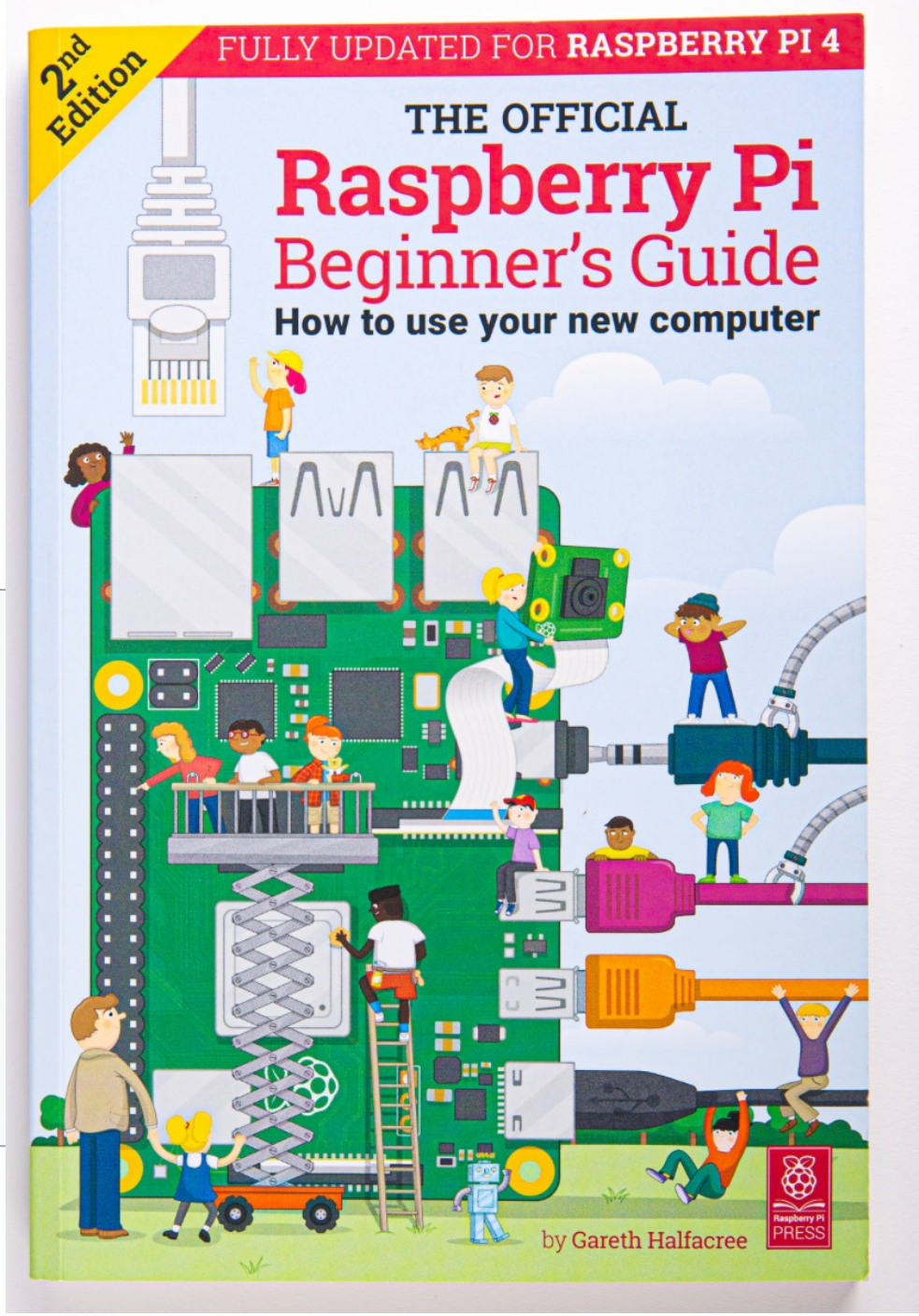
Raspberry Pi



Raspberry Pi

https://www.raspberrypi.com/

Introductory price	•US$4.00 (Pi Pico) •US$35.00 (Pi 4 2 GB) •US$55.00 (Pi 4 4 GB) •US$75.00 (Pi 4 8 GB) •US$70.00 (Pi 400 4 GB)



6.2.2.3 Operating Systems and Programming Languages for Raspberry Pi

The Raspberry Pi does not come with an OS. Hence, based on their projects, users can choose the type of OS that best suits their needs.

The **Raspbian OS** is officially supported by the Raspberry Pi Foundation, the Raspberry Pi SBC is capable of supporting a wide variety of OSes.

The Linux-based OSes supported by the Raspberry Pi include Ubuntu MATE, Snappy Ubuntu, Pidora, Linutop, SARPi, Arch Linux ARM, Gentoo Linux, FreeBSD, and Kali Linux.

The Raspberry Pi 2 and 3 can also run Windows based OSes like Windows 10 IoT Core

6 https://www.raspberrypi.org/magpi-issues/Projects_Book_v1.pdf
7 https://www.raspberrypi.org/products/
8 https://www.raspberrypi.org/products/
9 https://www.raspberrypi.org/magpi/raspberry-pi-3-specs-benchmarks/
10 https://www.raspberrypi.org/blog/raspberry-pi-zero/
11 https://www.raspbian.org/
12 https://www.raspberrypi.org/downloads/raspbian/
13 https://www.sos.sk/productdata
14 https://www.raspberrypi.org/products/pi-zero-wireless/
15 https://www.raspberrypi.org/products/

Raspberry Pi OS

Your Raspberry Pi needs an operating system to work. This is it. Raspberry Pi OS (previously called Raspbian) is our official supported operating system.

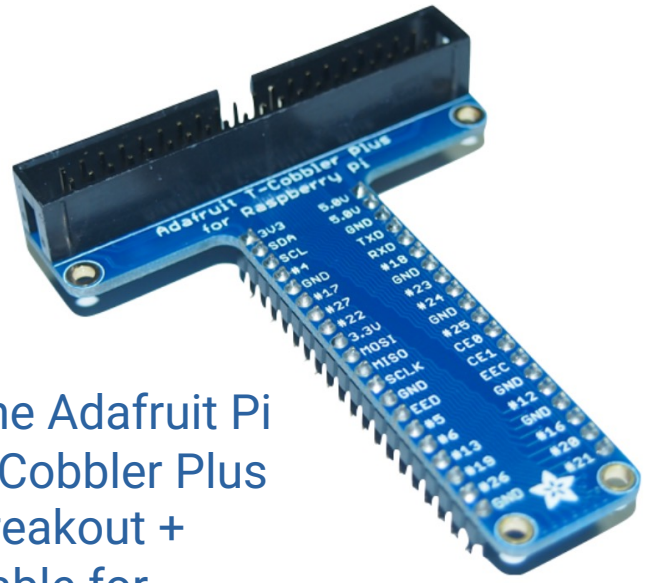
NEW Raspberry Pi OS update (May 2020)

https://www.raspberrypi.com/software/

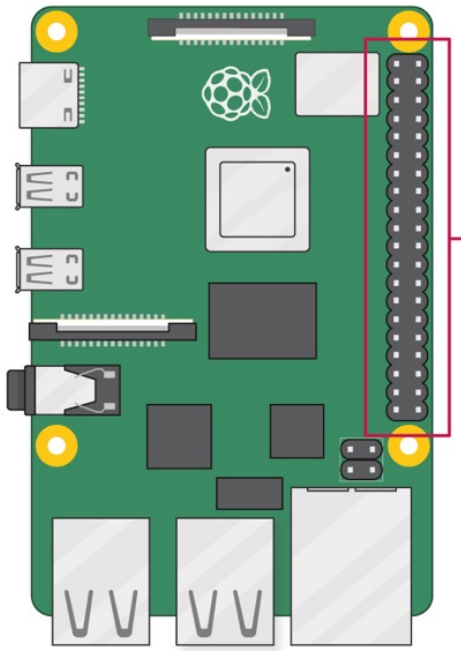
GPIO and the 40-pin Header

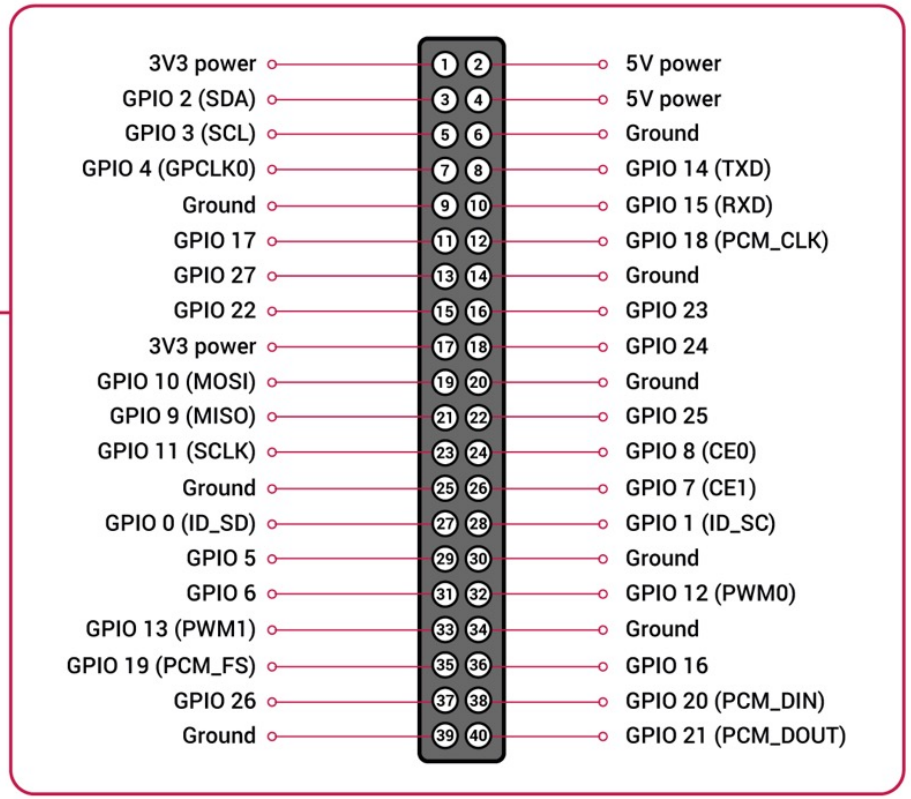
Edit this on GitHub

A powerful feature of the Raspberry Pi is the row of GPIO (general-purpose input/output) pins along the top edge of the board. A 40-pin GPIO header is found on all current Raspberry Pi boards (unpopulated on Pi Zero and Pi Zero W). Prior to the Pi 1 Model B+ (2014), boards comprised a shorter 26-pin header.



