



Computer Network

# Lecture 1

# INTRODUCTION

2020. 03. 01

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Department of Software Convergence

# Contents

- Introduction (with Physical Computing & CPS)
- OSI 7 Layer
- Open Source Hardwares
- Single Board Computer (SBC)
- Linux

## Computer Network(ing)

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- What is Computer :

“A computer is a device that can be instructed to carry out sequences of arithmetic or logical operations automatically via computer programming. Modern computers have the ability to follow generalized sets of operations, called programs. These programs enable computers to perform an extremely wide range of tasks.”

## Introduction

# Computer Network(ing)

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- What is Computer :

- » Desktop Computer
- » Server Computer
- » Tablet Computer
- » Smart Phones
- » Smart Watches
- » Wearable Computers
- » IoT (Internet of Things) & Sensor Devices
- » Smart Consumer Electronics (TV, Refrigerator, Airconditioner, etc)
- » Vehicles - (Industrial and Consumer) Robots - Drones
- » More and More

# Introduction

# Computer Network(ing)



## Introduction

# Computer Network(ing)

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### ● Latest Definition

Computer Networking > Computer Network

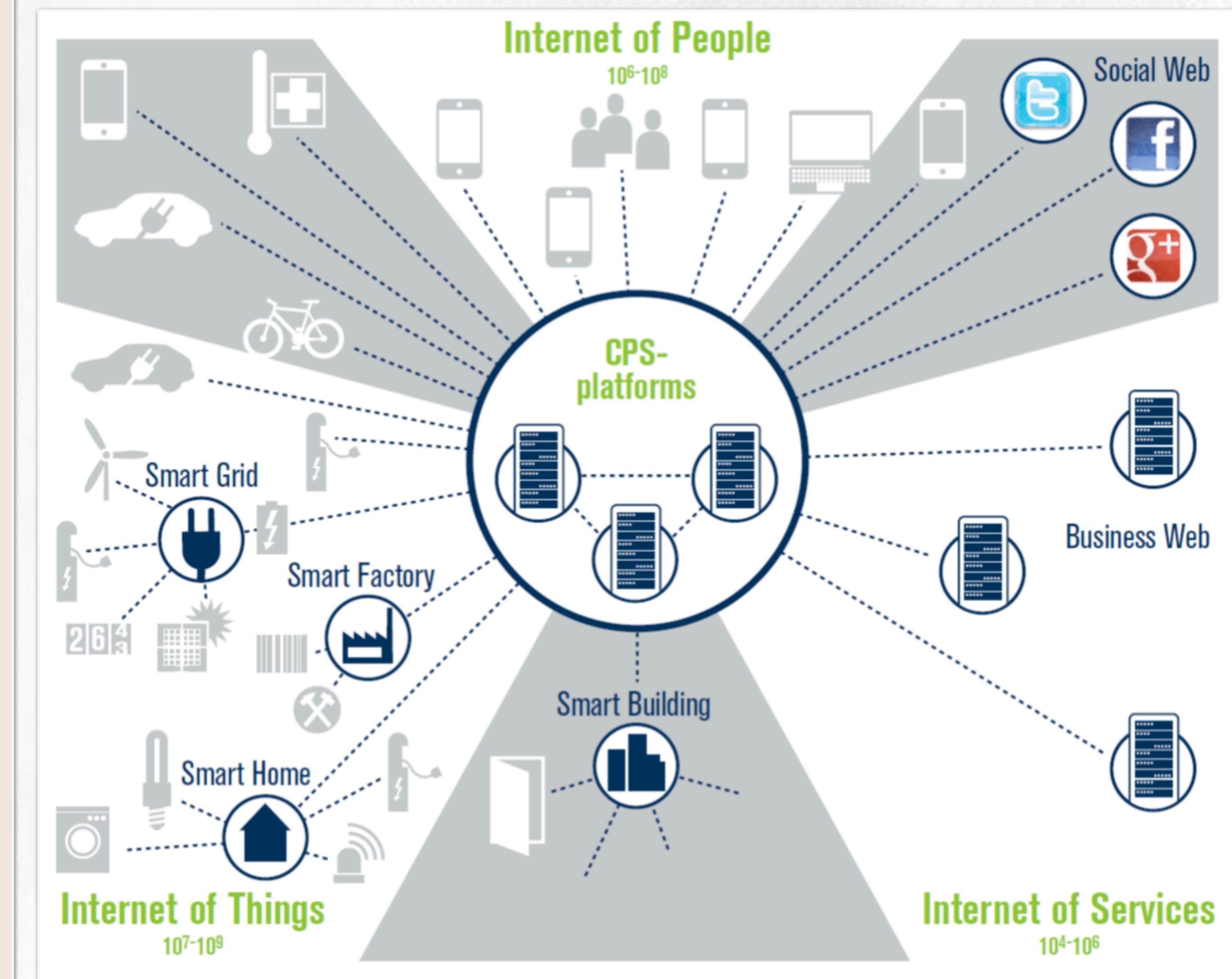
Networking of Softwares > Networking of Devices

Thus, Software Defined Networking,

Datacenter Networking

# Physical Computing & Cyber Physical System (CPS)

## Industry 4.0



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# OSI 7 Layer

“컴퓨터 네트워킹의 가장 중요한 원칙”

## Talking

Sender, Receiver and Carrier

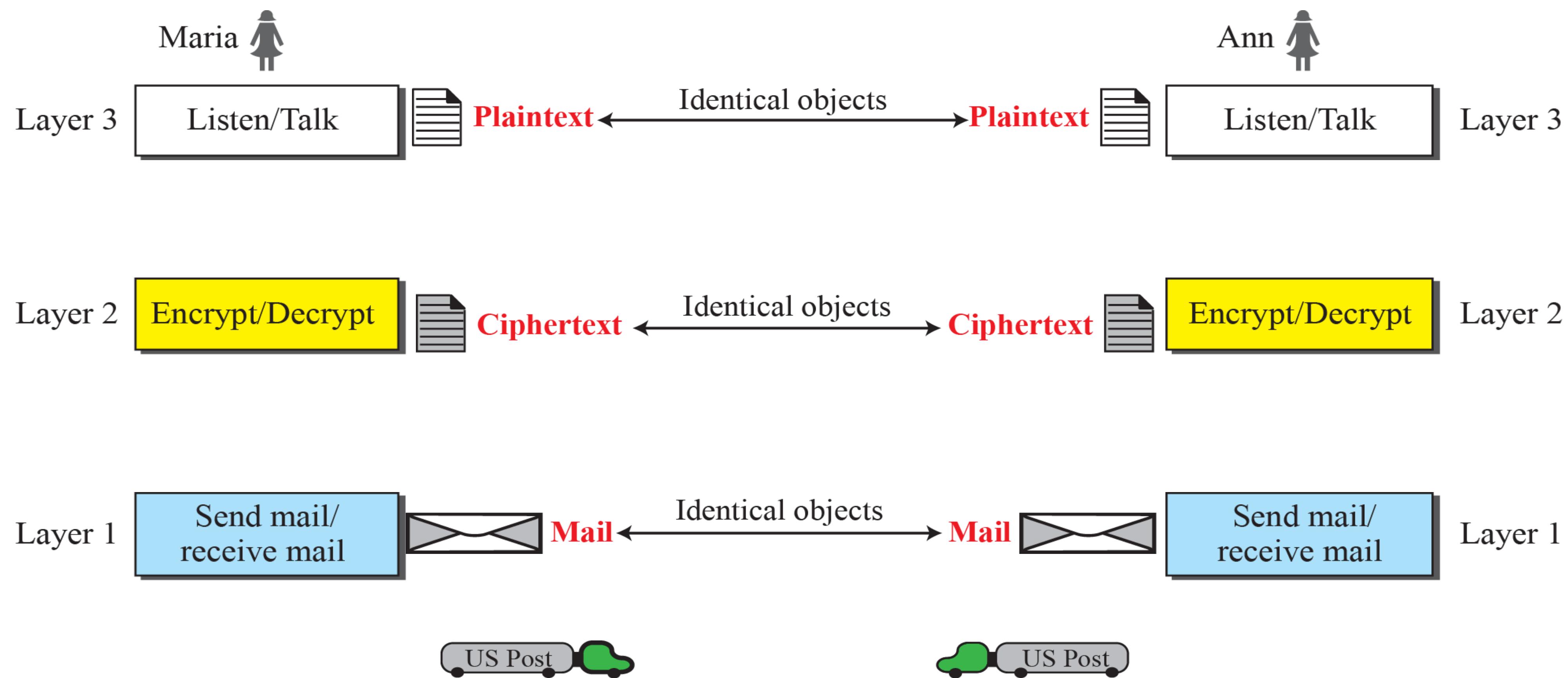


# OSI 7 Layer

“컴퓨터 네트워킹의 가장 중요한 원칙”