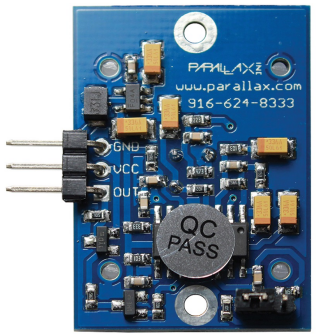
The Adafruit Pi T-Cobbler Plus Breakout + Cable for Raspberry Pi

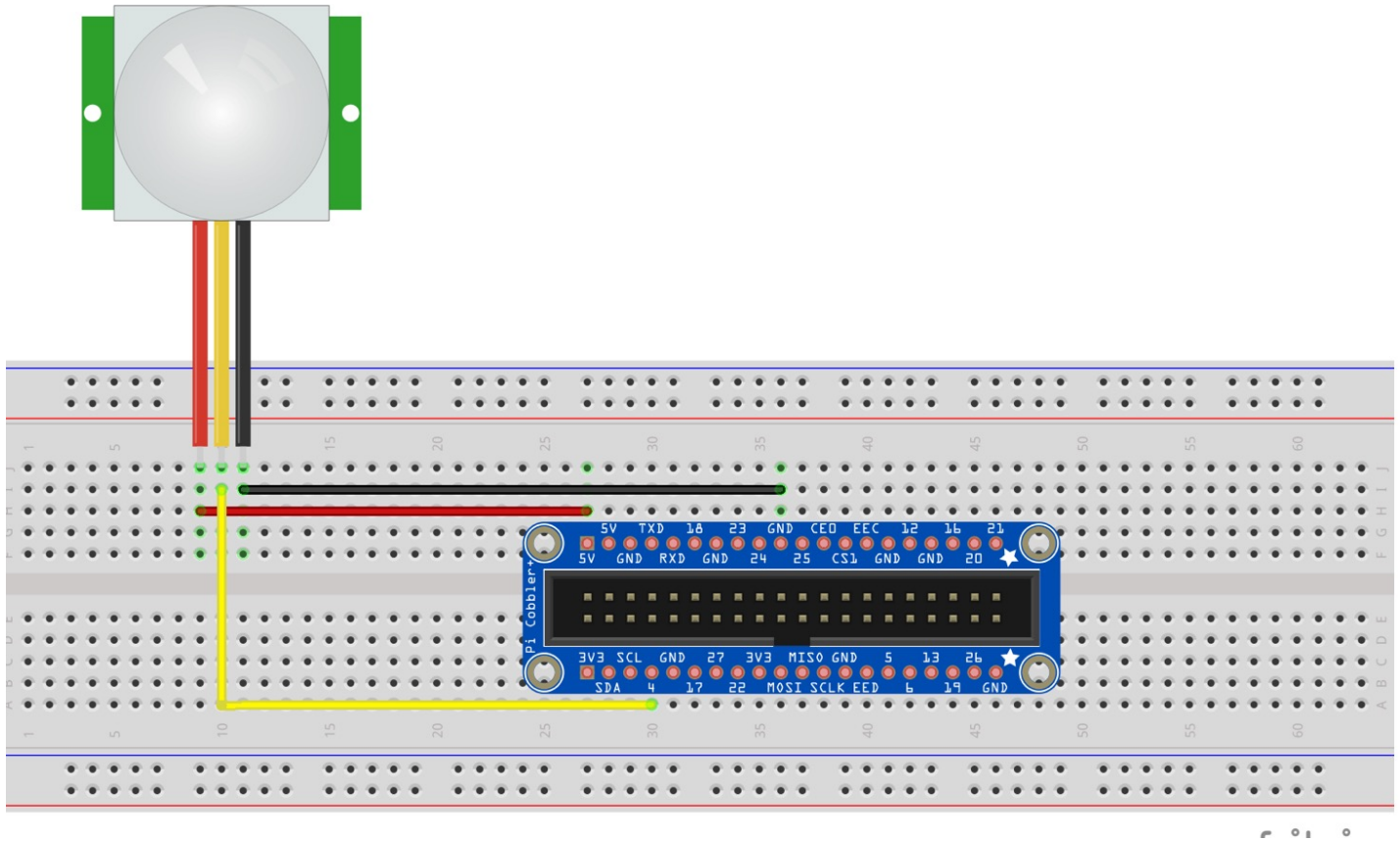




https://www.raspberrypi.com/documentation/computers/os.html#gpio-and-the-40-pin-header

Connecting to a Sensor to Detect Motion





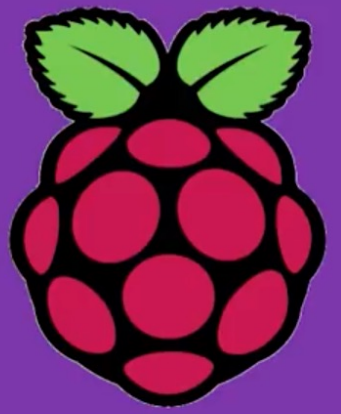
Specifications

Arduino Uno
Single-board Microcontroller

- Control Unit – ATmega328 Microcontroller
- RAM – 2KB
- CPU Architecture – 8bit
- Operating System – No
- Processing Speed – 16MHz
- Power Consumed – 175MW
- I/O Current Drive Strength – 40mA

Raspberry Pi 3B+
Single-board Computer

- Control Unit – Broadcom BCM2837B0 SoC
- RAM – 1GB
- CPU Architecture – 64bit
- Operating System – Yes
- Processing Speed – 1.4GHz
- Power Consumed – 700MW
- I/O Current Drive Strength – 16mA



Single-board Microcontroller

- Does not support audio and GUIs
- Arduino-specific IDE and Compiler
- Uses "*Shields*" for extending functionalities
- Best at controlling machines and performing repetitive tasks.

Single-board Computer

- Supports audio and GUIs
- Wide-range of Operating Software
- Uses "*Hats*" for extending functionalities
- Best at logical processing of data and communicating with other systems.

Good for sensors

Arduino
$25
ATmega328

ChipKIT
$30
PIC

LaunchPad
$4
MSP430

Good for some sensors a

STM32
$30
ARM Cortex M0,
M3, M4

Particle
$35
ARM
WiFi Internet

Good for processing and network

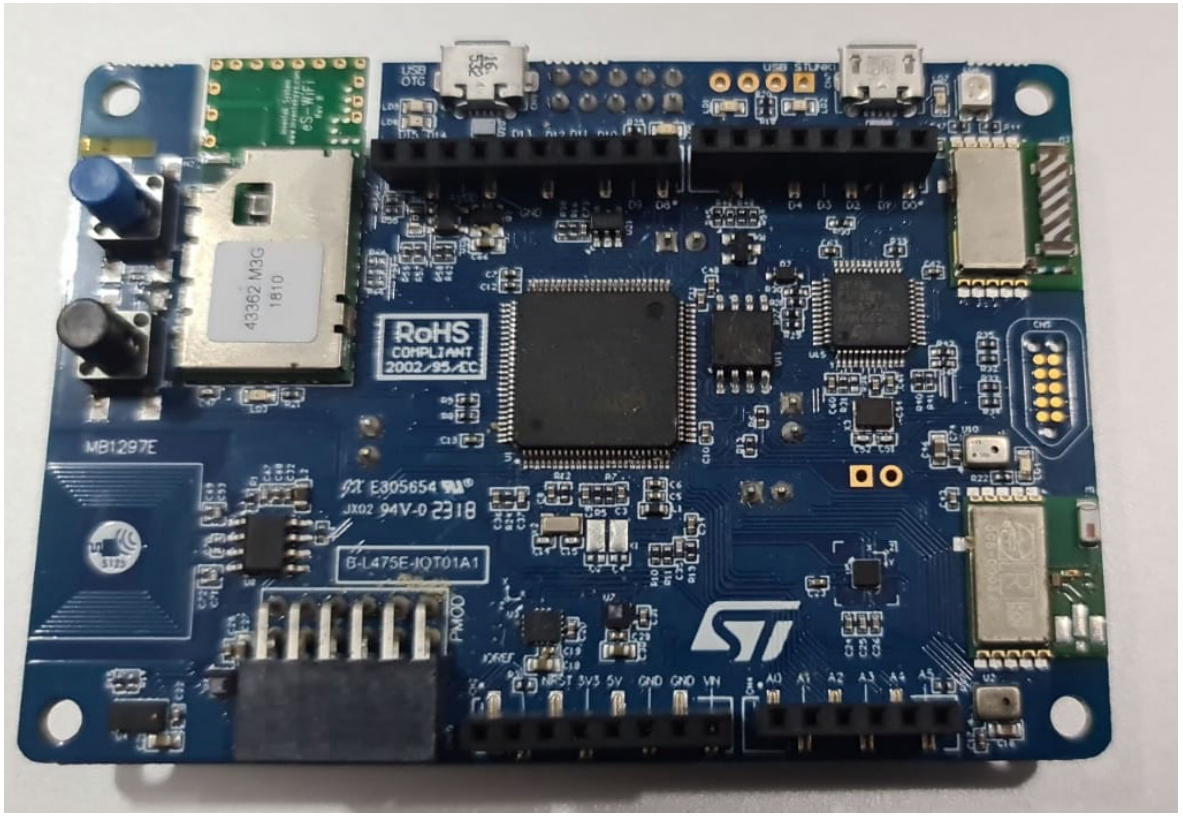
Raspberry Pi
$35
900 MHz ARM, GPU
1 GB RAM

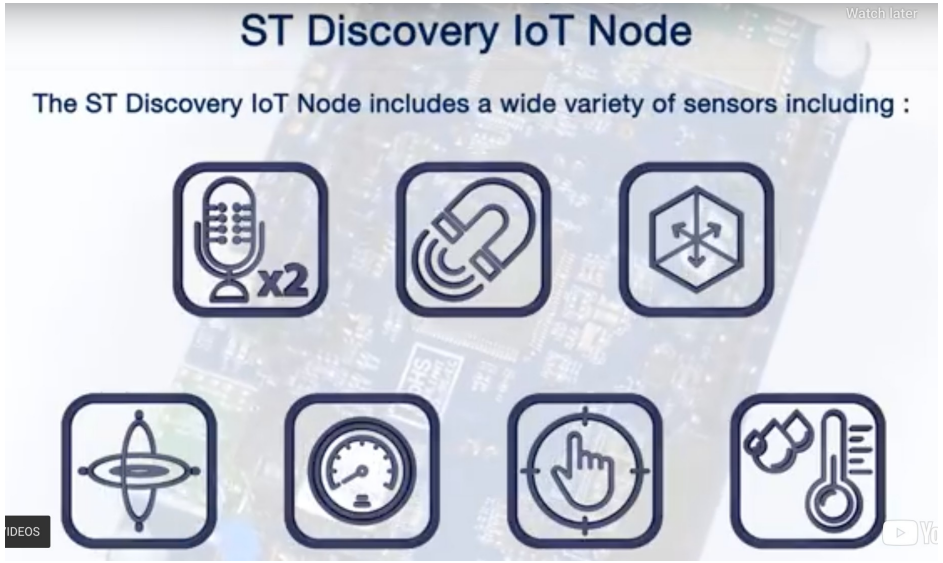
Compute Module

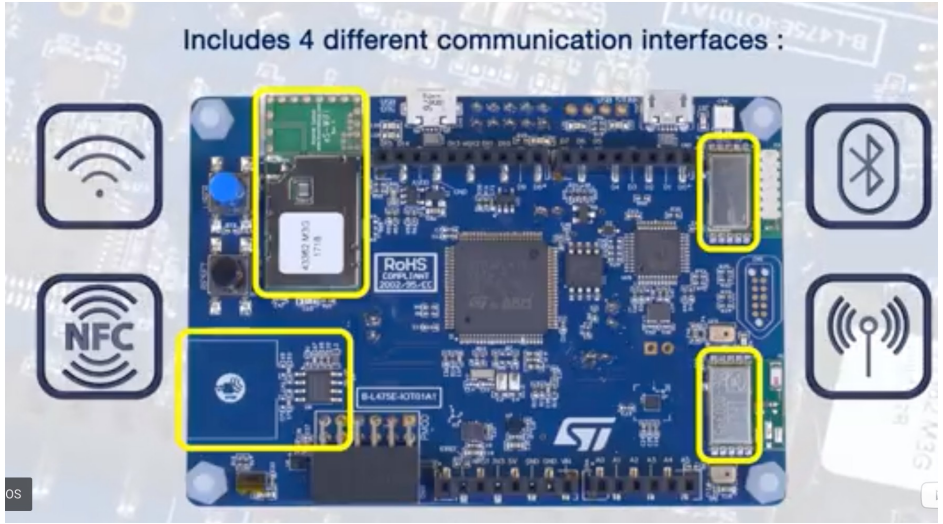
Intel® Galileo
$50
400 MHz Quark x86
256 MB RAM

Intel® Edison
$70

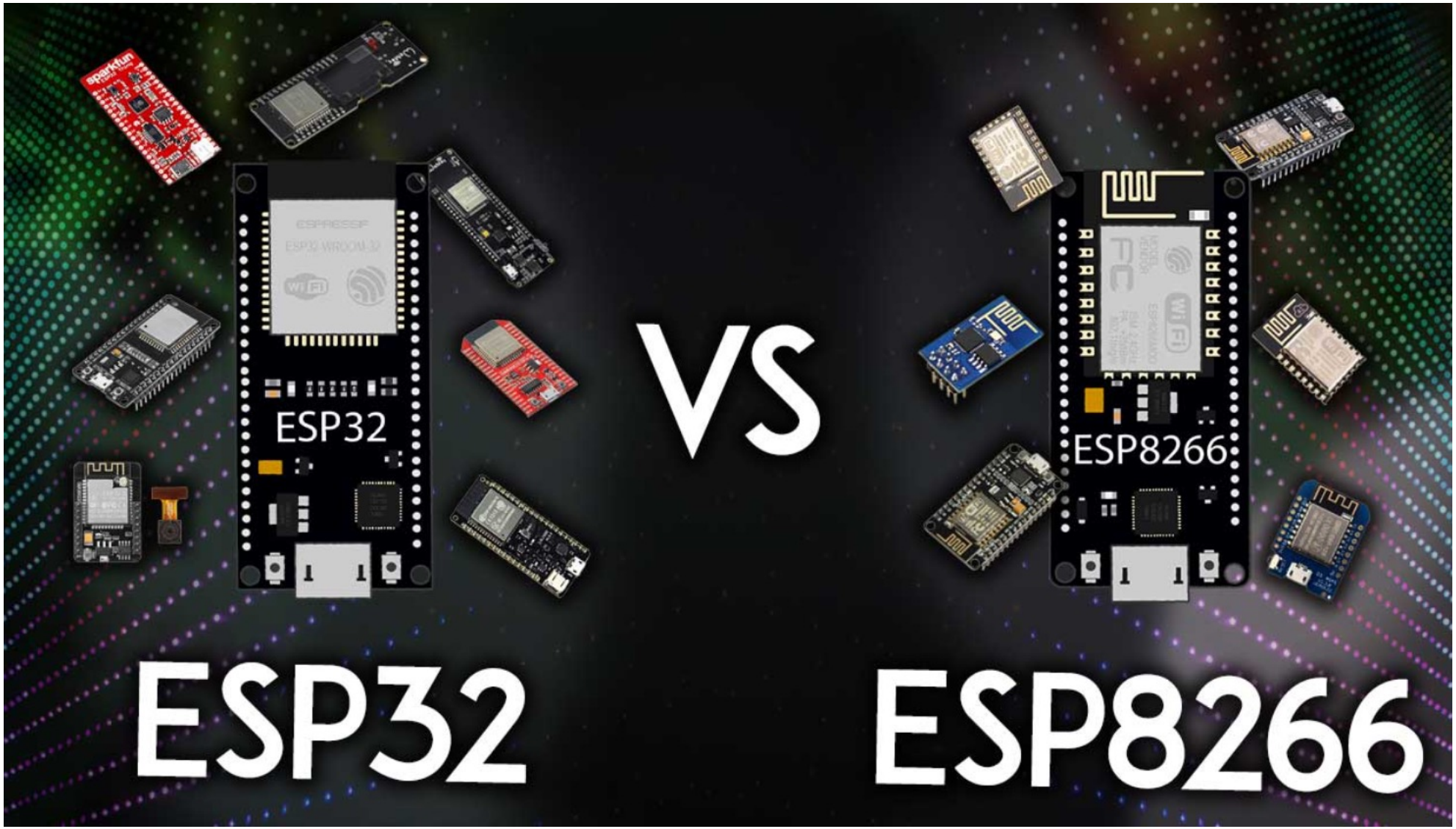
1 GHz Dual Core Atom x86
1 GB RAM
WiFi
BLE
4 GB Flash


RoHS
COMPLIANT
2002/95/EC
MB1297E
B-L475E-IOT01A1

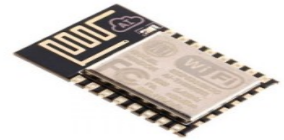

ST Discovery IoT Node
The ST Discovery IoT Node includes a wide variety of sensors including :
x2
Watch later


Includes 4 different communication interfaces :
NFC
RoHS
B-L475E-IOT01A1

The ESP32 and ESP8266 are cheap Wi-Fi modules perfectly suited for DIY projects in the Internet of Things (IoT) and Home Automation fields.

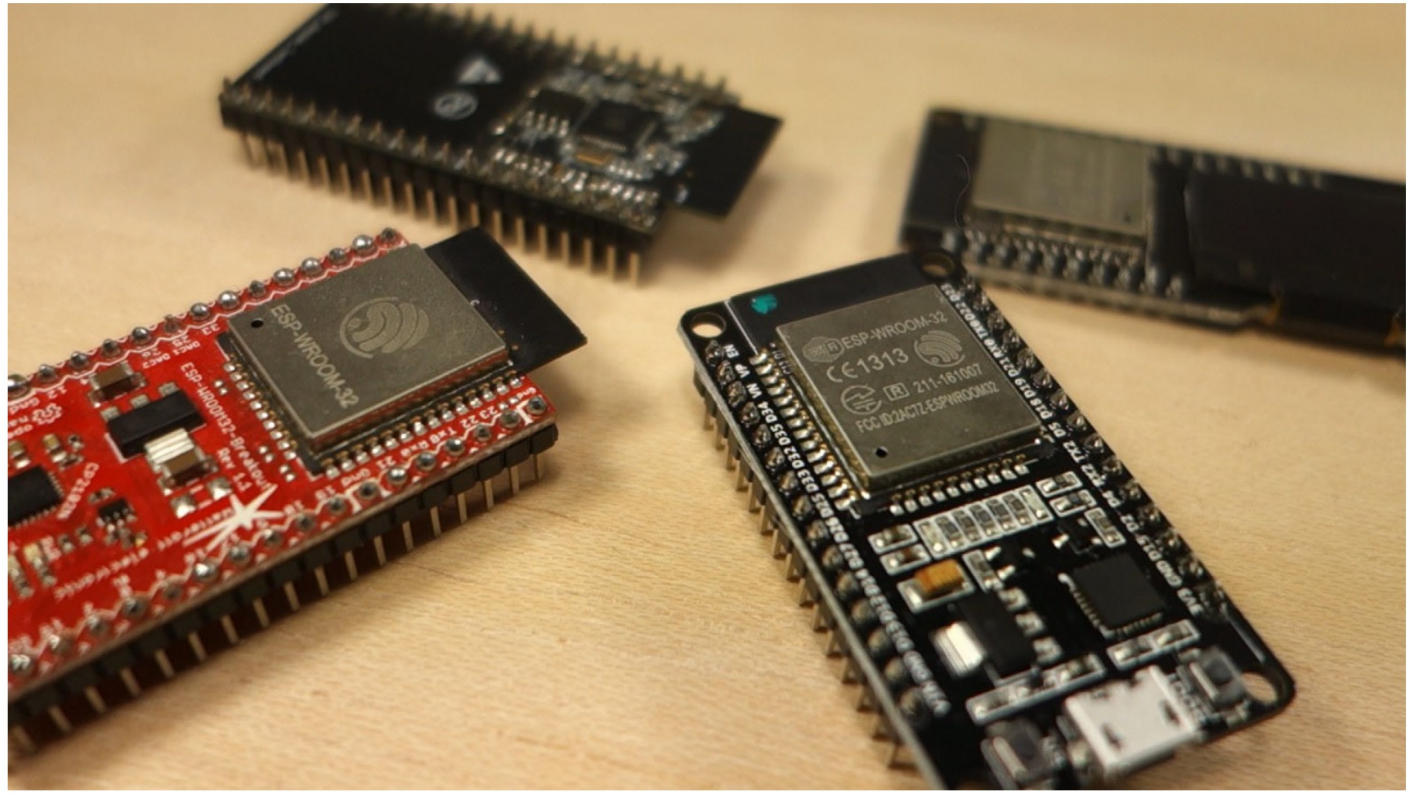


wireless networking included, which makes them apart from other microcontrollers like the Arduino.

	ESP8266	ESP32
		
MCU	Xtensa Single-core 32-bit L106	Xtensa Dual-Core 32-bit LX6 with 600 DMIPS
802.11 b/g/n Wi-Fi	HT20	HT40
Bluetooth	✗	Bluetooth 4.2 and BLE
Typical Frequency	80 MHz	160 MHz
SRAM	✗	✓
Flash	✗	✓
GPIO	17	34
Hardware /Software PWM	None / 8 channels	None / 16 channels
SPI/I2C/I2S/UART	2/1/2/2	4/2/2/2
ADC	10-bit	12-bit
CAN	✗	✓
Ethernet MAC Interface	✗	✓
Touch Sensor	✗	✓
Temperature Sensor	✗	✓ (old versions)
Hall effect sensor	✗	✓
Working Temperature	-40°C to 125°C	-40°C to 125°C
Price	$ (3$ - $6)	$$ ($6 - $12)
Where to buy	Best ESP8266 Wi-Fi Development Boards	ESP32 Development Boards Review and Comparison

Getting Started with the ESP32 Development Board

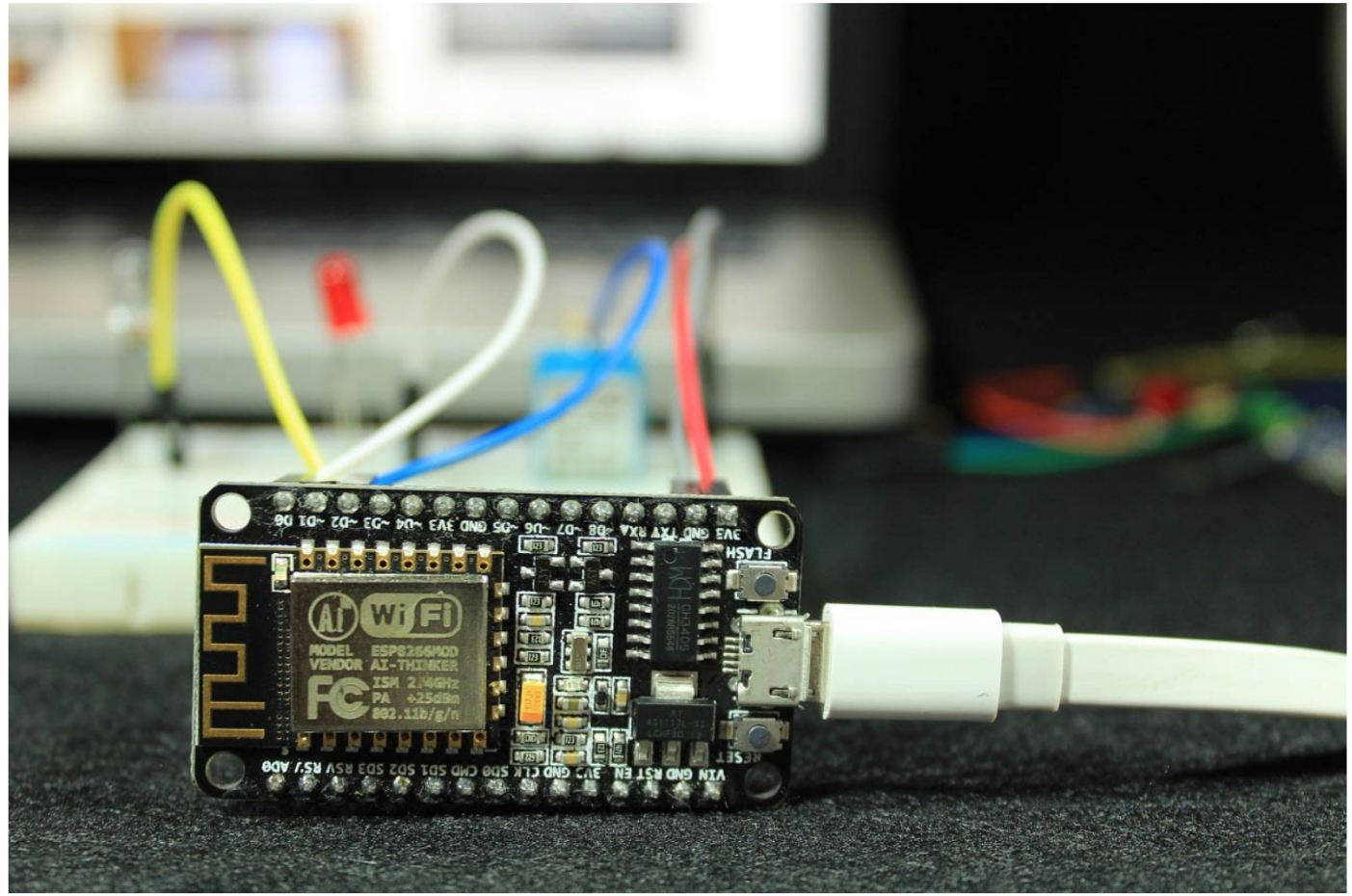
This article is a getting started guide for the ESP32 development board. If you're familiar with the ESP8266, the ESP32 is its sucessor. The ESP32 is loaded with lots of new features. The most relevant: it combines WiFi and Bluetooth wireless capabilities and it's dual core.



https://randomnerdtutorials.com/getting-started-with-esp32/

Getting Started with ESP8266 WiFi Transceiver (Review)

The ESP8266 is a Wi-Fi module great for IoT and Home Automation projects. This article is a getting started guide for the ESP8266 development board.