## Post Office

Communication between peer layers

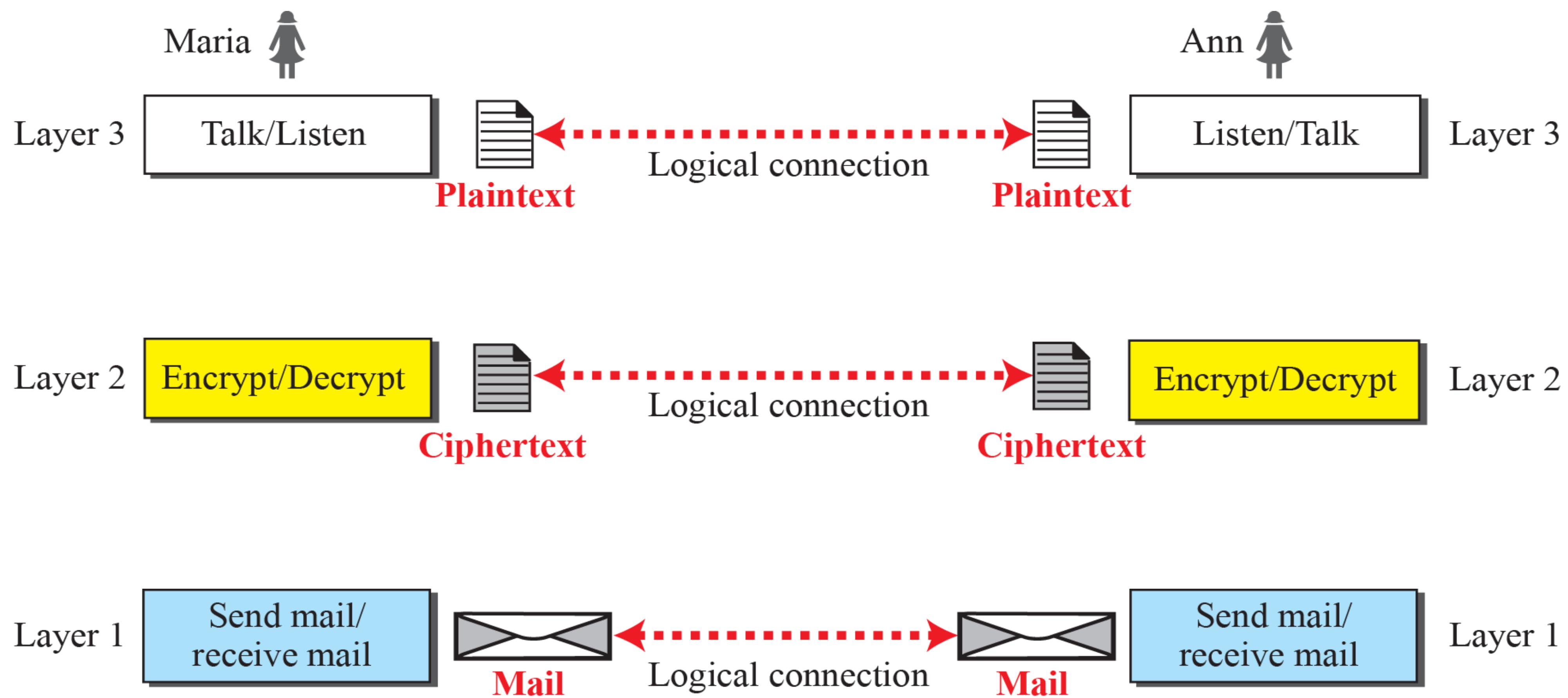


# OSI 7 Layer

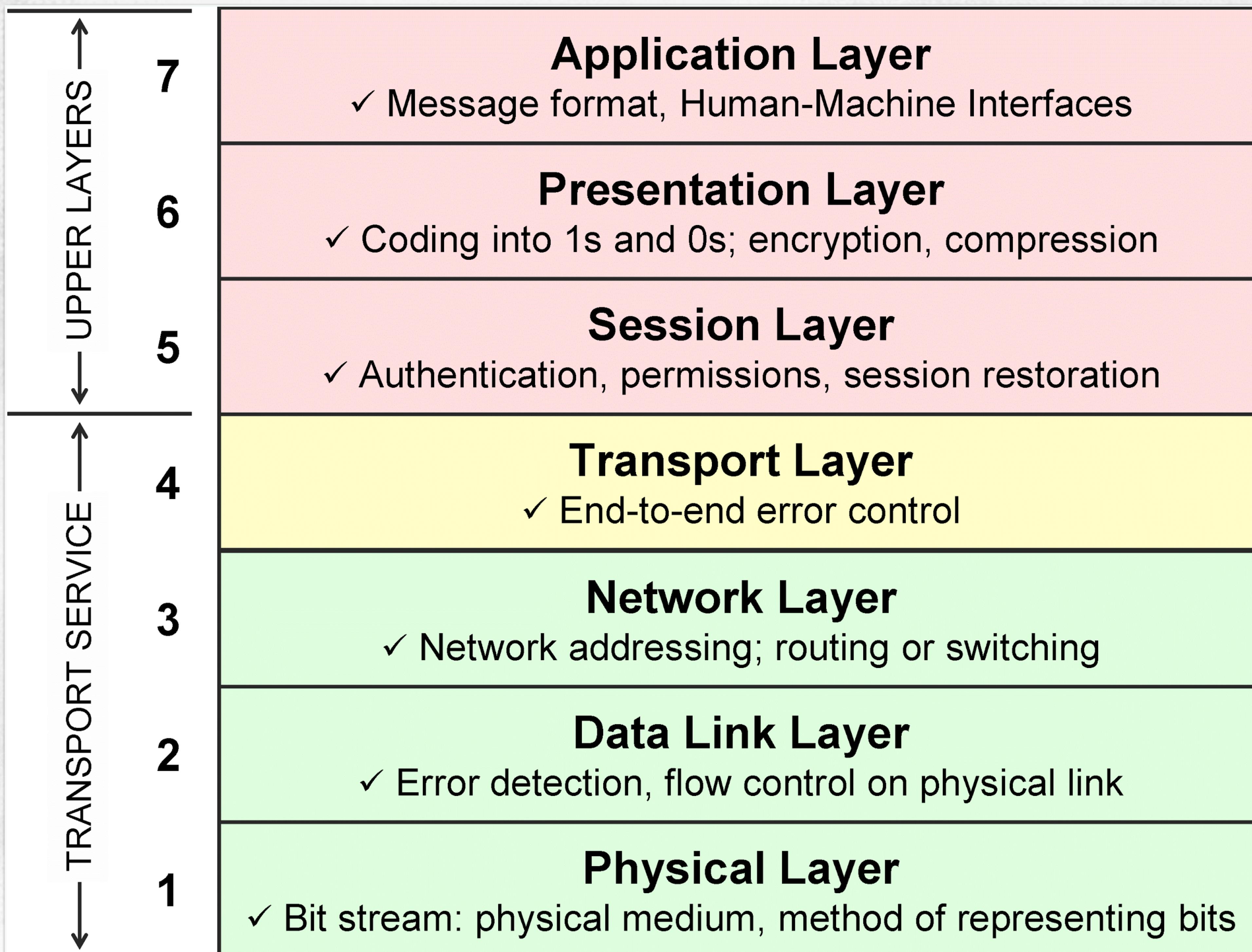
“Peer Communication”

## Post Office

Sender, Receiver and Carrier

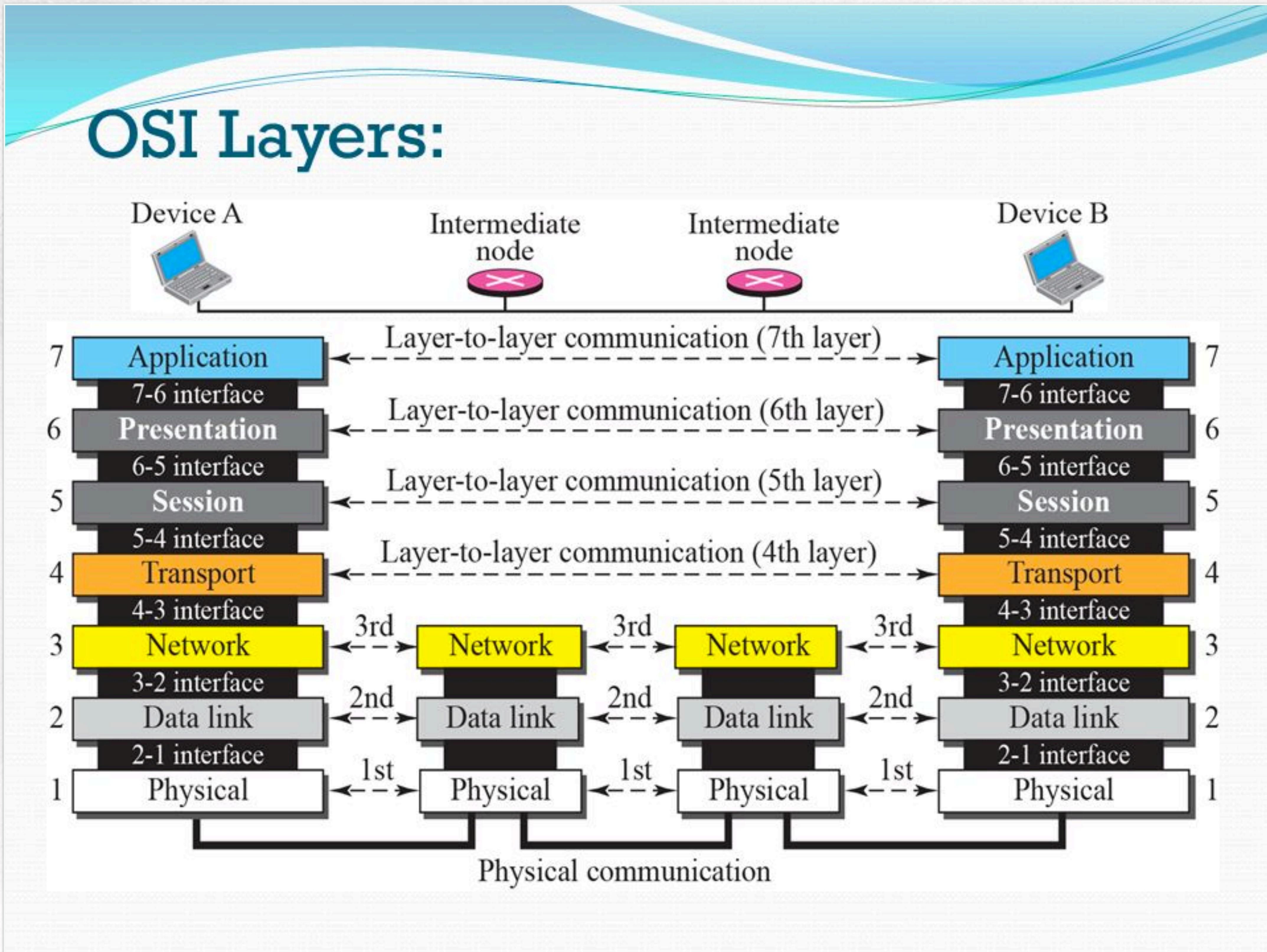


# What is this? (Top-Down)



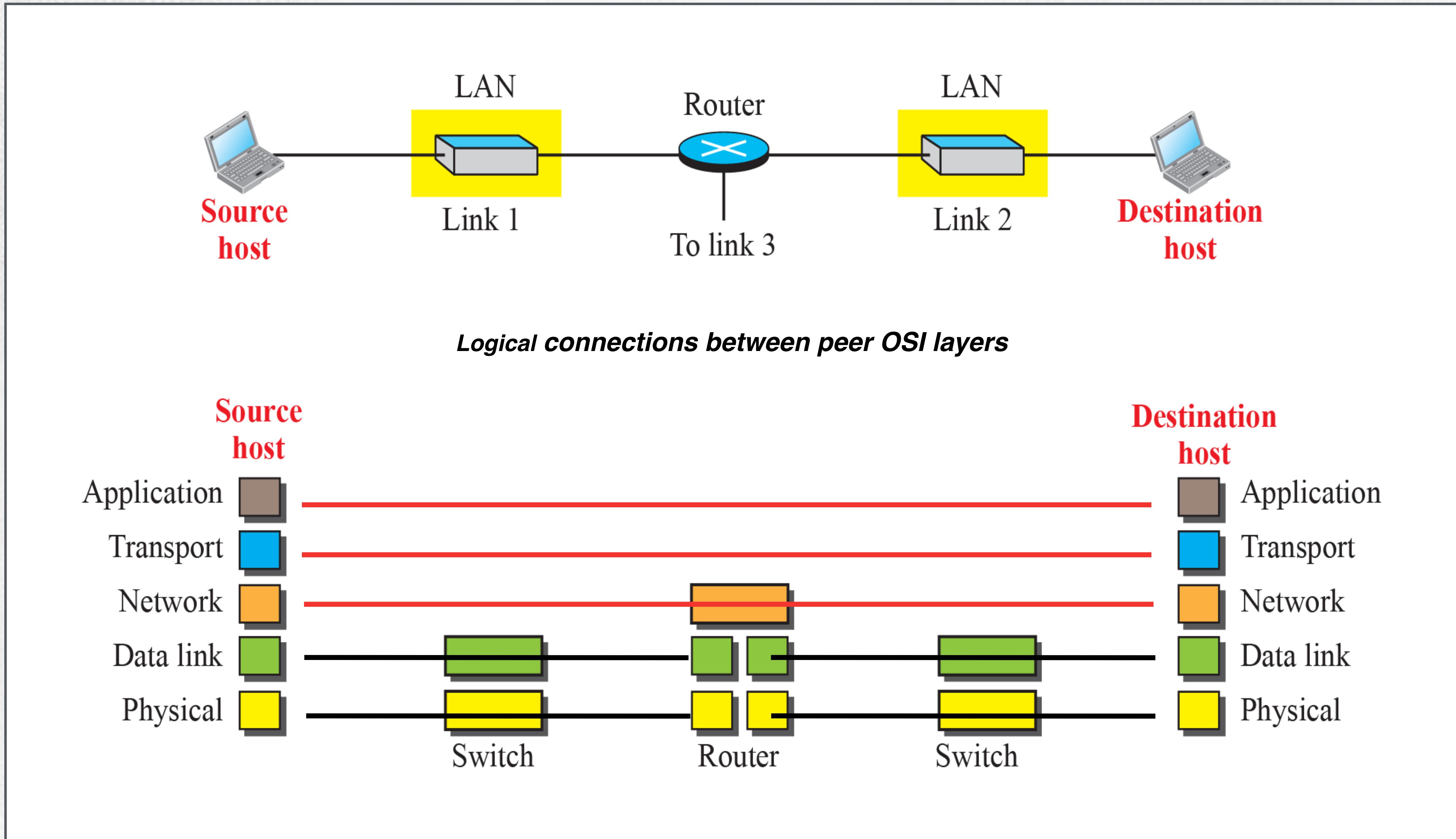
# OSI 7 Layer

## What is this? (Peer-Communication)



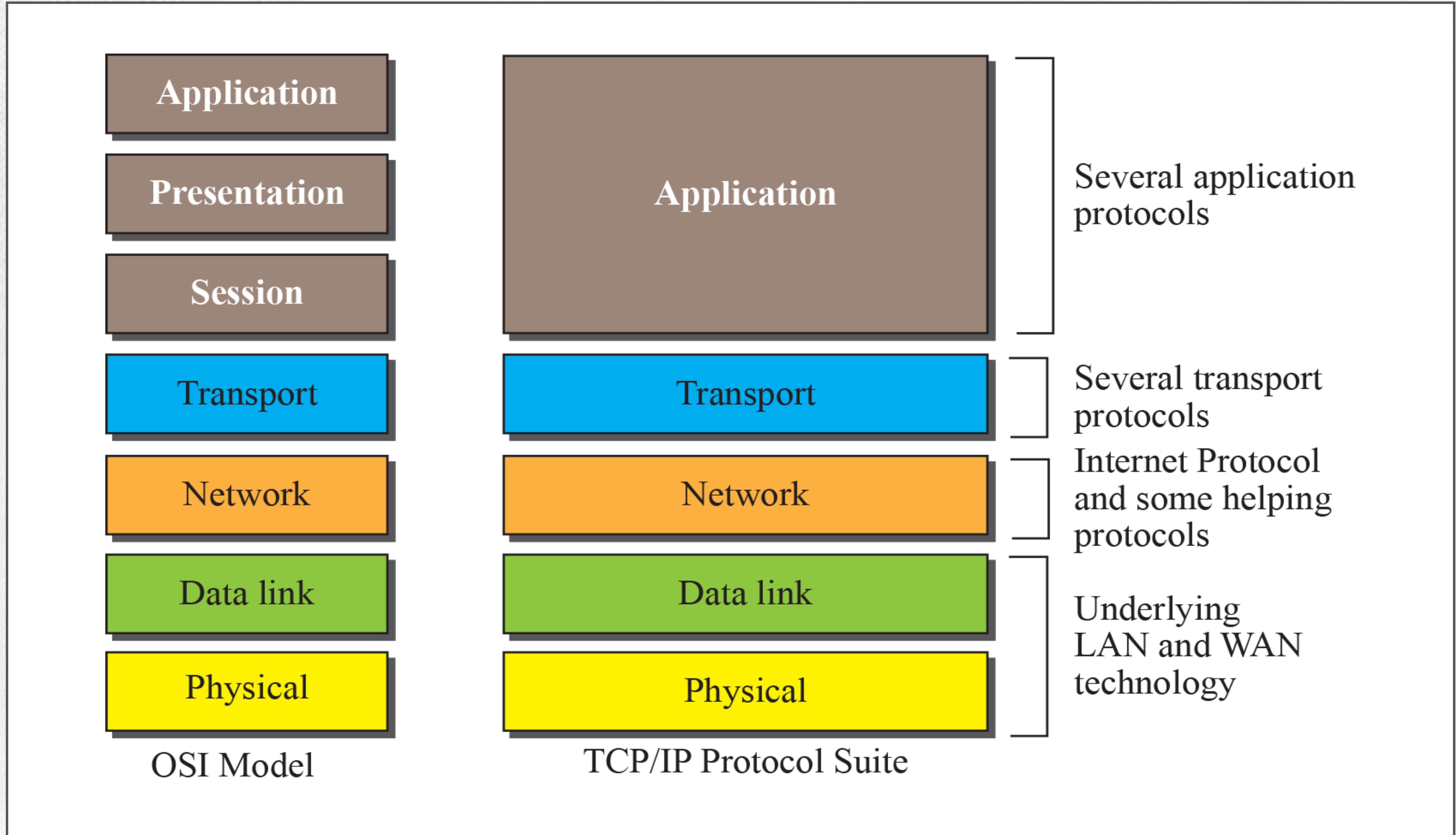
# OSI 7 Layer

## OSI Layer as a SW and HW



# OSI 7 Layer

## Simplified Model for Internet Service and Network



# OSI 7 Layer Background

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- The Open Systems Interconnection model (OSI model) is a conceptual model that characterizes and standardizes the communication functions of a telecommunication or computing system without regard to its underlying internal structure and technology.
- Its goal is the interoperability of diverse communication systems with standard protocols. The model partitions a communication system into SEVEN abstraction layers.

## Upper (aka Application) Layers

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- Application (Layer 7) : High-level APIs, including resource sharing, remote file access (sometimes, end-user application itself)
- Presentation (Layer 6) : Translation of data between a networking service and an application; including character/multi-media encoding, data compression and encryption/decryption
- Session (Layer 5) : Managing communication sessions (logical connection between applications), i.e. continuous exchange of information in the form of multiple back-and-forth transmissions between two nodes

## Lower Layers

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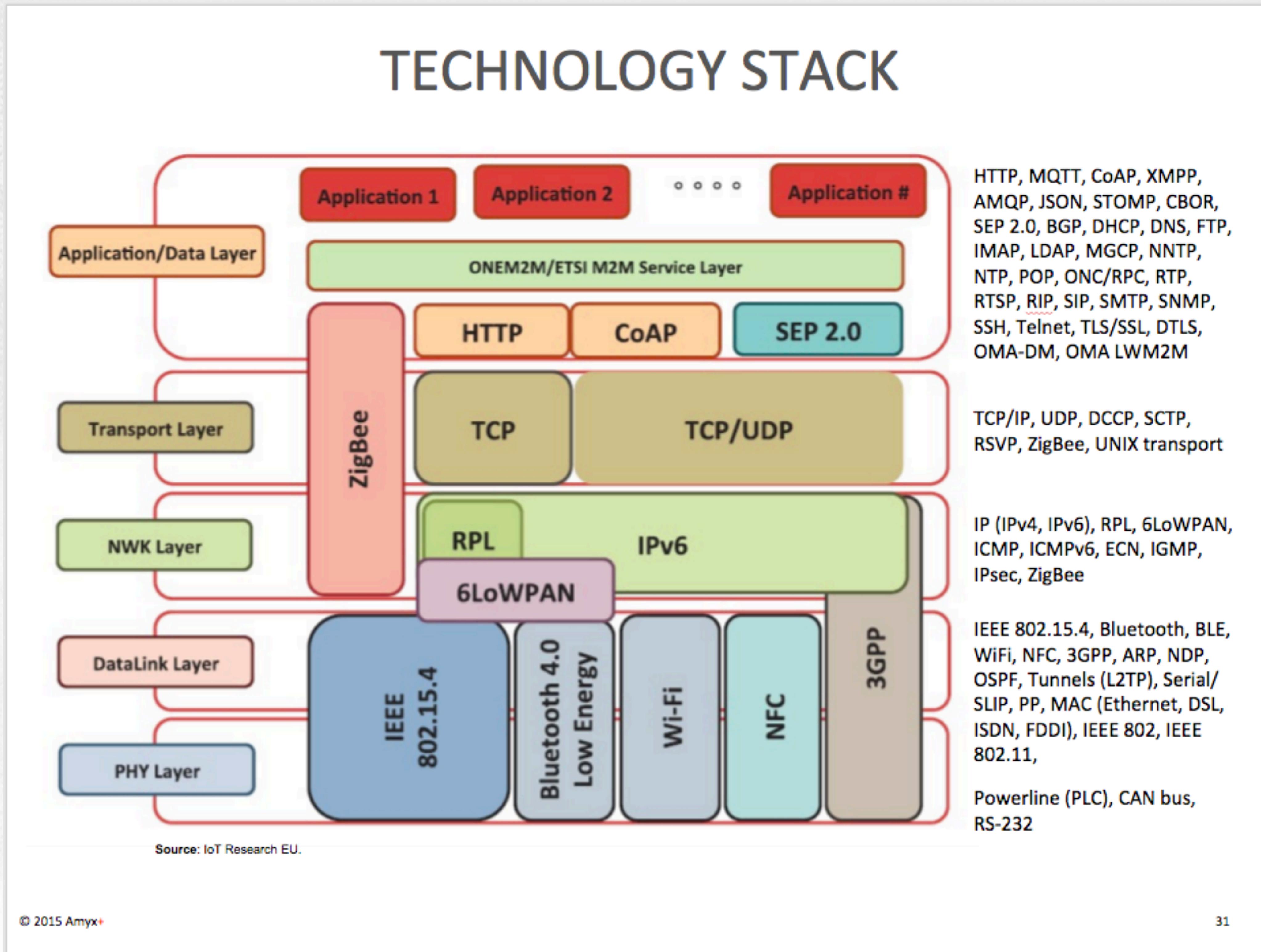
- Transport (Layer 4) : Reliable transmission of data segments between remote application processes, including segmentation, acknowledgement and multiplexing
- Network (Layer 3) : Structuring and managing a multi-node network, including addressing, routing and traffic control
- Datalink (Layer 2) : Reliable transmission of data frames between two adjacent nodes connected by a physical layer
- Physical (Layer 1) : Transmission and reception of raw bit streams over a physical medium

# Layering Operation Concept

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- Data processing by two communicating devices is done as such:
  - » The data to be transmitted is composed at the topmost layer of the transmitting device (layer N) into a protocol data unit (PDU).
  - » The PDU is passed to layer N-1, where it is known as the service data unit (SDU).
  - » At layer N-1 the SDU is concatenated with a header, a footer, or both, producing a layer N-1 PDU. It is then passed to layer N-2.
  - » The process continues until reaching the lowermost level, from which the data is transmitted to the receiving device.
  - » At the receiving device the data is passed from the lowest to the highest layer as a series of SDUs while being successively stripped from each layer's header or footer, until reaching the topmost layer, where the last of the data is consumed.

# Layering Example (Practical)



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# Arduino History

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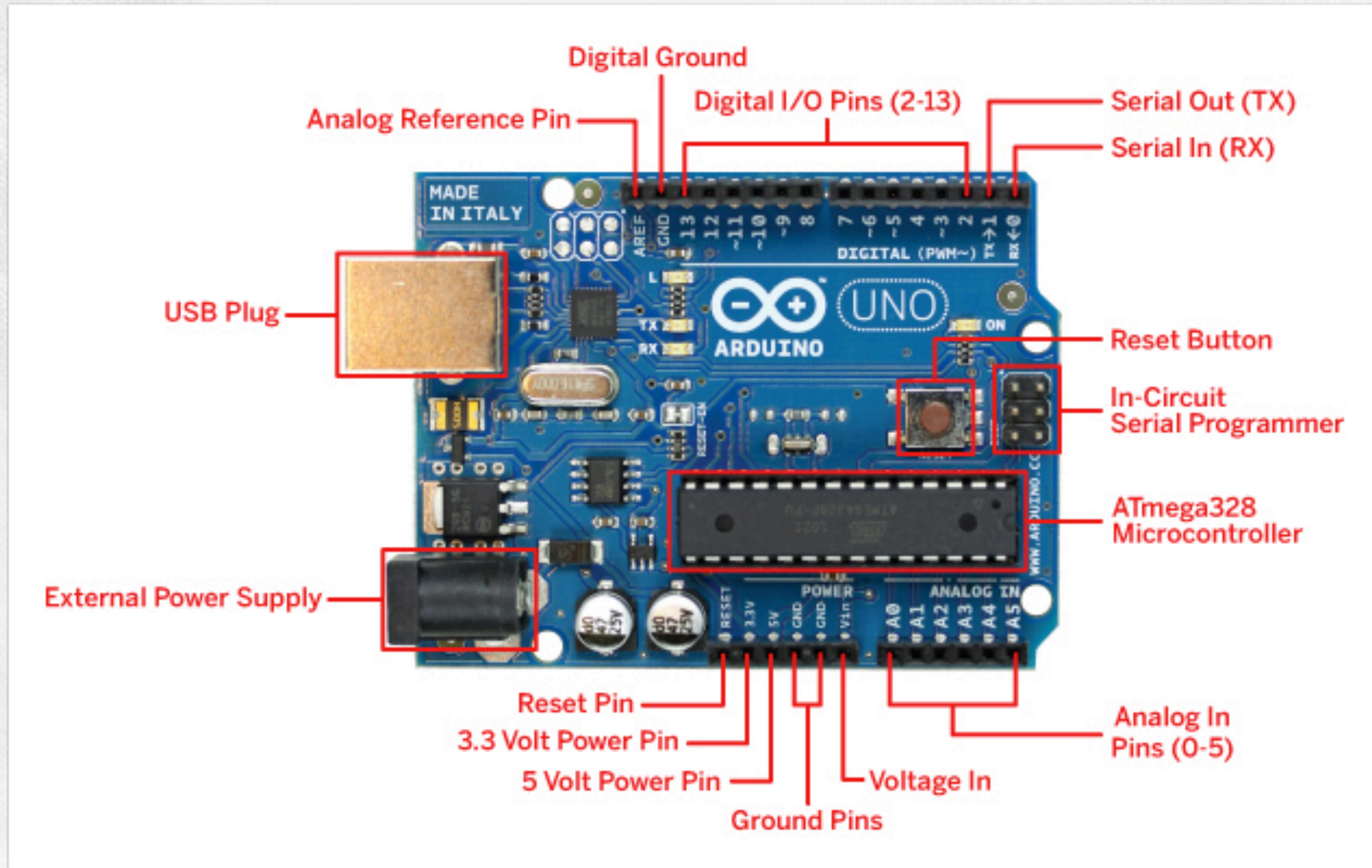
- The Arduino project started in 2003 as a program for students at the Interaction Design Institute Ivrea in Ivrea, Italy, aiming to provide a low-cost and easy way for novices and professionals to create devices that interact with their environment using sensors and actuators.
- In 2003, Hernando Barragán created the development platform Wiring as a Master's thesis project at IDII, the project goal was to create simple, low cost tools for creating digital projects by non-engineers.
- Massimo Banzi, with David Mellis, another IDII student, and David Cuartielles, added support for the cheaper ATmega8 microcontroller to Wiring. But instead of continuing the work on Wiring, they forked the project and renamed it Arduino.
- The name Arduino comes from a bar in Ivrea, Italy, where some of the founders of the project used to meet.