Here’s some examples of ESP32 boards:

DOIT DEVKIT V1

ESP32 DevKit

ESP-32S NodeMCU

ESP32 Thing

WEMOS LOLIN32

“WeMos” OLED

HUZZAH32

Others

(...)

ESP-01

ESP-02

ESP-03

ESP-04

ESP-05

ESP-06

ESP-07

ESP-08

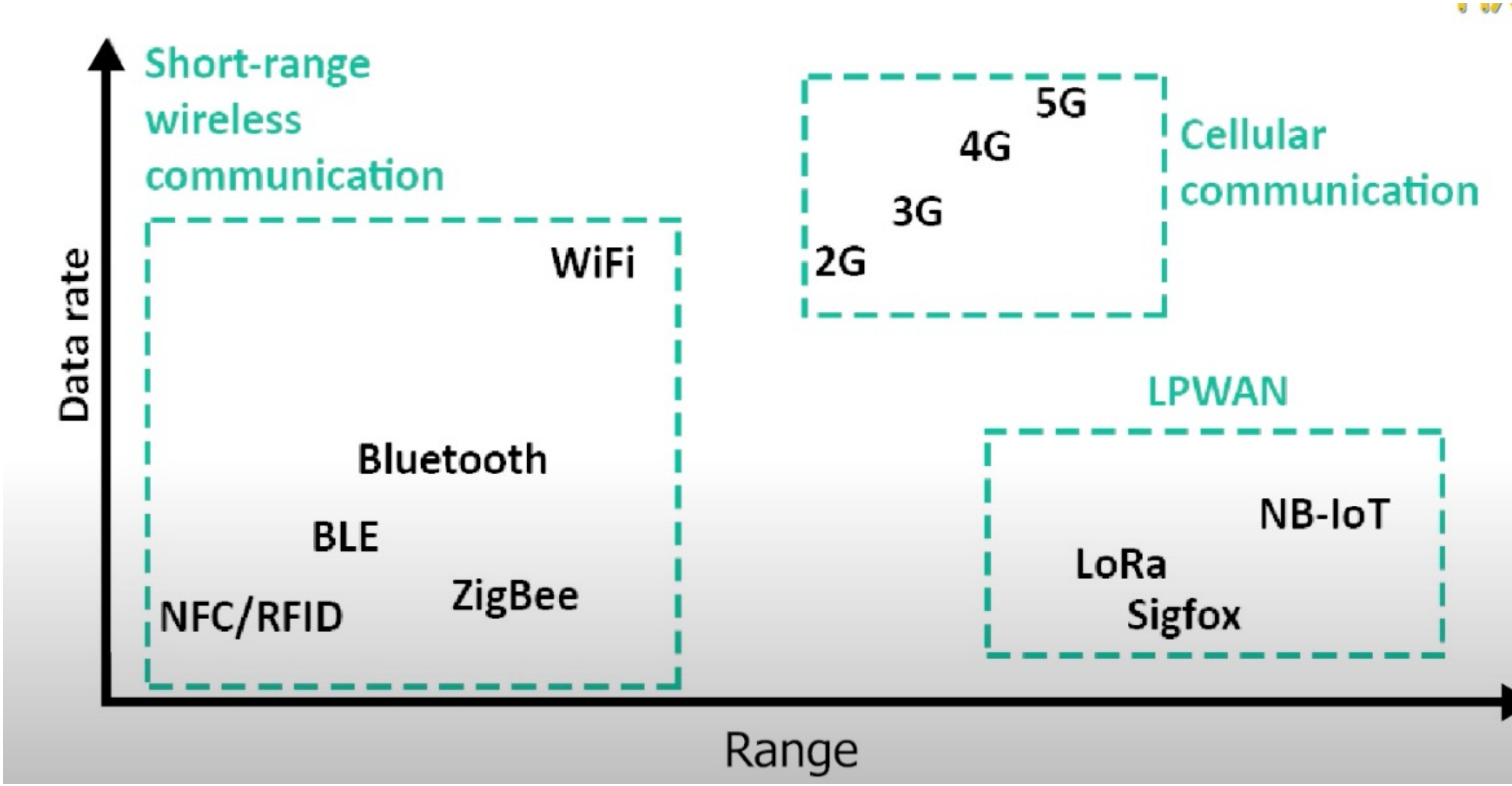
ESP-09

ESP-10

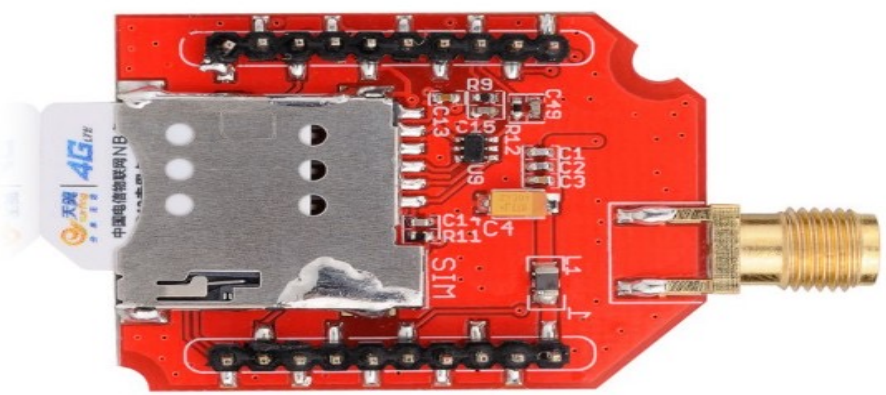
ESP-11

ESP-12E

WeMos
D1 Mini


Short-range
wireless
communication
WiFi
Bluetooth
BLE
ZigBee
NFC/RFID
5G
4G
3G
2G
Cellular
communication
LPWAN
NB-IoT
LoRa
Sigfox
Data rate
Range

NB-IoT Bee

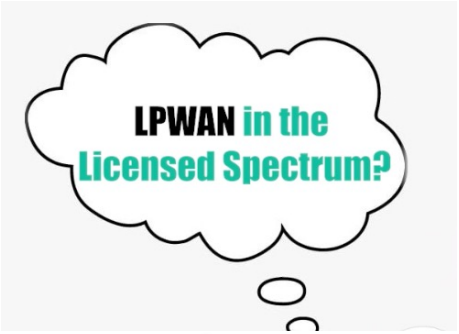


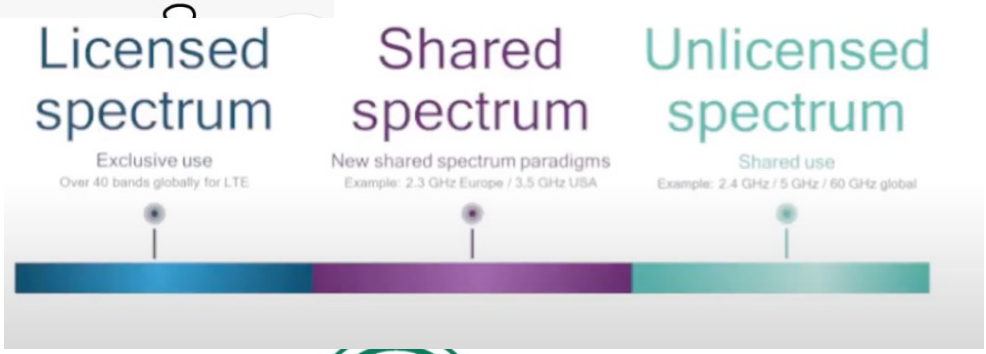
Click to open image!

NarrowBand-Internet of Things (NB-IoT) is a standards-based low power wide area (LPWA) technology developed to enable a wide range of new IoT devices and services. NB-IoT significantly improves the power consumption of user devices, system capacity and spectrum efficiency, especially in deep coverage. Battery life of more than 10 years can be supported for a wide range of use cases.

New physical layer signals and channels are designed to meet the demanding requirement of extended coverage – rural and deep indoors – and ultra-low device complexity. Initial cost of the NB-IoT modules is expected to be comparable to GSM/GPRS. The underlying technology is however much simpler than today's GSM/GPRS and its cost is expected to decrease rapidly as demand increases.