## What is it?

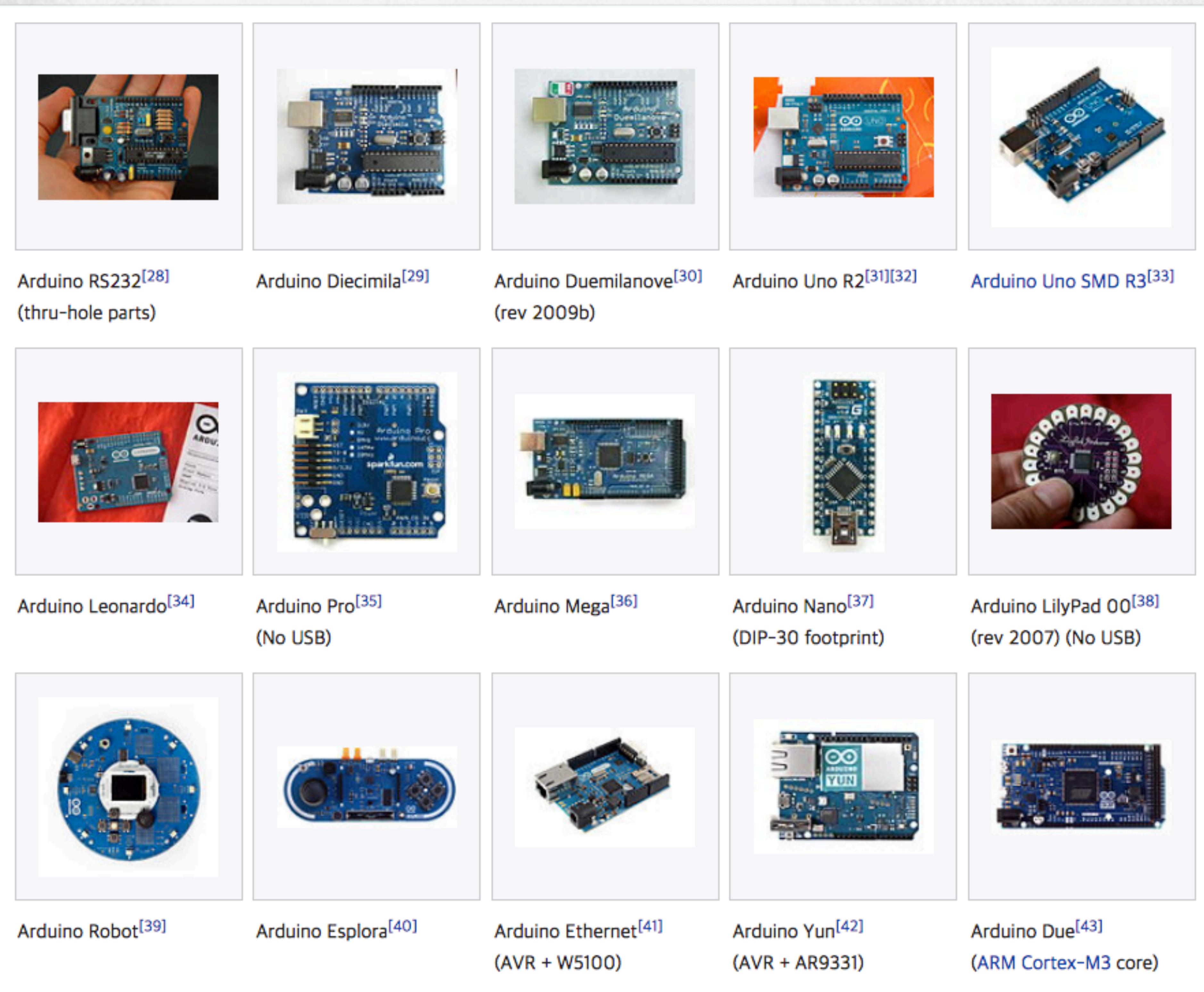
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- Arduino is an open source computer hardware and software company, project, and user community that designs and manufactures single-board micro controllers and micro controller kits for building digital devices and interactive objects that can sense and control objects in the physical world.
- The project's products are distributed as open-source hardware and software, which are licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of Arduino boards and software distribution by anyone.
- Arduino boards are available commercially in preassembled form, or as do-it-yourself (DIY) kits.

# Arduino Hardware

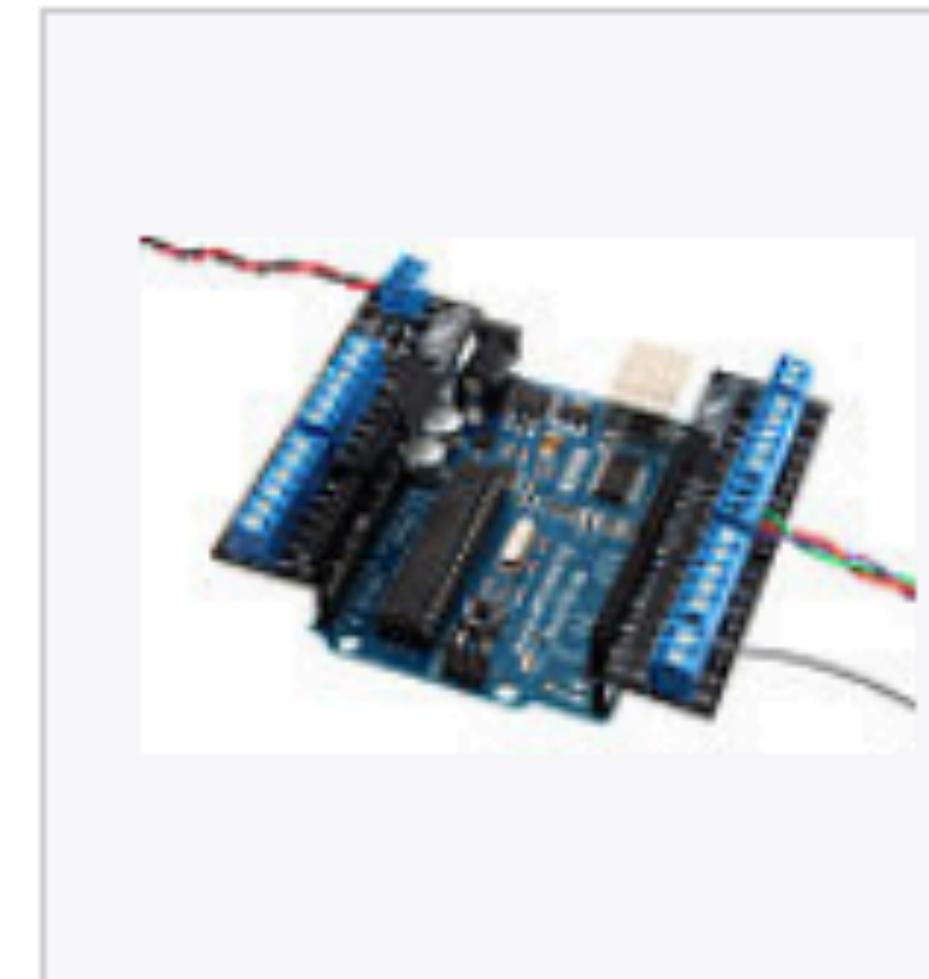


# Arduino Hardware - Official Boards



# Arduino

## Hardware - Shields



Multiple shields can be stacked. In this example the top shield contains a solderless breadboard.

Dragino Lora Shield allows the user to send data and reach extremely long ranges at low data-rates.

Screw-terminal breakout shield in a wing-type format

Adafruit Motor Shield with screw terminals for connection to motors

Adafruit Datalogging Shield with a Secure Digital (SD) card slot and real-time clock (RTC) chip

# Arduino Applications - Arduino Project Hub

The screenshot shows a web browser window with the Arduino Project Hub open. The URL in the address bar is <https://create.arduino.cc/projecthub>. The page features a prominent banner for "THE ALEXA AND ARDUINO SMART HOME CHALLENGE" in partnership with Amazon Alexa. Below the banner are five filter buttons: "All products", "All categories", "Trending", "Any difficulty", and "Any type". Three project cards are displayed:

- Simple Arduino Soldering Station** by lazyvlad: An image of a soldering station with a digital display showing "Stby 25°".
- Climate Cube for Greenhouse** by Istvan Sipka: An image of a black cube-shaped greenhouse control unit.
- In Servo We Trust!** by Moushira: An image of a large-scale architectural structure made of many reflective triangular panels.

At the bottom of each project card, there are statistics: views, comments, and respects.

Project	Views	Comments	Respects
Simple Arduino Soldering Station	954	0	5
Climate Cube for Greenhouse	4,401	2	22
In Servo We Trust!	5,955	1	35

# Arduino

# Applications - hackster.io

The screenshot shows the Arduino Projects section of the hackster.io website. The top navigation bar includes tabs for 'Arduino Project Hub', 'Arduino projects', and 'Maker Faire |'. The main search bar contains the text 'What are you looking for?'. On the right, there are 'Log in' and 'Sign up' buttons. A 'Join Community' button is also visible. The main content area features a section for 'Arduino' with a logo and a brief description: 'Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software.' Below this are links to 'Buy an Arduino' and 'Visit website'. The 'Projects' tab is selected in the navigation bar. Below the navigation, there are four filter dropdowns: 'Trending', 'All products', 'All categories', and 'All difficulties'. The main content displays eight project cards in two rows of four. The first row includes:

- PROTIP Development Board for ATtiny MCU** by Vincenzo G. (Image: Development board with OSH Park Perfect Purple PCB logo). Likes: 10, Views: 570.
- TUTORIAL The Flappy Bird on Arduino** by Techduino (Image: LCD screen showing a Flappy Bird game). Likes: 6, Views: 496.
- TUTORIAL LoRa Gateway for DeviceHive** by DeviceHive (Image: Arduino board connected to a laptop displaying DeviceHive software). Likes: 17, Views: 2.5K.
- TUTORIAL Infrared Replicator** by Gustavo Gonnet (Image: Hand holding a device). Likes: 21, Views: 2.4K.

The second row includes:

- PROTOTYPING** (Image: A complex mechanical prototype with multiple components).
- PROJECT** (Image: Two people standing next to large pixelated models of Pac-Man and a ghost).
- PROJECT** (Image: A close-up of a flame or fire).
- PROJECT** (Image: A device mounted on a window blind, labeled 'Voice Activated Arduino Blinds').



# Arduino

# Applications - Maker Faire

The screenshot shows a web browser window with three tabs: "Arduino Project Hub", "Arduino projects", and "Maker Faire |". The "Maker Faire" tab is active, displaying the <https://makerfaire.com> website.

The page features a large banner for the "Maker Faire Rome" event, which took place from December 1-3, 2017. The banner includes images of various robotic and mechanical projects, a "ROME 1-3 DICEMBRE 2017 WWW.MAKERFAIREROME.EU" badge, and social media sharing icons.

Below the banner, there are sections for "Our Flagship Faires:" (Bay Area and New York), "Save the Date: May 18-20, 2018" for the "Maker Faire Bay Area" (with a "More information Coming Soon" note and a "DETAILS COMING SOON" button), and "World Maker Faire: Sept 23 + 24, 2017" (with a "That's a Wrap!" message, "Stay tuned for details on 2018!", and a "SEE 2017 SLIDESHOW" button).

At the bottom, there is a link to "Meet the World Maker Faire 2017 Makers: See all" and two small thumbnail images.



# Arduino Applications - AliExpress

The screenshot shows the AliExpress search results for "Arduino Robot". The search bar at the top has "Arduino Robot" entered. Below the search bar, there are filters for "Brands", "Price", and "Sort by". The main content area displays several products:

- TENSTA Intelligent Car Learning Suite Robot Intelligent Turtle Wireless**: Price ₩ 46,340 / piece, Free Shipping, 4.5 stars (54 reviews), 143 orders.
- Intelligent Car Learning Suite Wireless Control Based For**: Price ₩ 112,030 / piece, Free Shipping, 4.5 stars (37 reviews), 47 orders.
- Elecrow 4WD RC Smart Car Chassis with S3003 Metal Servo**: Price ₩ 56,010 / piece, Free Shipping, 4.5 stars (75 reviews), 104 orders.
- Arduino Robot 6 DOF Aluminium Clamp Claw Mount Kit Mechanical Robotic Arm & Servos & Metal Servo Horn-Silver**: Price ₩ 55,158 – ₩ 100,815 / piece, Discount Price ₩ 44,122 – ₩ 80,647 / piece (20% off), 7 days left, Get our app to see exclusive prices, Bulk Price.
- SunFounder DIY 4-DOF Robot Kit -Sloth Learning Kit for Arduino**: Price ₩ 60,491 / piece, Free Shipping, 4.5 stars (36 reviews), 74 orders.
- New Avoidance tracking Motor Smart Robot Car Chassis Kit**: Price ₩ 21,064 / Set, Free Shipping, 4.5 stars (49 reviews), 138 orders.
- LANDZO Altar 1s Programmable Smart Robot Car Kit with Arduino**: Price ₩ 75,964 / piece, Shipping: ₩ 1,535 / lot via AliExpress Standard Shipping, 4.5 stars (9 reviews), 28 orders.
- Smart Electronics Motor Smart Robot Car Chassis Kit Speed**: Price ₩ 22,353 / piece, Free Shipping, 4.5 stars (305 reviews), 635 orders.

On the right side of the page, there is a detailed product view for the "Arduino Robot 6 DOF Aluminium Clamp Claw Mount Kit Mechanical Robotic Arm & Servos & Metal Servo Horn-Silver". It shows a large image of the robot arm, its specifications, and a "Buy Now" button.



# Open Compute Project

# Facebook's Open Source Datacenter

The screenshot shows the homepage of the Open Compute Project (OCP) website. The header features the OCP logo and navigation links for About, Learn, Buy, Participate, Projects, News, Contact, Sign In, and a search icon. The main content area has a background image of a server room. On the left, a section titled "About OCP" contains the following text:

**The Open Compute Project (OCP) is a collaborative community focused on redesigning hardware technology to efficiently support the growing demands on compute infrastructure.**

On the right, there are two circular callout boxes. The top one is dark grey with white text: "Hundreds of active members". The bottom one is light green with white text: "Collaborating to improve infrastructure design". To the right of these boxes is a sidebar titled "Projects" with a list of categories: Storage, Networking, Server Design, Open Rack, Certification, Hardware Management, and Data Center.