IoT through cellular network

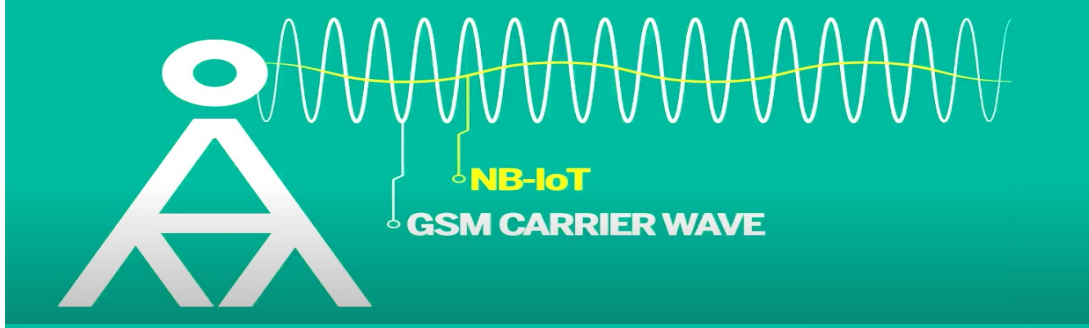


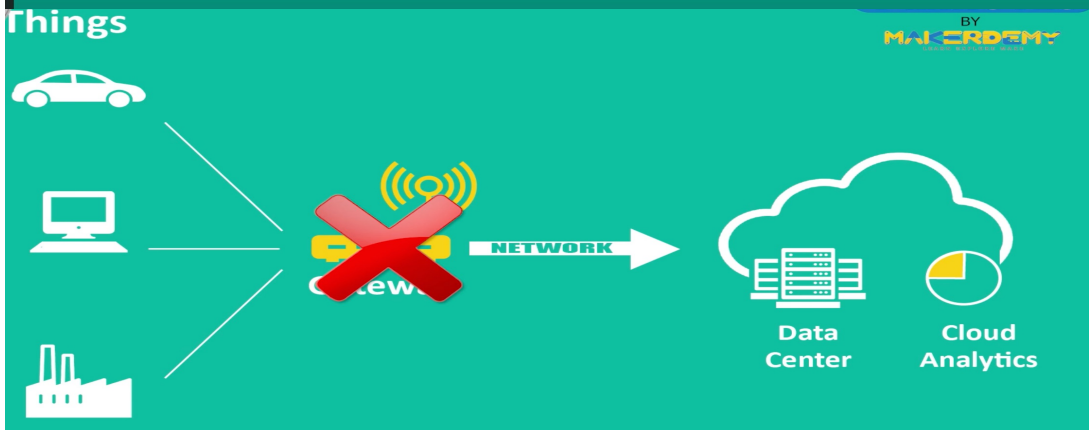


NB-IoT™

150-200 kbps

- LPWAN
- Standards based
- Based on existing cellular network infrastructure





NB-IoT USE CASES

BY MAKERDEMY

- Systems with High Device Density
- Deep Indoors
- Underground

LoRa™

Long Range

LoRaWAN®

Application Layer

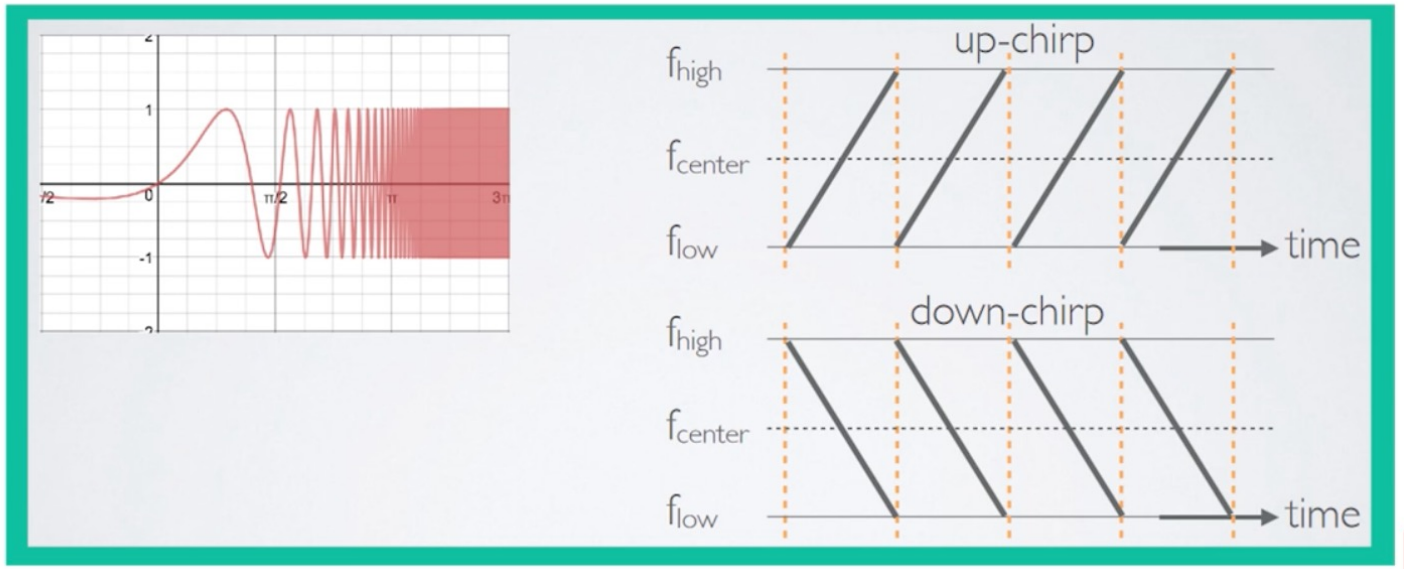
Media Access Control (MAC) Layer

} LoRaWAN

Physical (PHY) Layer

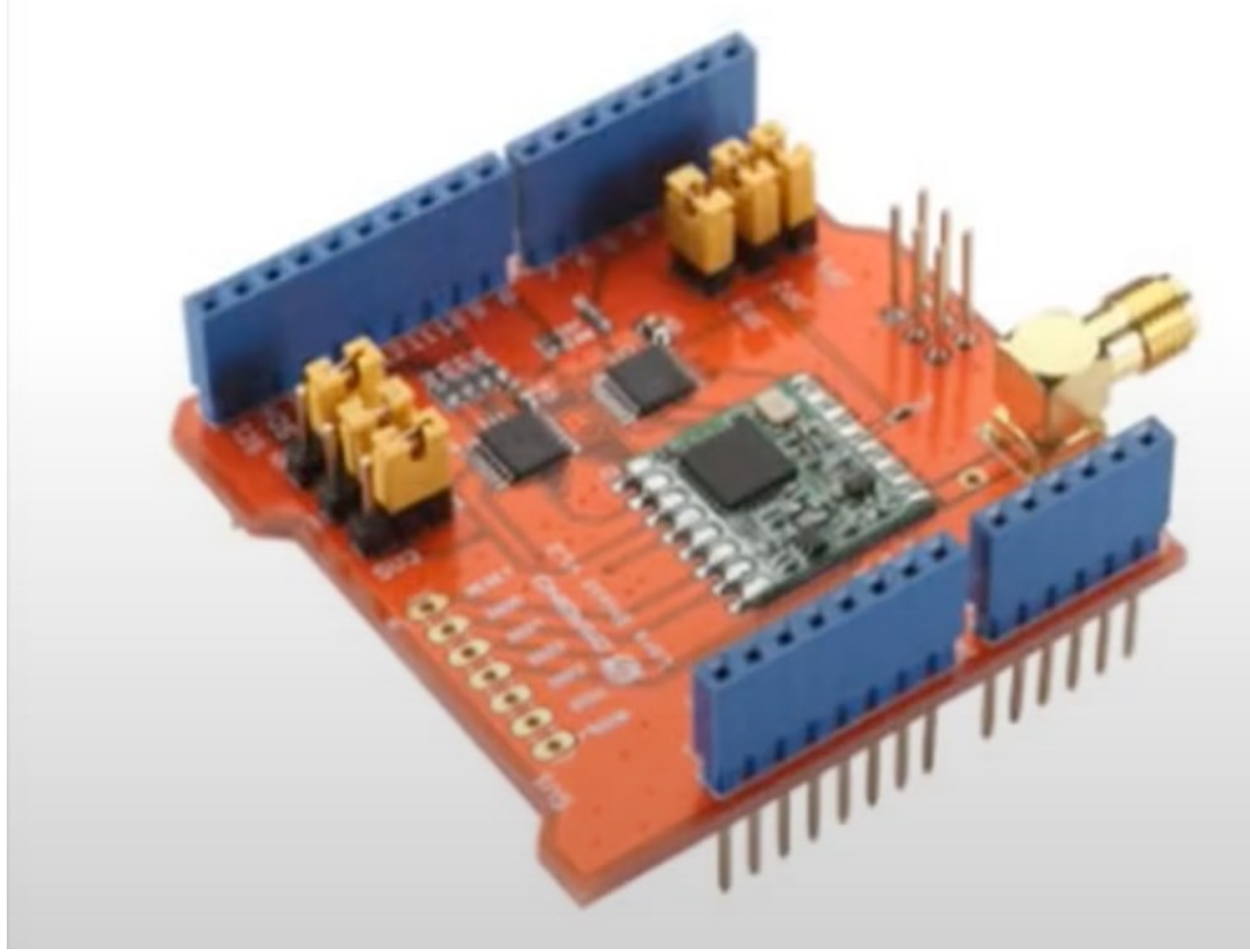
} LoRa

CHIRP SPREAD SPECTRUM MODULATION



https://www.youtube.com/watch?v=hMOwbNUpDQA

LoRa Shield



LoRa Nodes

SEMTECH

LoPy
868/915 MHz
ESP32
WiFi/BLE
4 MB Flash
Python

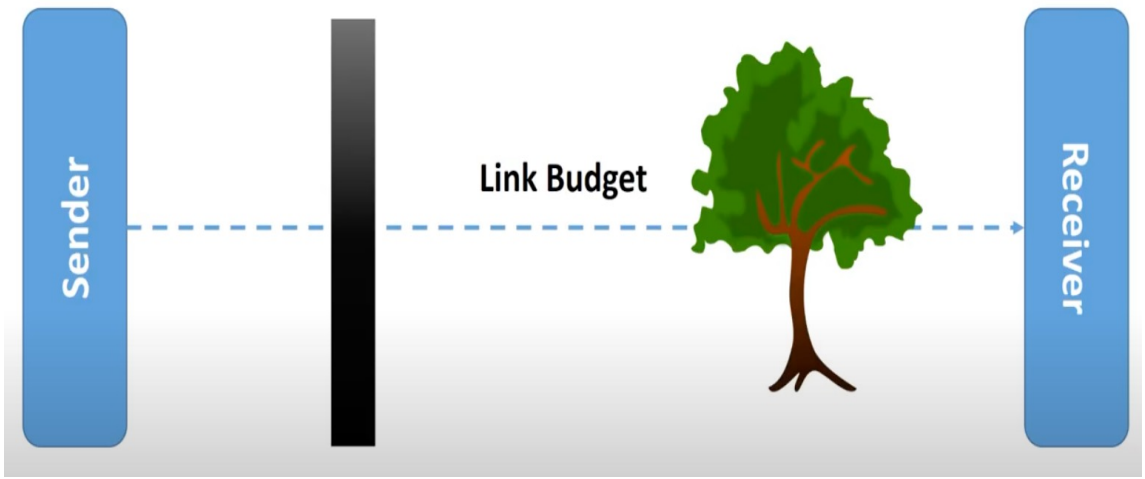
LORA GPS Hat
868/433/915 MHz
LoRa
GPS
SPI
Raspberry Pi 2/3

RN2483
868/433 MHz
Microchip

Bandwidth

Wide Area  **Low Power**

Feature	LoRaWAN	Narrow-Band	LTE Cat-1	LTE Cat-M	NB-LTE
Modulation	SS Chirp	UNB/GSK/BPSK	OFDMA	OFDMA	OFDMA
Rx bandwidth	500-125 kHz	100 Hz	20 MHz	20-1.4 MHz	200 KHz
Data Rate	290 bps – 50 Kbps	100 bit/sec 12 / 8 bytes max	10 Mbps	200 kbps – 1 Mbps	20 Kbps
Max output power	20 dBm	20 dBm	23 – 46 dBm	23/30 dBm	20 dBm
Battery lifetime – 2000 mAh	105 months (~9 years)	90 months (7.5 years)		18 months (1.5 years)	
Link budget	154 dB	151 dB	130 dB+	146 dB	150 dB
Security	Yes	No	Yes	Yes	Yes



Products

- Antennas 900 MHz
- Antennas 2.4 GHz
- Antennas 3.5 GHz
- Antennas 4.7 GHz
- Antennas 5 GHz panel/sector
- Antennas 5/6 GHz parabolic
- Antennas 6 GHz
- Antennas 10/11 GHz
- Antennas 13 GHz
  - JRMC-400-13 NEW
  - JRMC-680-13 NEW
  - JRMC-900-13 NEW
  - JRMC-1200-13 NEW
  - JRMC-1800-13 NEW
- Antennas 17/18 GHz
- Antennas 24/26 GHz
- Antennas 80 GHz
- Accessories
- 3D print
- Archives

Radio link budget calculator

Application serves for approximate radio link budget compute. Inserted data are not stored or processed.
The interactive map temporarily out of order.

Manually

Distance

1000 km

Site A	Site B
Antenna Gain	**Antenna Gain**
0 dBi	0 dBi
Elevation	**Elevation**
0 m	0 m
Antenna height above terrain	**Antenna height above terrain**
0 m	0 m
Cable Attenuation	**Cable Attenuation**
0 dB	0 dB
Output Power	**Output Power**
0 dBm	0 dBm

Frequency

0.5 GHz

Rain Rate

0 mm/h

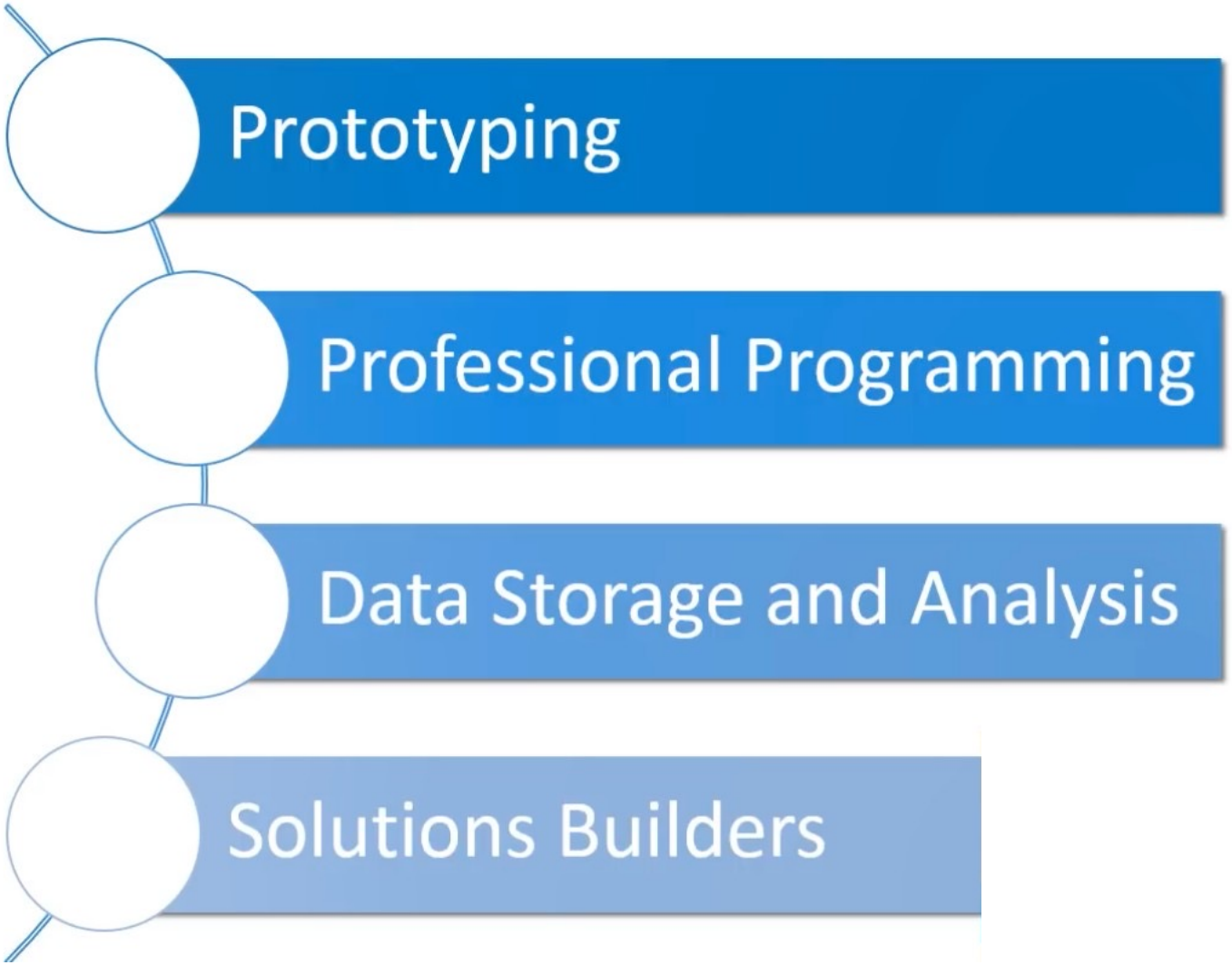
World | Europe | N. America | S. America | Africa | Australia | W. Asia | E. Asia