# 2011 Facebook

## Server



Open Compute motherboards are power-optimized, barebones designs that provide the lowest capital and...

[Learn More](#)

## Storage



Storage is a key component of any data center, and offers many opportunities for efficiency ...

[Learn More](#)

## Data Center Design



Designed in tandem with Open Compute servers, the data center maximizes mechanical...

[Learn More](#)

## Networking



Designing fully open network technology stacks.

[Learn More](#)

## Hardware Management



Designing remote management tools...

[Learn More](#)

## Certification



Designing standards for Solution Providers...

[Learn More](#)

## Open Rack



The first rack standard that's designed for data centers...

[Learn More](#)

## Solution Providers



Open Compute Project Solution Providers...

[Learn More](#)

2013  
Network



**OPEN**  
Compute Project

## SW Interfaces for an Open Compute Project Switch

Authors: Aviad Raveh, Matty Kadosh, Ariel Almog



**OPEN**  
Compute Project

**10/40 Gigabit Ethernet Rack Mountable Switch  
Standard**

Author: Michael Miller

# Open Source Telecom OCP Roadmap



2011

2012

2013

2014

2015

2016

# Open Source Telecom

## Why OCP?

**OPEN Compute Summit**

**Delivering the Datacenter of the Future**  
Making the Open Compute Vision a Reality

Eric Hooper  
Director, Rack Scale Architecture  
Cloud Platforms Group  
Intel Corporation

### Rack Scale Architecture – Near Term

Component	Improvement
OCP Boards	Up to $5X^2$ Provisioned Power
Silicon Photonics Interconnect	Up to $3X^1$ Cables
Remote Direct Attach Storage	Up to $1.5X^2$ Density
Open Network Platform	Up to $25X^1$ NW Downlink

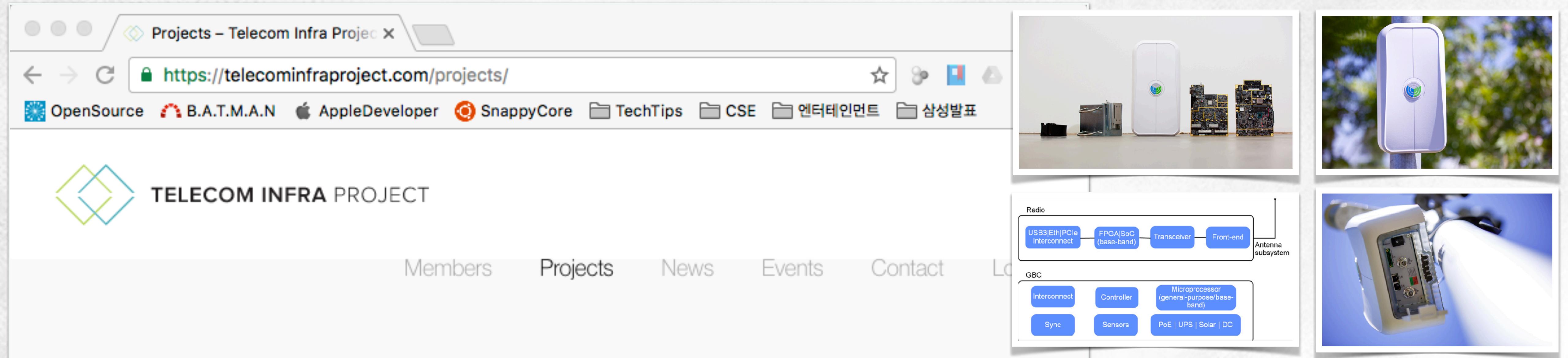
Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. Results have been estimated based on internal Intel analysis and are provided for informational purposes only. Any difference in system hardware or software results have been estimated based on internal Intel analysis and are provided for informational purposes only. Any difference in system hardware or software design or configuration may affect actual performance.

1. Improvement based on standard rack with 40 DP servers, 48 port ToR switch, 1GE downlink/server and 4 x10GE uplinks, Cables: 40 downlink and 4 uplink vs. rack with 42 DP servers, SiPh patch panel, 25Gb/s downlink, 100Gb/s uplink, Cables: 14 optical downlink, and 1 optical uplink. Actual improvement will vary depending on configuration and actual implementation.

2. Improvement as compared to 20 Dell PowerEdge R720, N+1 redundant power, 705W PSU x2, peak power provisioned 30,000 Watts vs. same server, shared DC power using 1 power shelf of 7x 700W modules and 4200W (N+1) : power provisioned 4900 Watts

6

# Open Source Telecom OCP TIP for Mobile Networking



The screenshot shows the Telecom Infra Project website at <https://telecominfraproject.com/projects/>. The page features a navigation bar with links for Members, Projects, News, Events, Contact, and a search bar. On the right side, there are three images of networking hardware: a white access point, a small outdoor unit, and a close-up of a white device. Below these images is a detailed block diagram of a Radio module architecture, showing components like USB3|Eth|PCIe Interconnect, FPGA|SoC (base-band), Transceiver, Front-end, Antenna subsystem, GBC, Interconnect, Controller, Microprocessor (general-purpose/base-band), Sync, Sensors, and PoE | UPS | Solar | DC.

## Projects

The project groups were created to support three strategic network areas: Access, Backhaul and Core & Management. Within each area, the initial set of project groups will address some of the most pressing industry needs including connecting the unconnected or underserved populations, and augmenting the development of powerful new technologies like 5G that will pave the way for better connectivity and richer services. Specifications and designs are contributed to TIP through the TIP project groups.

This project group will deliver recipes for services/applications in the radio core network, leveraging open cloud architecture, libraries, software stacks and APIs. The group will provide a framework to enable disaggregated cloud scale computing for Radio Core Network (RCN) applications and services, such as IMS, P-Gateway, S-Gateway, EPC, etc. The scope also includes 5G & IOT infrastructure.

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# Open or Close Google's own Hardwares and Softwares

## Jupiter Rising: A Decade of Clos Topologies and Centralized Control in Google's Datacenter Network

Arjun Singh, Joon Ong, Amit Agarwal, Glen Anderson, Ashby Armistead, Roy Bannon, Seb Boving, Gaurav Desai, Bob Felderman, Paulie Germano, Anand Kanagala, Jeff Provost, Jason Simmons, Eiichi Tanda, Jim Wanderer, Urs Hözle, Stephen Stuart, and Amin Vahdat  
Google, Inc.  
jupiter-sigcomm@google.com

### ABSTRACT

We present our approach for overcoming the cost, operational complexity, and limited scale endemic to datacenter networks a decade ago. Three themes unify the five generations of datacenter networks detailed in this paper. First, multi-stage Clos topologies built from commodity switch silicon can support cost-effective deployment of building-scale networks. Second, much of the general, but complex, decentralized network routing and management protocols supporting arbitrary deployment scenarios were overkill for single-operator pre-planned datacenter networks. We built a centralized control mechanism based on a global view pushed to all datacenter switches. Finally, modular hardware design coupled with software allowed our design to scale across wide-area networks at dozens of sites and grow by 100x over ten years.

### CCS Concepts

• Networks → Data centers

### Keywords

Datacenter Networks; Clos topology; Merchant Silicon; Centralized control and management

### 1. INTRODUCTION

Datacenter networks are critical to delivering web services, modern storage infrastructure, and are a key en-

abler for cloud computing. Bandwidth demands in the datacenter are doubling every 12-15 months (Figure 1), even faster than the wide area Internet. A number of recent trends drive this growth. Dataset sizes are continuing to explode with more photo/video content, logs, and the proliferation of Internet-connected sensors. As a result, network-intensive processing pipelines must operate over ever-larger clusters. Next, Web services are processing more data requests. Finally, often share sub-clusters within a cluster; conserving ads.

operational center networks. The number of network nodes at a point in time [24].

marvels, typically re-setting wide area deployments. These switches were differentiated with hardware support for a range of protocols (e.g., IP multiprotocol) by pushing the envelope of chip memory (e.g., Internet-scale routing tables, off chip DRAM for deep buffers, etc.). Network control and management protocols targeted autonomous individual switches rather than pre-configured and largely static datacenter fabrics. Most of these features were not useful for datacenters, increased cost, complexity, delayed time to market, and made network management more difficult.

Datacenter switches were also built as complex chassis targeting the highest levels of availability. In a WAN Internet deployment, losing a single switch/router can have substantial impact on applications. Because WAN links are so expensive, it makes sense to invest in high availability. However, more plentiful and cheaper datacenter bandwidth makes it prudent to trade cost for somewhat reduced intermittent capacity. Finally, switches operating in a multi-vendor WAN environment with arbitrary end hosts require support for many protocols to ensure interoperability. In single-operator data-

ACM SIGCOMM  
2015

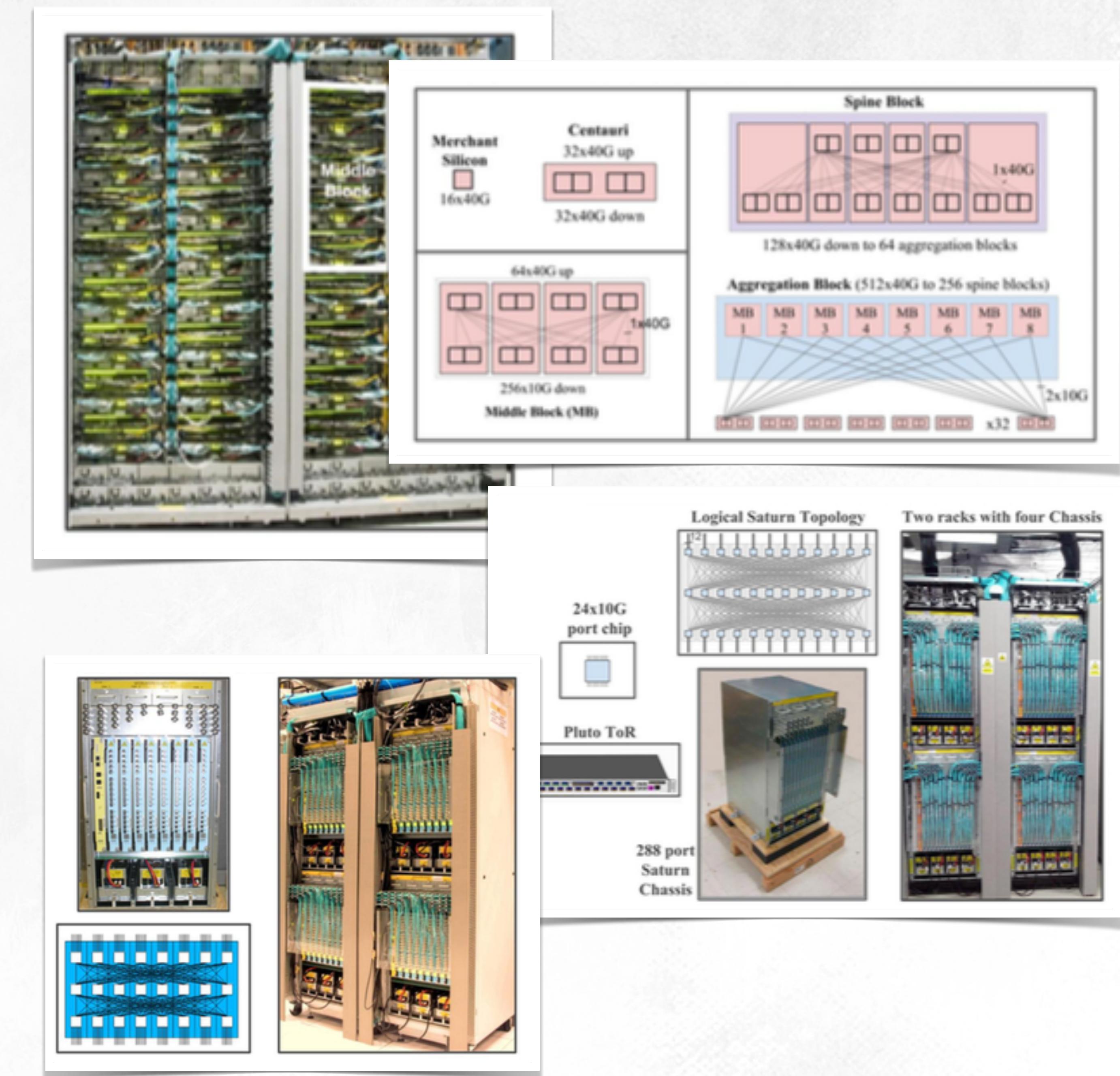
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# RaspberryPi

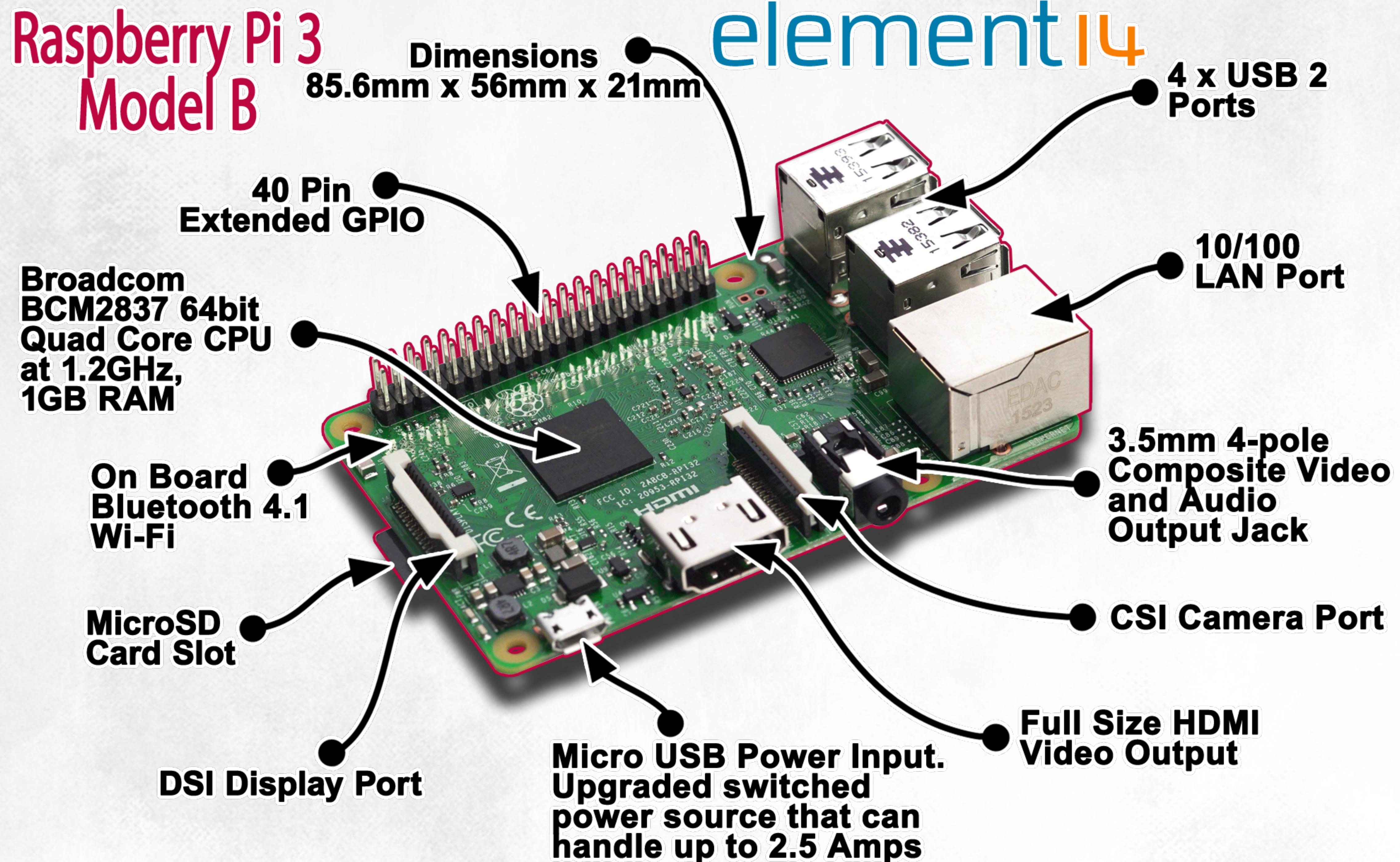
## What is it?

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- The Raspberry Pi is a series of small single-board computers developed in the United Kingdom by the Raspberry Pi Foundation to promote the teaching of basic computer science in schools and in developing countries.
- The original model became far more popular than anticipated, selling outside of its target market for uses such as robotics.
- According to the Raspberry Pi Foundation, over 5 million Raspberry Pis have been sold before February 2015, making it the best-selling British computer.[8] By November 2016 they had sold 11 million units, reaching 12.5m in March 2017, making it the third best-selling "general purpose computer" ever. In July 2017 it was announced that the total sales have now reached nearly 15 million units.