SOURCE : *Recommendation ITU-R P.837-6 - Characteristics of precipitation for propagation modelling*

Compute

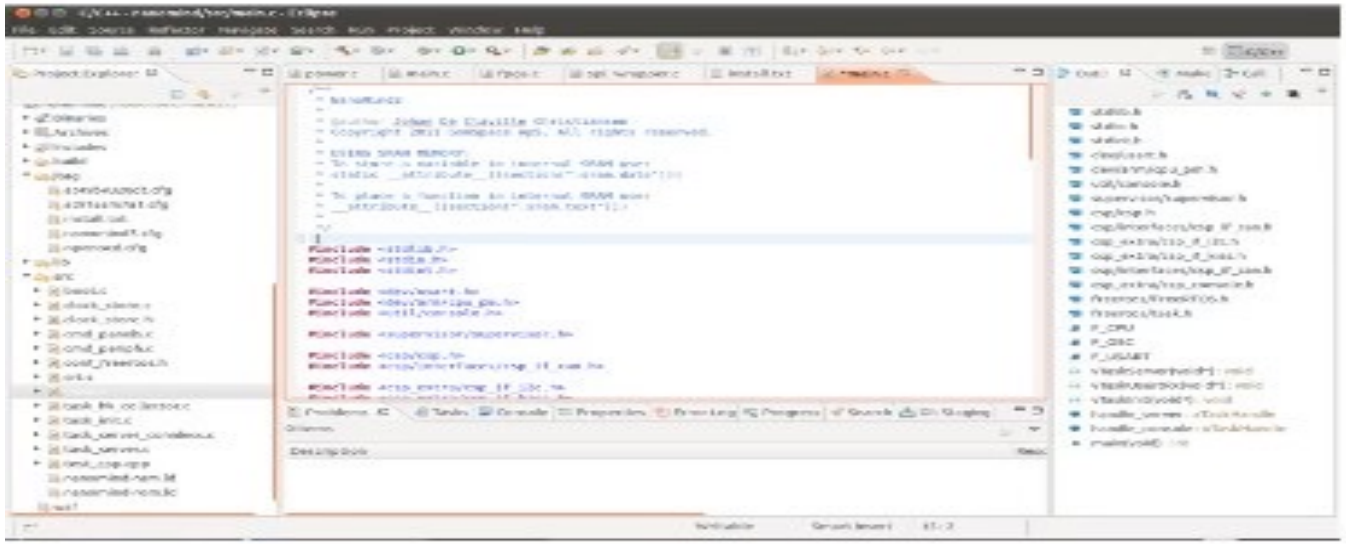
Site A	Site B
Received Power HORIZONTAL	**Received Power HORIZONTAL**
-146.4 dBm	-146.4 dBm
Received Power VERTICAL	**Received Power VERTICAL**
-146.4 dBm	-146.4 dBm
$EIRP_A$	**$EIRP_B$**
0.0 dBm	0.0 dBm

Software


Prototyping
Professional Programming
Data Storage and Analysis
Solutions Builders

Professional Programming

ECLIPSE

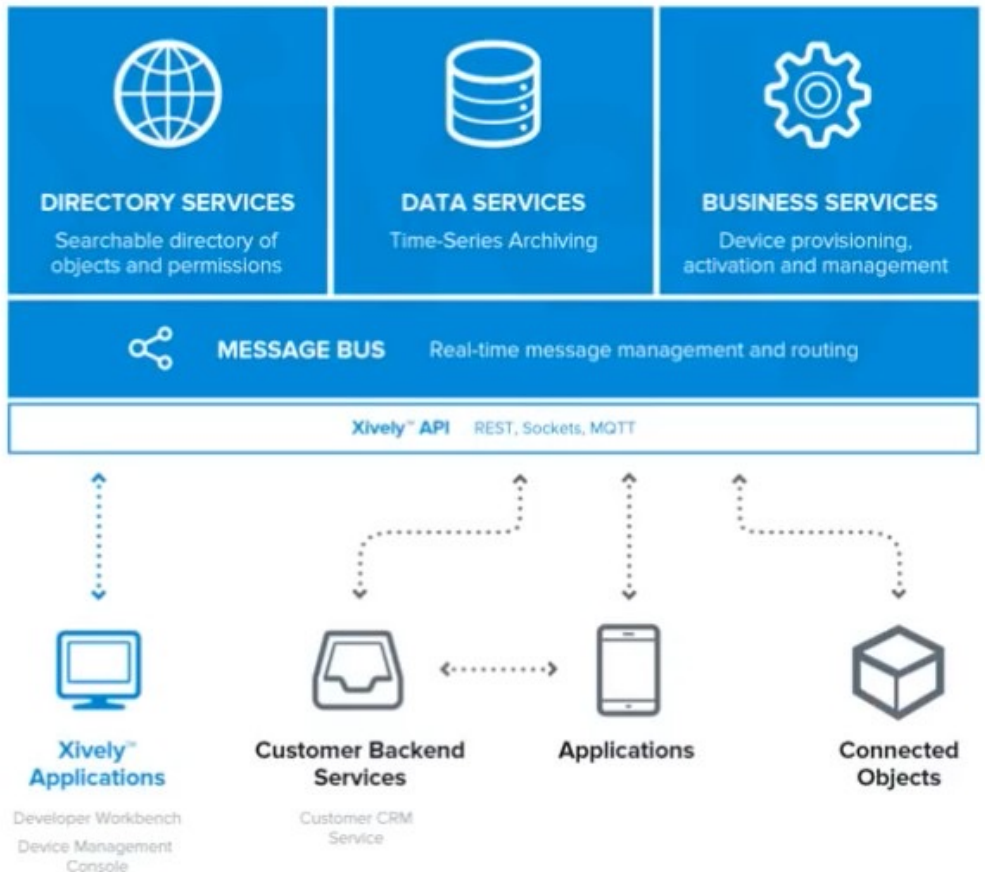


VIM

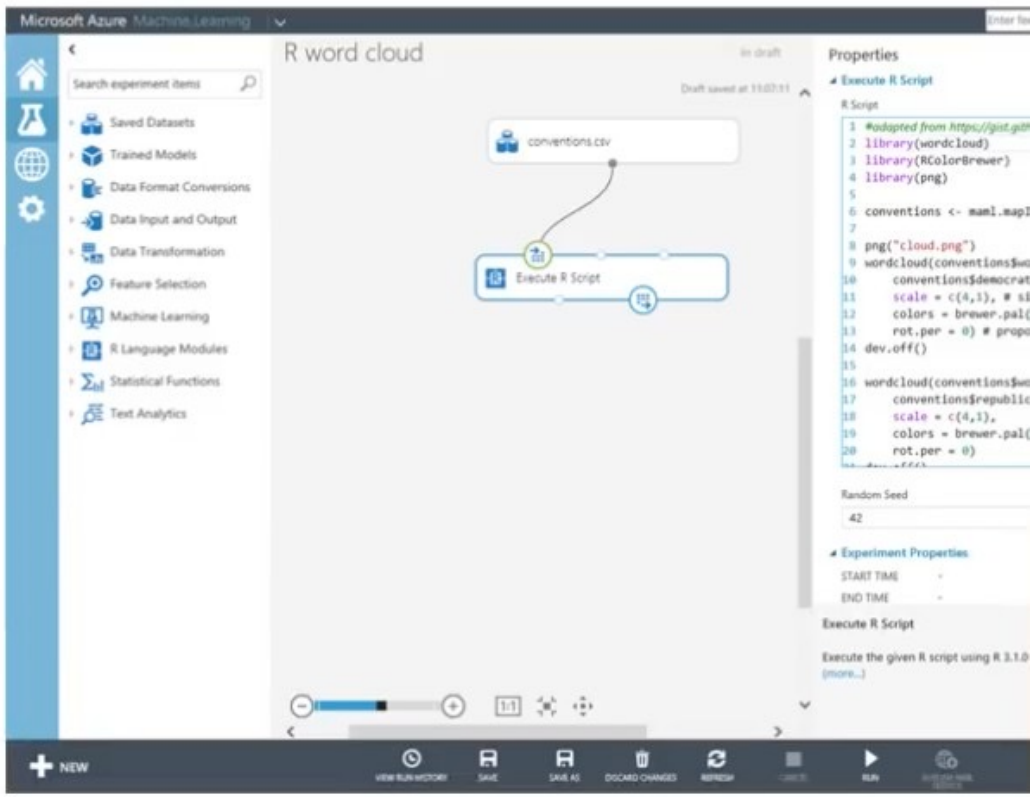
Eclipse is an integrated development environment (IDE) used in computer programming.[6] It contains a base workspace and an extensible plug-in system for customizing the environment. Eclipse is written mostly in Java and its primary use is for developing Java applications, but it may also be used to develop applications in other programming languages via plug-ins, including Ada, ABAP, C, C++, C#, Clojure, COBOL, D, Erlang, Fortran, Groovy, Haskell, JavaScript, Julia,[7] Lasso, Lua, NATURAL, Perl, PHP, Prolog, Python, R, Ruby (including Ruby on Railsframework), Rust, Scala, and Scheme. It can also be used to develop documents with LaTeX (via a TeXlipse plug-in) and packages for the software Mathematica. Development environments include the Eclipse Java development tools (JDT) for Java and Scala, Eclipse CDT for C/C++, and Eclipse PDT for PHP, among others.

Data Acquisition and Analysis

XIVELY



MICROSOFT AZURE



Fragmented and unconsolidated, the IoT platform market nonetheless has several major players enjoying the largest market share. The list of the top five, fully-fledged solutions in alphabetical order is as follows:

- **Amazon Web Service (AWS) IoT platform, (https://aws.amazon.com/iot/)**
- **Cisco IoT, (https://www.cisco.com/c/en/us/solutions/internet-of-things/overview.html)**
- **Google Cloud IoT, (https://cloud.google.com/solutions/iot)**
- **IBM Watson IoT platform, (https://www.ibm.com/cloud/watson-iot-platform)**
- **Microsoft Azure IoT. (https://azure.microsoft.com)**

All five options have a core solution with basic functionality and a set of additional modules you can add when necessary. Below, we'll explore building blocks of key platforms in more detail.

Proposal 2 / Final project / report Task :

Explore Internet for Arduino / Raspberry Pi - IoT projects for the final course Project.