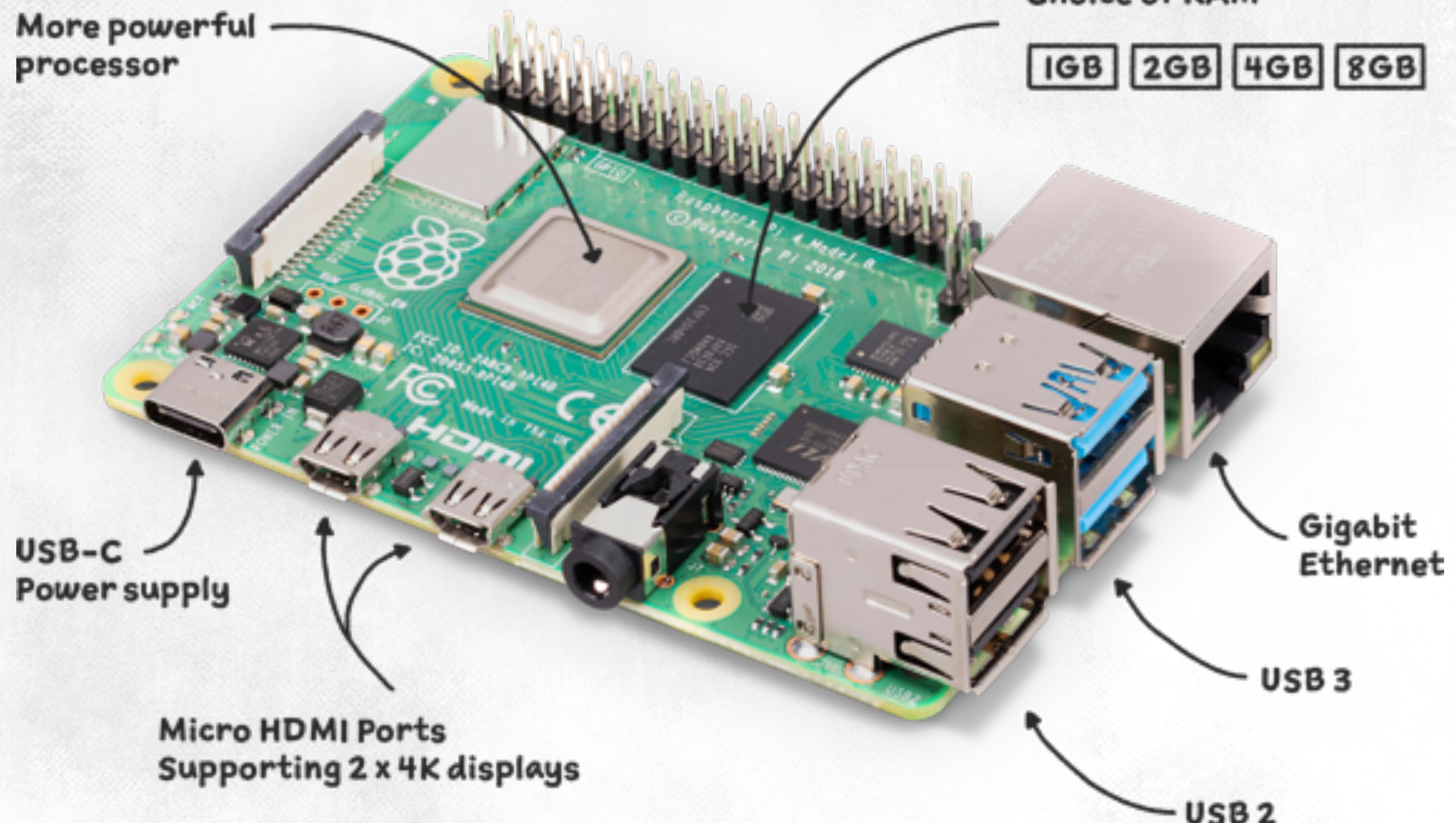


# RaspberryPi Hardware



# RaspberryPi Hardware

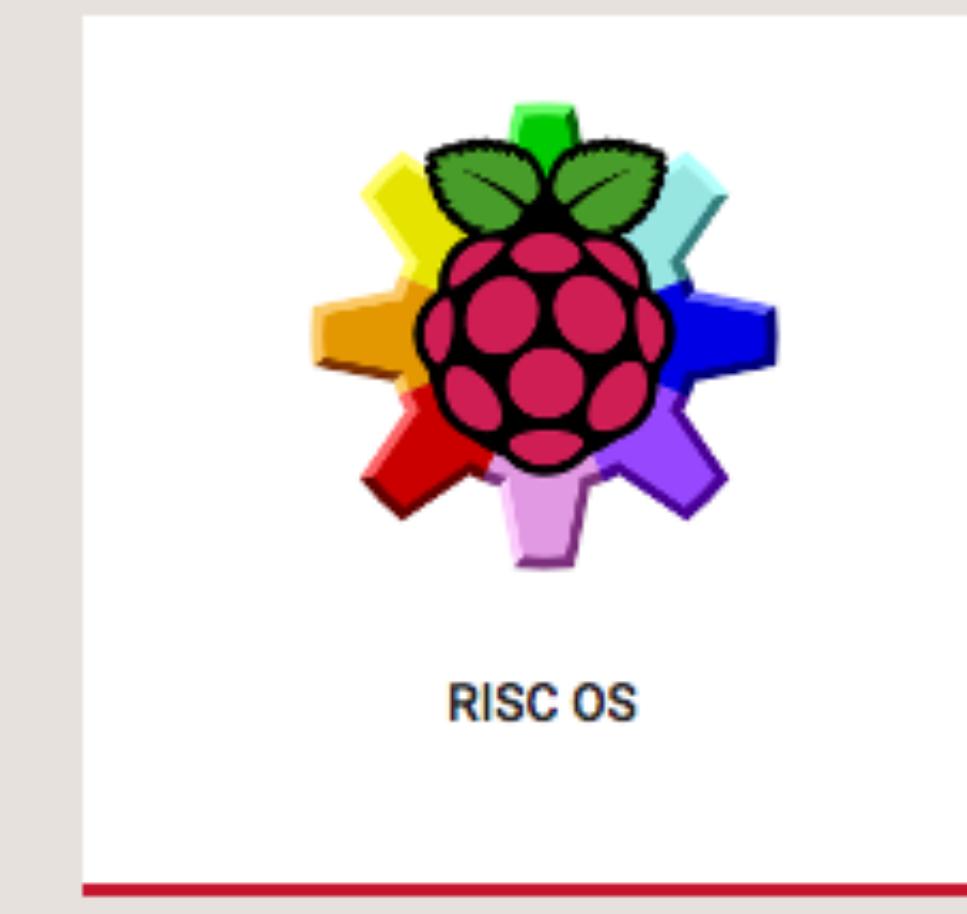
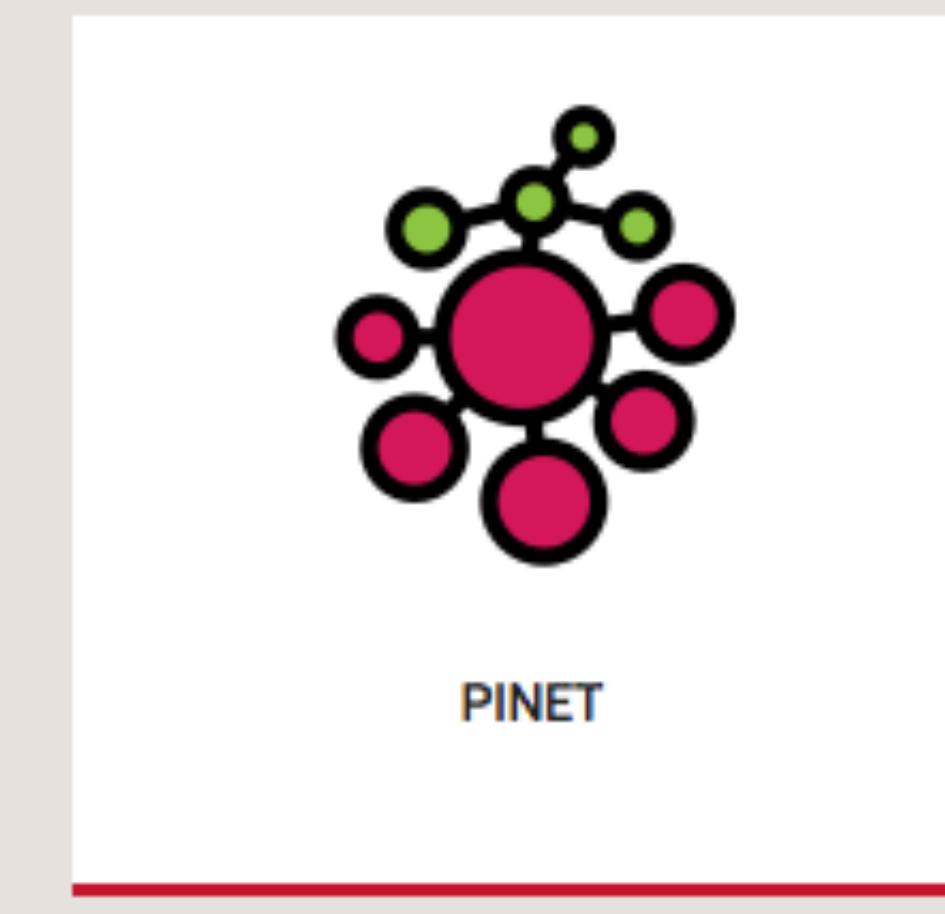
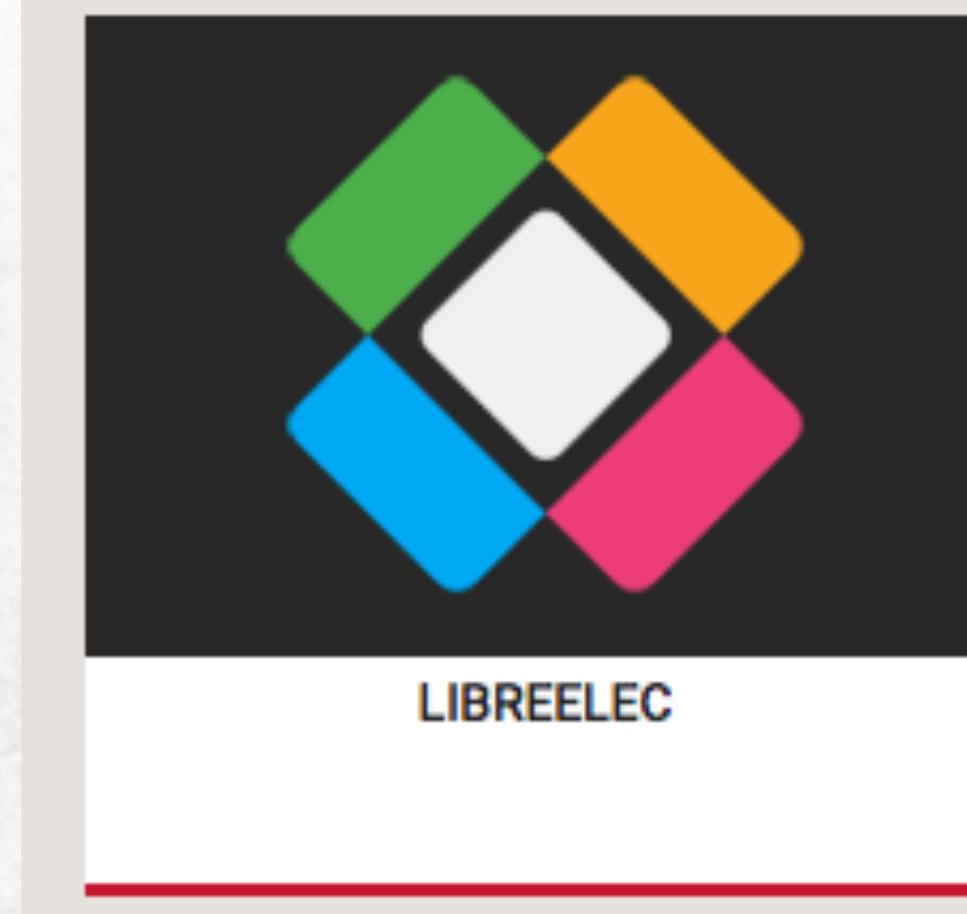
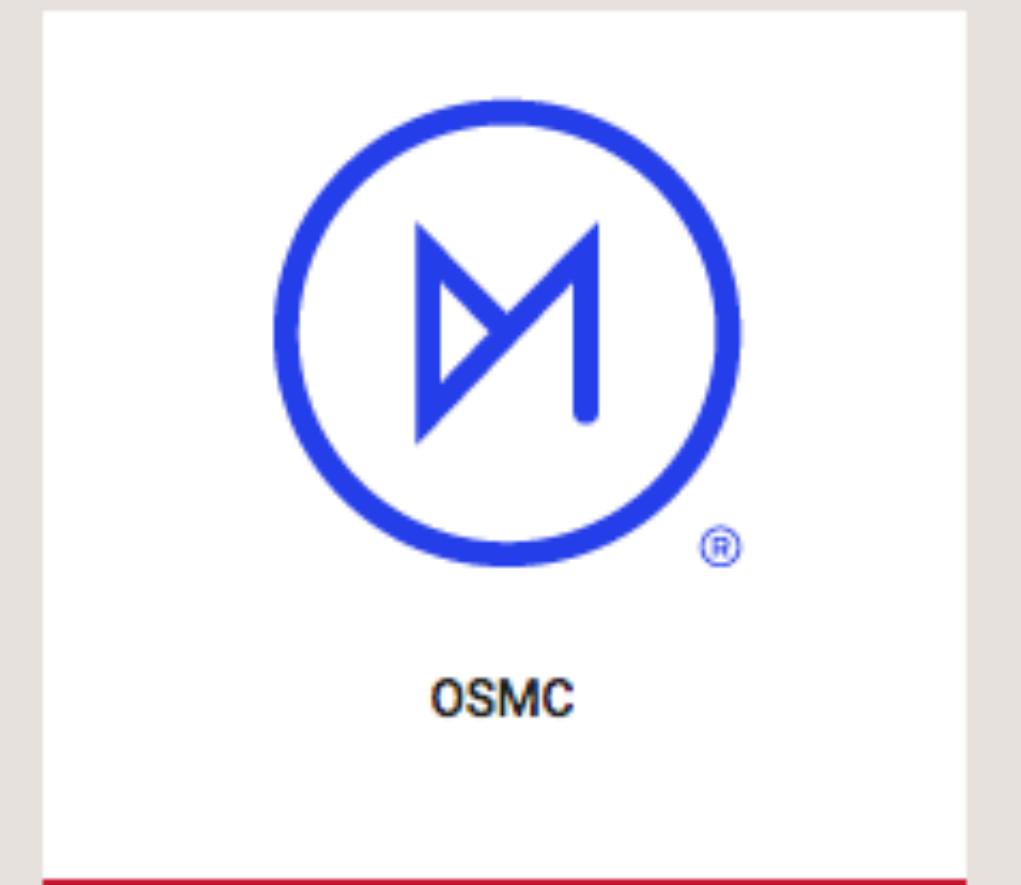
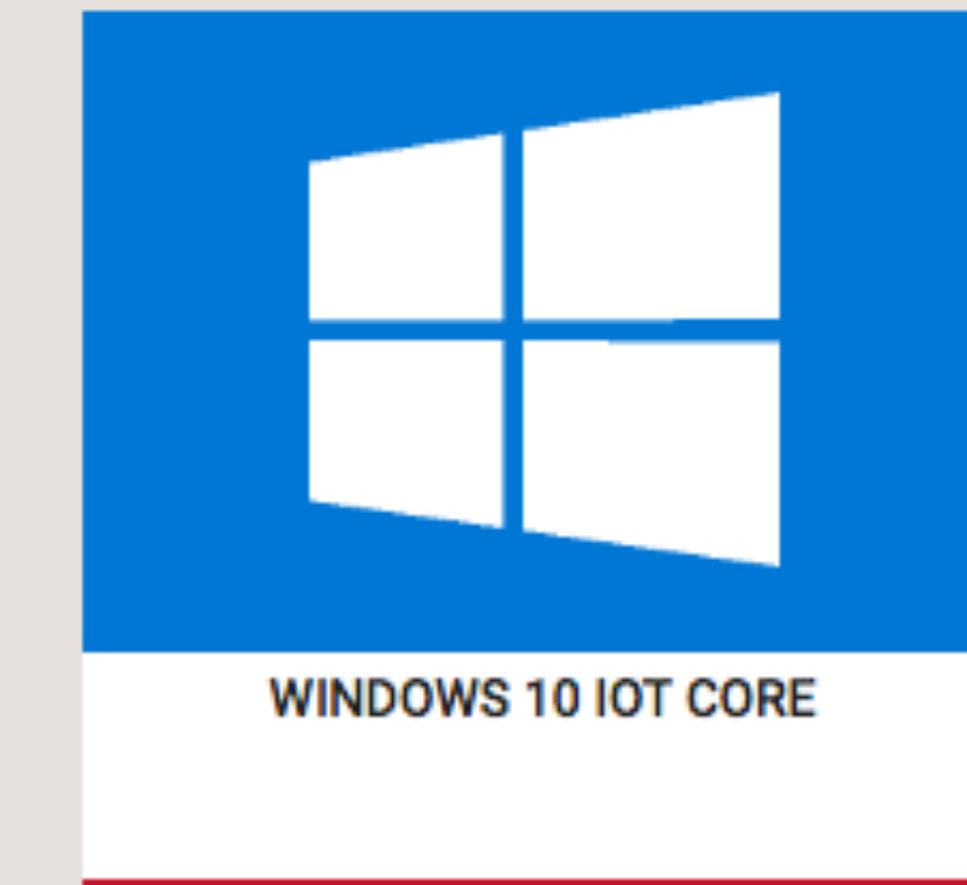
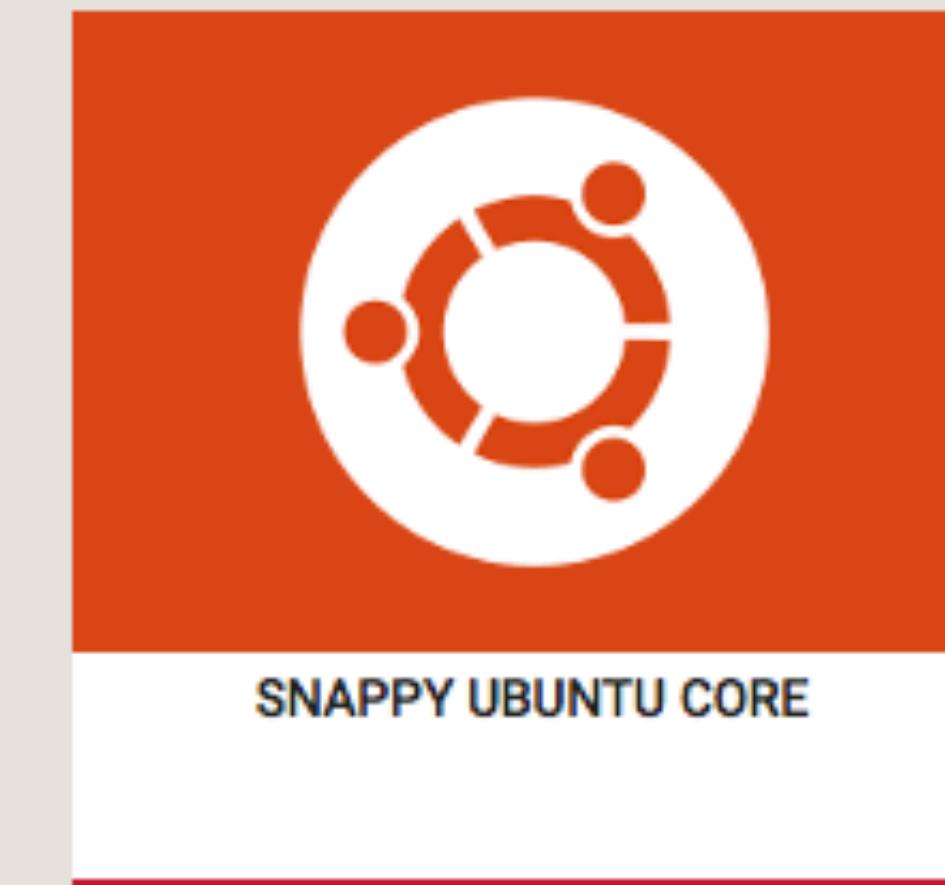
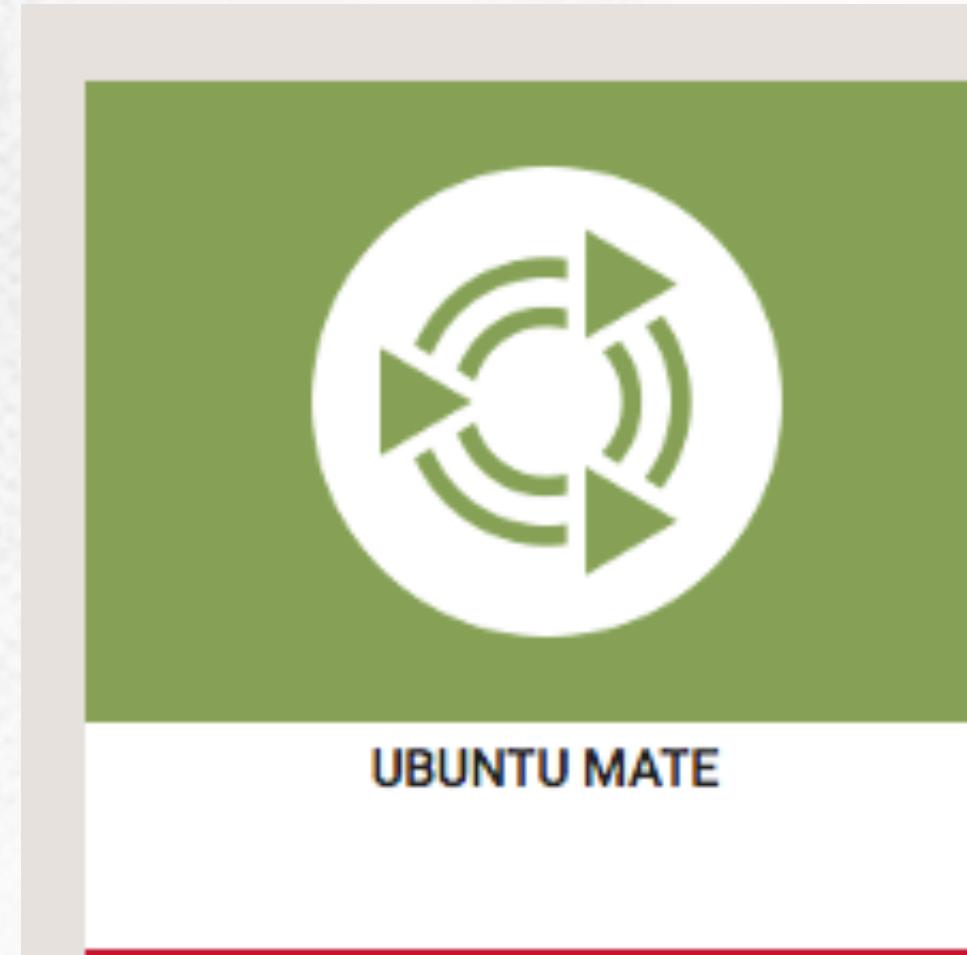
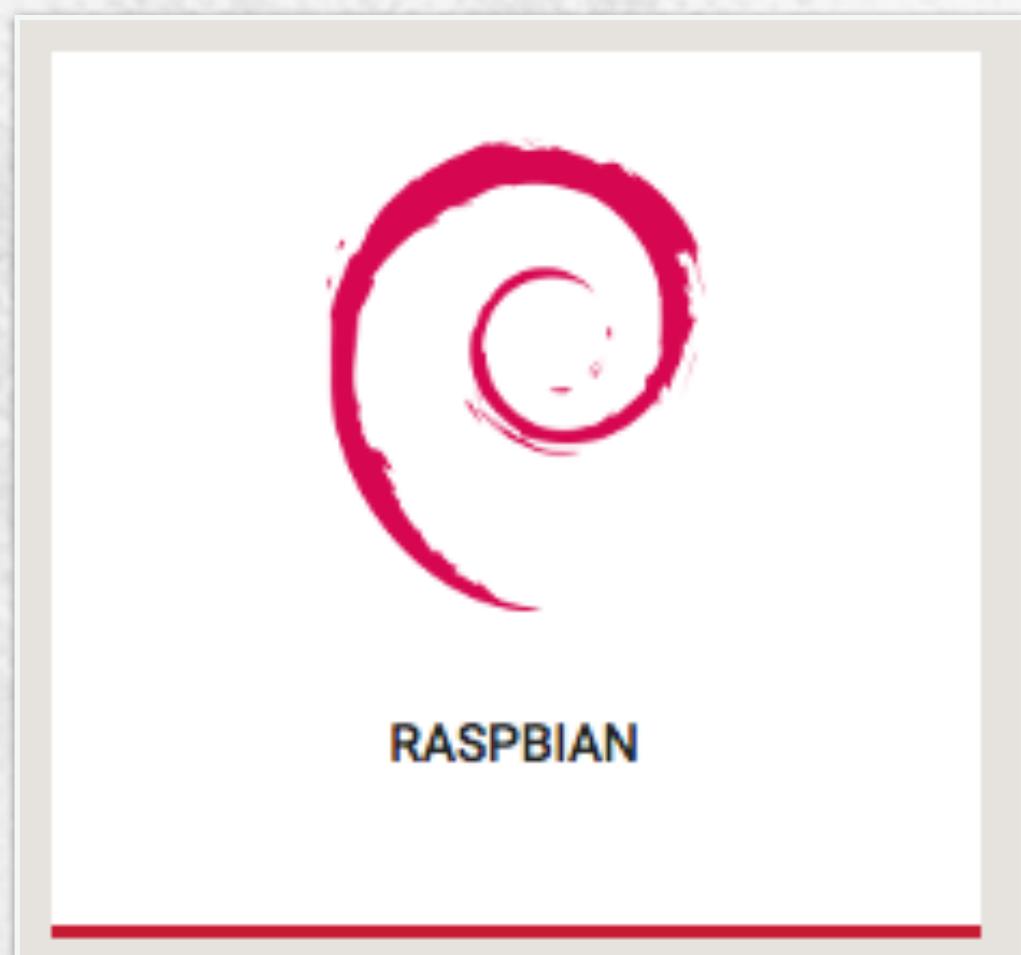
**Broadcom BCM2711,  
Quad core Cortex-A72 (ARM v8)  
64-bit SoC @ 1.5GHz**