Your outcome needs to be submitted as a report / final project proposal

Final Project Ideas (proposal needs to be turn it in after seminar 1, by the end of November (T Nov 30)

- Option 1 : Practical implementation

- Option 2 : design idea / research survey paper (simulation of using exsiting IoT data sets for IoT analytics)

Grab your Raspberry Pi and some sensors from our friends at Seeed Studio [1]

and get building. Without further ado, please meet IoT For Beginners: A Curriculum! [2]

[1] https://www.seeedstudio.com/IoT-for-beginners-with-Seeed-and-Microsoft-Raspberry-Pi-Starter-Kit-p-5004.html

[2] https://github.com/microsoft/IoT-For-Beginners

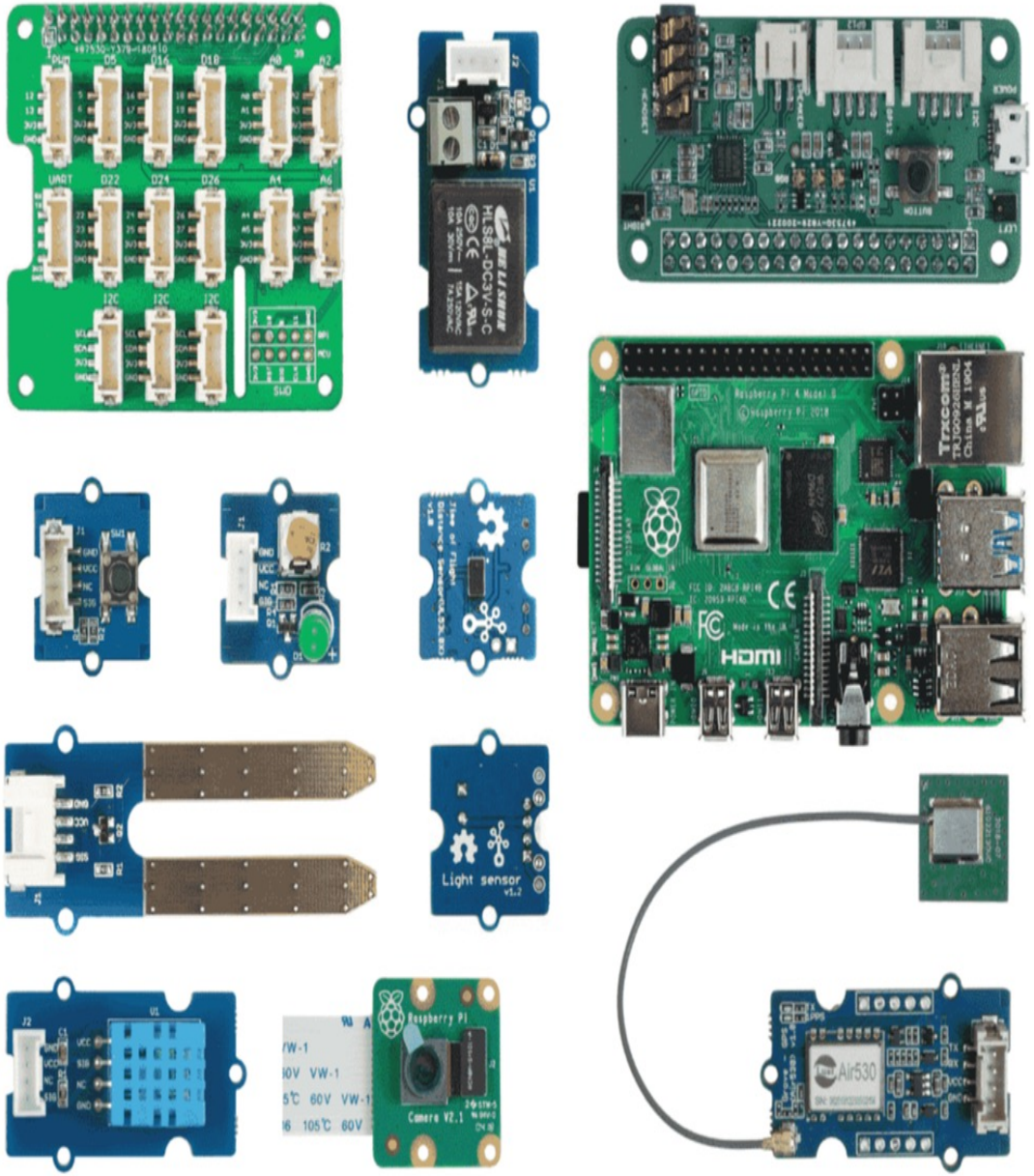
Examples/Ideas for IoT Projects

Learn the Internet of Things with “IoT for Beginners” and Raspberry Pi

https://www.raspberrypi.com/news/learn-the-internet-of-things-with-iot-for-beginners-and-raspberry-pi/

Learn the basics of the Internet of Things with this free 12-week, 24-lesson curriculum from the Microsoft Cloud Advocates. Build prototypes of real-world IoT projects with Raspberry Pi 4 and compatible modules as you learn all about IoT whilst following the journey of food from farm to table.

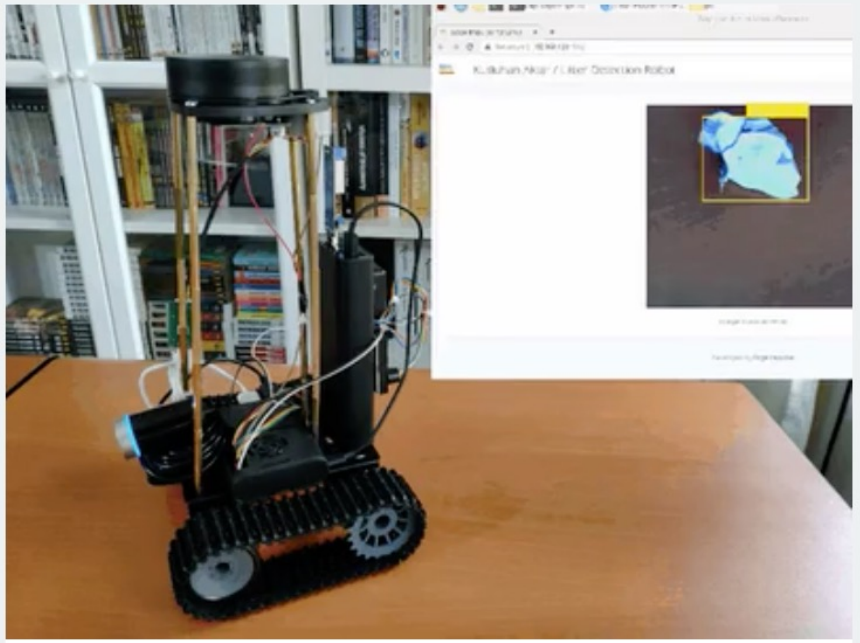
Modules *		Quantity	
☑	Grove Base Hat for Raspberry Pi	- 1 +	$10.90
☑	Raspberry Pi Camera Module V2 (Out of Stock)	- 1 +	$29.95
☑	ReSpeaker 2-Mics Pi HAT	- 1 +	$9.90
☑	Grove - Light Sensor v1.2 - LS06-S phototransistor	- 1 +	$3.20
☑	Grove - Temperature & Humidity Sensor (DHT11) (Out of Stock)	- 1 +	$6.50
☑	Grove - Relay	- 1 +	$3.20
☐	Grove - GPS (Air530) (Out of Stock)	- 1 +	$13.10
☑	Grove - Time of Flight Distance Sensor(VL53L0X)	- 1 +	$14.20
☑	Grove - Button	- 1 +	$2.10
☑	Grove - Green LED (Out of Stock)	- 2 +	$2.10
☑	Grove - Soil Moisture Sensor	- 1 +	$3.30



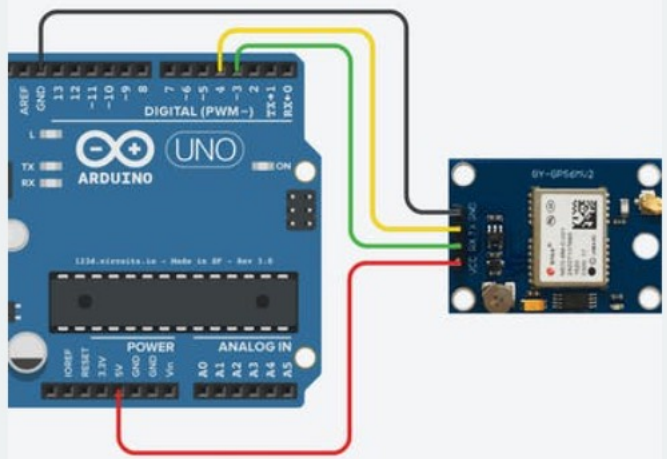
PROJECT HUB

https://create.arduino.cc/projecthub

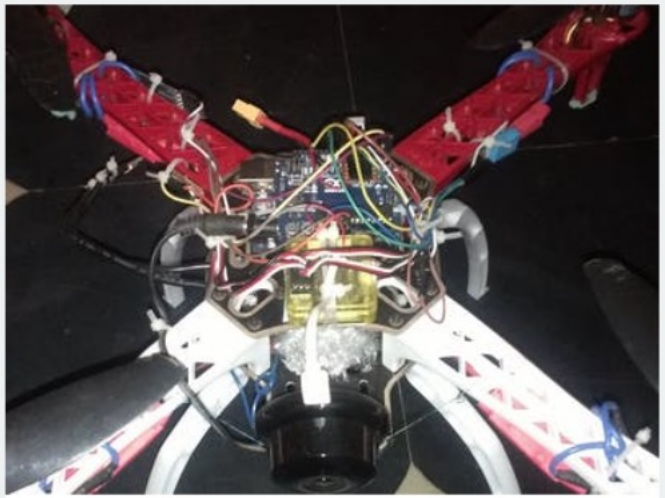
TinyML Aerial Forest Fire Detection



Autonomous (LIDAR) Litter Detection Robot w/ Edge...



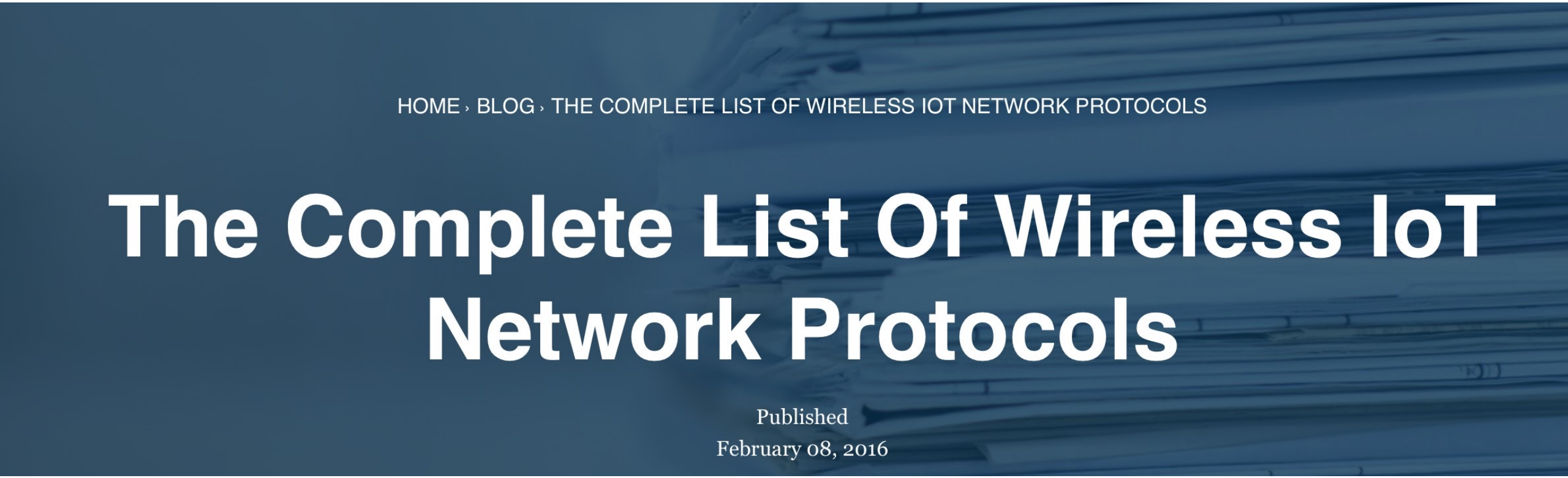
How to Interface GPS Module (NEO-6m) with Arduino



Autopilot Drone

IoT Application in Agriculture for Smart Farming

https://www.link-labs.com/blog/complete-list-iot-network-protocols



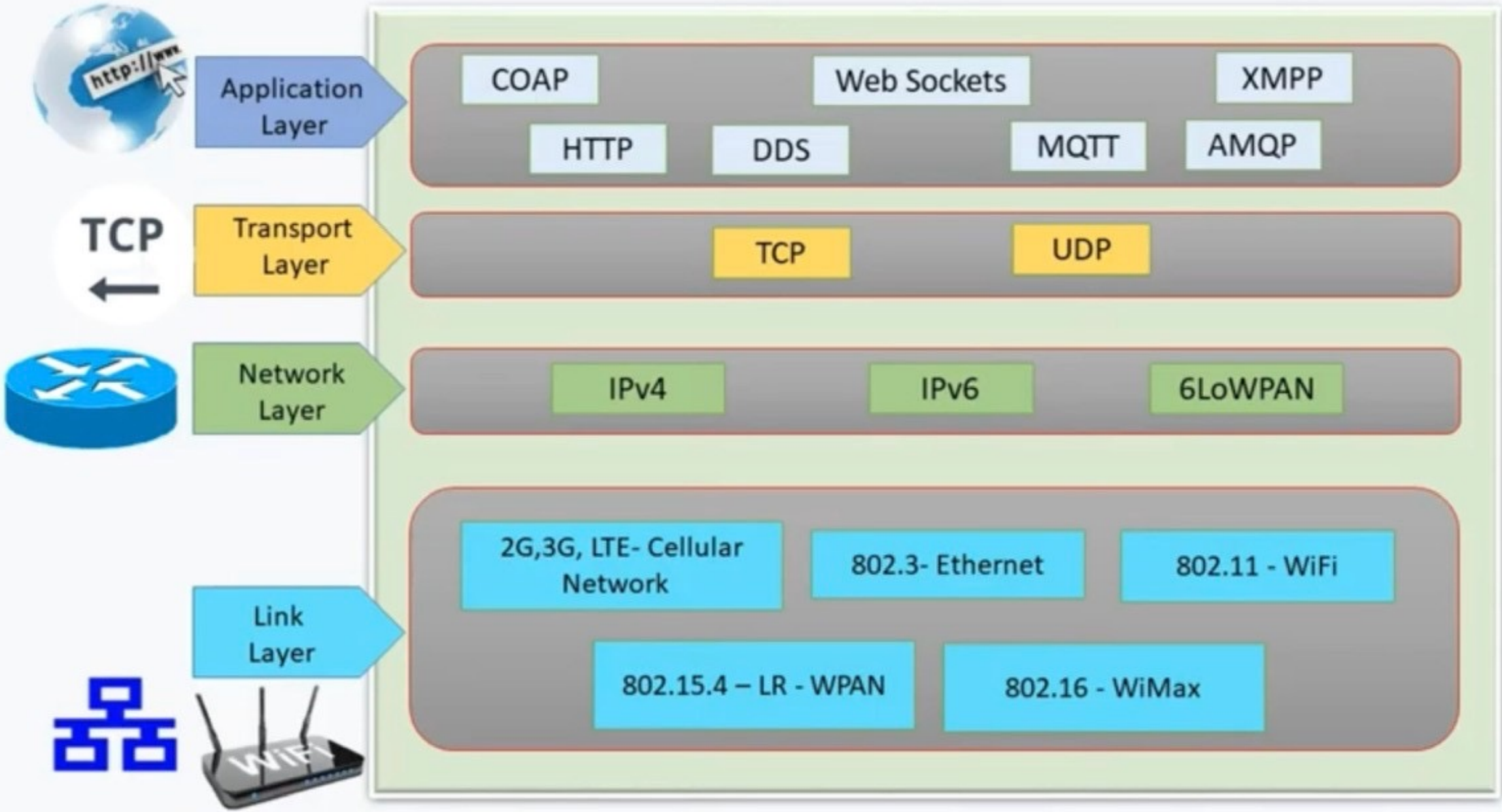
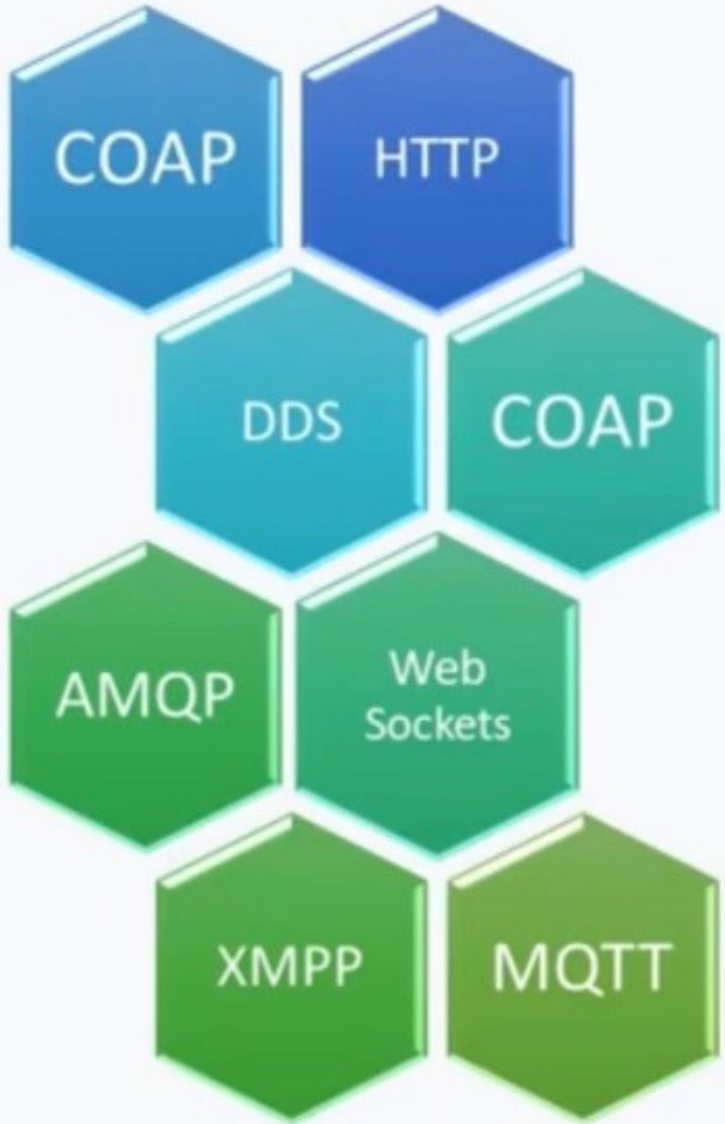


Figure: Protocol layers in IoT



2. Application Layer

Application layer protocols define **how the applications interface with the lower layer protocols to send the data packets over the network.**

The application data typically **use files** as a **transfer mechanism**.

Port numbers are used for application addressing. (for example port 80 for HTTP port 22 for SSH etc.).

Application layer protocols enable process-to-process connections using ports.

HTTP: Hyper **T**ext **T**ransfer **P**rotocol.

- It is the foundation of **W**orld **W**ide **W**eb (WWW).
- HTTP includes commands such as GET, PUT, POST, DELETE, HEAD, TRACE, OPTIONS, etc.
- The protocol uses **request-response communication model**.
- HTTP is a stateless protocol.
- An HTTP client can be a browser or an application running on the client.
- HTTP uses **U**niversal **R**esource **I**dentifiers (URI's) to identify HTTP resources.

COAP: Constrained **A**pplication **P**rotocol (**CAP**)

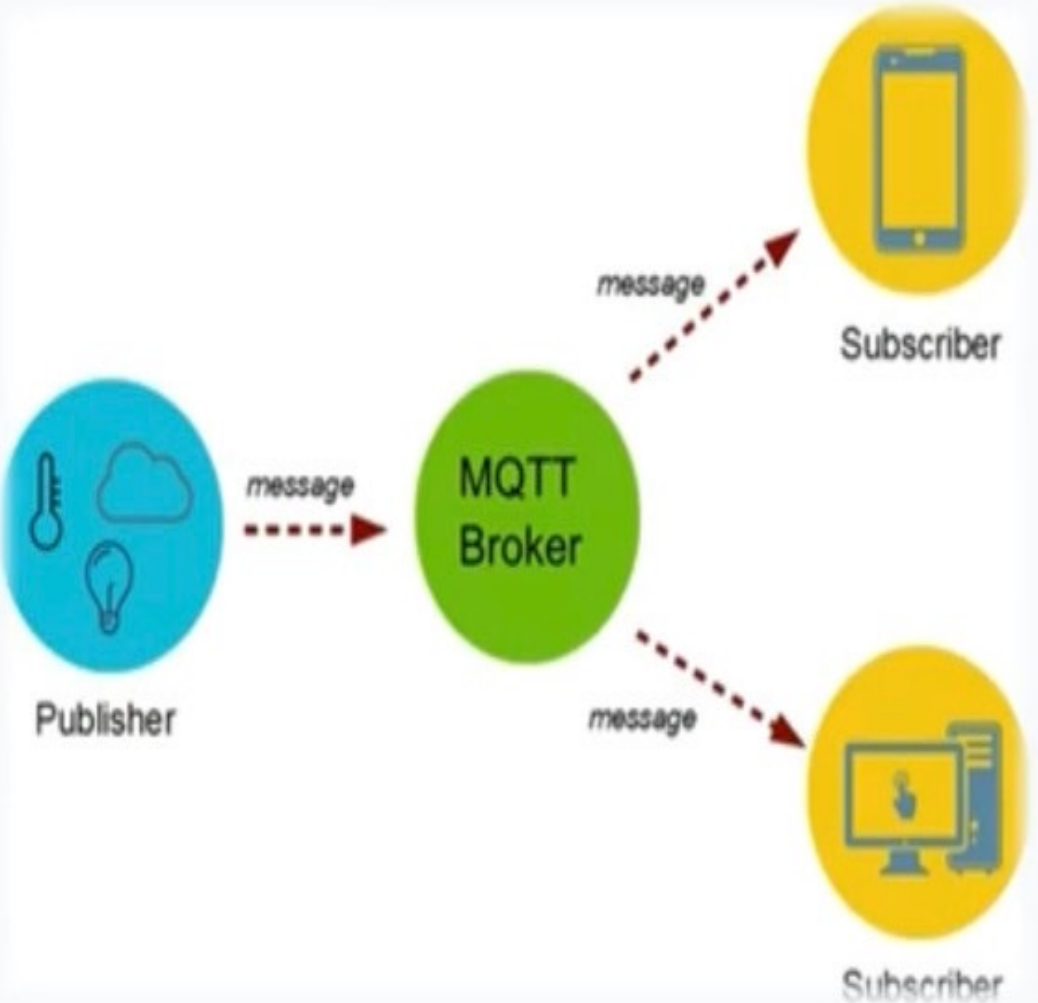
- It is an application layer protocol **for machine-to-machine (M2M)** communication.
- Used for embedded devices, controlled environments and controlled networks.
- Similar to HTTP, COAP is a web transfer protocol and uses a request-response model.
- However it runs on top of UDP instead of TCP.
- COAP is also designed to support commands GET, PUT, POST, and DELETE.

WebSocket:

- Allows **full duplex communication** over single connection for sending messages between client and server.
- Its is **based on TCP** which establishes a connection before transferring any data packets.
- Once connection is made between client and server same connection is used for stream transfer until closed by the client explicitly.

MQTT: Message Queue Telemetry Transport.

- It is a light weight messaging protocol.
- It is Based on the publish - subscribe communication model.
- MQTT uses a client-server architecture.
- MQTT is well suited for constrained environments where the devices have limited processing and memory resources and the network bandwidth is low.



XMPP: Extensible **M**essaging and **P**resence **P**rotocol (XMPP)

- Used for real-time communication and streaming XML data between network entities.
- XMPP powers wide range of applications including messaging, presence, data syndication, gaming, multi-party chat and voice or video calls.

XMPP: Extensible Messaging and Presence Protocol (XMPP)

- Used for real-time communication and streaming XML data between network entities.
- XMPP powers wide range of applications including messaging, presence, data syndication, gaming, multi-party chat and voice or video calls.
- Allows sending small chunks of XML data from one network entity to another in near real-time.
- It is a decentralized protocol, and uses a client-server architecture.
- XMPP supports both client-to-server and server-to-server communication paths.
- It allows real-time communication between IoT devices.

DDS: Data Distribution Service.

- It is a data-centric middleware standard for device-to-device or machine-to-machine communication.
- It uses a publish-subscribe model.
- Where, **publishers** for example devices that **generate data**, create topics to which **subscribers** for example devices that **want to consume data**, can subscribe.
- DDS provides quality-of-service (QoS) control and configurable reliability.

AMQP: Advanced Message Queuing Protocol.

- It is an open application layer protocol for business messaging.
- It supports both point-to-point and publisher or subscriber model, routing and queuing of data.
- An AMQP broker manages messages flow through the network.
- It receive messages from and route them subscribed consumer.
- This is done using Queuing technique.
- Published messages copied into to queues.
- Messages are either delivered by the broker to the consumers which have subscribed to the queues or the consumers can pull the messages from the queues.

https://people.engr.ncsu.edu/hp/papers/Paridhika.pdf

http://www.openmobilealliance.org/documents/whitepapers/OMA-WP-Protocol_Comparison-V1_0-20200121-A.pdf