# RaspberryPi Software

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## ● General Purpose Operating Systems



# RaspberryPi Projects

**Raspberry Pi Project - Google**

안전한 | https://www.google.co.kr/search?q=Raspberry+Pi+Project&oq=Raspberry+Pi+Project&aqs=chrom&tbo=isch&sourceid=chrome&ie=UTF8

OpenSource GoormEDU WebSites TechTips FutureWorks Entertainment C++17 Preparing Tomorrow

**Google** Raspberry Pi Project

전체 이미지 동영상 뉴스 지도 더보기 설정 도구

검색결과 약 18,000,000개 (0.56초)

**Raspberry Pi: Top 31 projects to try yourself | IT PRO**  
www.itpro.co.uk › Mobile › In-depth ▾ 이 페이지 번역하기  
2017. 11. 14. - The best projects to try with the Raspberry Pi and Raspberry Pi Zero.

**Top 10 Raspberry Pi Projects for Beginners - Lifehacker**  
https://lifehacker.com/top-10-raspberry-pi-projects-for-beginners... ▾ 이 페이지 번역하기  
2017. 1. 14. - Maybe you picked up a Raspberry Pi for the holidays, or you've been sitting on one of the super versatile, palm-sized computers for a while ...

**Raspberry Pi projects - Hackster.io**  
https://www.hackster.io/raspberry-pi/projects ▾ 이 페이지 번역하기  
Explore 1653 projects built with Raspberry Pi, and share your own! Join 20477 hardware developers who follow Raspberry Pi on Hackster.io.

**Raspberry Pi 3 Model B's projects - Hackster.io**  
https://www.hackster.io/raspberry-pi/.../raspberry-pi-3-model-b ▾ 이 페이지 번역하기  
632 hardware projects made with Raspberry Pi 3 Model B from Raspberry Pi.

**Raspberry Pi Projects - Instructables**  
www.instructables.com/id/Raspberry-Pi-Projects/ ▾ 이 페이지 번역하기  
Raspberry Pi is a dynamic microcontroller that is capable of just about anything a computer is. It runs with the Python programming language, and is a great way ...

**Best Raspberry Pi Projects: 15 tasty treats to bake in November 2017 ...**  
www.trustedreviews.com › Opinion ▾ 이 페이지 번역하기  
2017. 11. 9. - Best Raspberry Pi Projects for November 2017: The tastiest Raspberry Pi 3 and Pi Zero projects to try baking today. From beginner builds to ...

**1043 Projects tagged with "raspberry pi" | Hackaday.io**  
https://hackaday.io/projects?tag=raspberry%20pi ▾ 이 페이지 번역하기  
1043 Projects tagged with "raspberry pi". Browse by Tag ... ZeroPhone - a Raspberry Pi smartphone · Arsenijs ... Project Jarvis - A.I Home Automation & Assistant.

**Raspberry Pi Projects - Google**

Lee 안전한 | https://www.google.co.kr/search?q=Raspberry+Pi+Projects&sourceid=chrome&ie=UTF8

OpenSource GoormEDU WebSites TechTips FutureWorks Entertainment C++17 Preparing Tomorrow

**Google** Raspberry Pi Projects

전체 이미지 동영상 뉴스 도서 더보기 설정 도구

저장된 이미지 보기 세이프서치 ▾





### 3rd Platforms

# ODROID (Made in Korea)

The screenshot shows a web browser displaying the Hardkernel ODROID website at [www.hardkernel.com/main/main.php](http://www.hardkernel.com/main/main.php). The page features a navigation bar with links for Products, Wiki, Magazine, Forum, Blog, Videos, Store, 커뮤니티 (Community), and 구매하기 (Purchase). The main content area displays three product cards:

- ODROID-XU4**: A blue single-board computer with a blue fan and various connectors.
- ODROID-C2**: A black single-board computer with a black heatsink and connectors.
- ODROID-C1+**: A blue single-board computer with a blue heatsink and connectors.

Each card includes a brief description and a "See more detail >>" link.

Product	Description	Operating System	Connectivity	Dimensions	Weight	Price
ODROID-XU4	Heterogeneous Multi-Processing (HMP) Octa Core Linux Computer. It is a new generation of computing device with more powerful, more energy-efficient hardware and a smaller form factor. By implementing the eMMC 5.0, USB 3.0 and Gigabit Ethernet interfaces, the ODROID-XU4 boasts amazing data transfer speeds, a feature that is increasingly required to support advanced processing power on ARM devices.	Ubuntu 15.04 or Android 4.4 Operating System	2 x USB3.0 Host, 1 x USB 2.0 Host, Gigabit Ethernet port	82 x 58 x 22 mm approx(including cooling fan)	65g(including heatsink)	US\$59.00
ODROID-C2	ARM 64bit 1.5Ghz quad core single board computer! The most advanced architecture for mobile devices and embedded 64-bit computing. Featuring 1.5Ghz cortex-A53 cores, high-performance 2Gbyte DDR3 SDRAM, Gigabit Ethernet and eMMC5.0 HS400, it shows marvellous performance. The ODROID-C2 also has a 40+7pin GPIO header to make a physical interface between the board and the outside world.	Ubuntu 16.04 or Android5.1 Operating System	4 x USB2.0 Host, 1 x USB 2.0 OTG, Gigabit Ethernet port	85 x 56 x 18 mm	65g(including heatsink)	US\$46.00
ODROID-C1+	The most powerful low-cost single board computer available! Featuring a quad-core Amlogic processor, advanced Mali GPU, and Gigabit Ethernet, it can function as a home theater set-top box, a general purpose computer for web browsing, gaming and socializing, a compact tool for college or office work, a prototyping device for hardware tinkering, a controller for home automation, a workstation for software development, and much more.	Ubuntu 15.04 or Android4.4 Operating System	4 x USB2.0 Host, 1 x USB 2.0 OTG, Gigabit Ethernet port	85 x 56 x 18 mm	65g(including heatsink)	US\$35.00



# 3rd Platforms

## BeagleBone

The screenshot shows a web browser window displaying the [beagleboard.org/bone](http://beagleboard.org/bone) page. The page features a navigation bar with links to Start, Discover Boards, Learn, Explore, and Collaborate. The main content area is titled "BeagleBone" and describes the platform as a high-performance, low-power solution for various applications. It highlights the BeagleBone Black, BeagleBone, SeeedStudio BeagleBone Green, and SanCloud BeagleBone Enhanced boards. Each board is shown with a thumbnail image and a brief description. A "Purchase" button with a shopping cart icon and a dropdown menu for selecting a distributor are also present.

BeagleBoard.org - bone

beagleboard.org/bone

Start ▾ Discover Boards ▾ Learn ▾ Explore ▾ Collaborate ▾

BeagleBoard.org › bone

## BeagleBone

Explore the high-performance, low-power world with the tiny, affordable, open-source Beagles. Putting Android, Ubuntu and other Linux flavors at your fingertips, the Beagle family revs as high as 1GHz with flexible peripheral interfaces and a proven ecosystem of feature-rich "Cape" plug-in boards.

**BeagleBone Black**



The benchmark for open hardware Linux computers.

Get the workhorse 1GHz AM335x ARM® Cortex-A8 processor, expanded peripherals, low power consumption and open source software compatibility.

[Learn more »](#)

**Purchase** 

Select a distributor to buy ▾

**BeagleBone**



This previous generation Beagle is powered by a 720MHz ARM Cortex-A8 processor and includes power management, microSD card with Linux, built-in FTDI-based serial / JTAG and on-chip Ethernet.

[Learn more »](#)

**SeeedStudio BeagleBone Green**



Seeed's Grove connectors make IoT developers life simpler large family of Grove sensors and drivers.

[Learn more »](#)

**SanCloud BeagleBone Enhanced**



With a Gigabyte of RAM, gigabit Ethernet, extra USB host ports and a WiFi/Bluetooth option, make this the ultimate Bone.

[Learn more »](#)

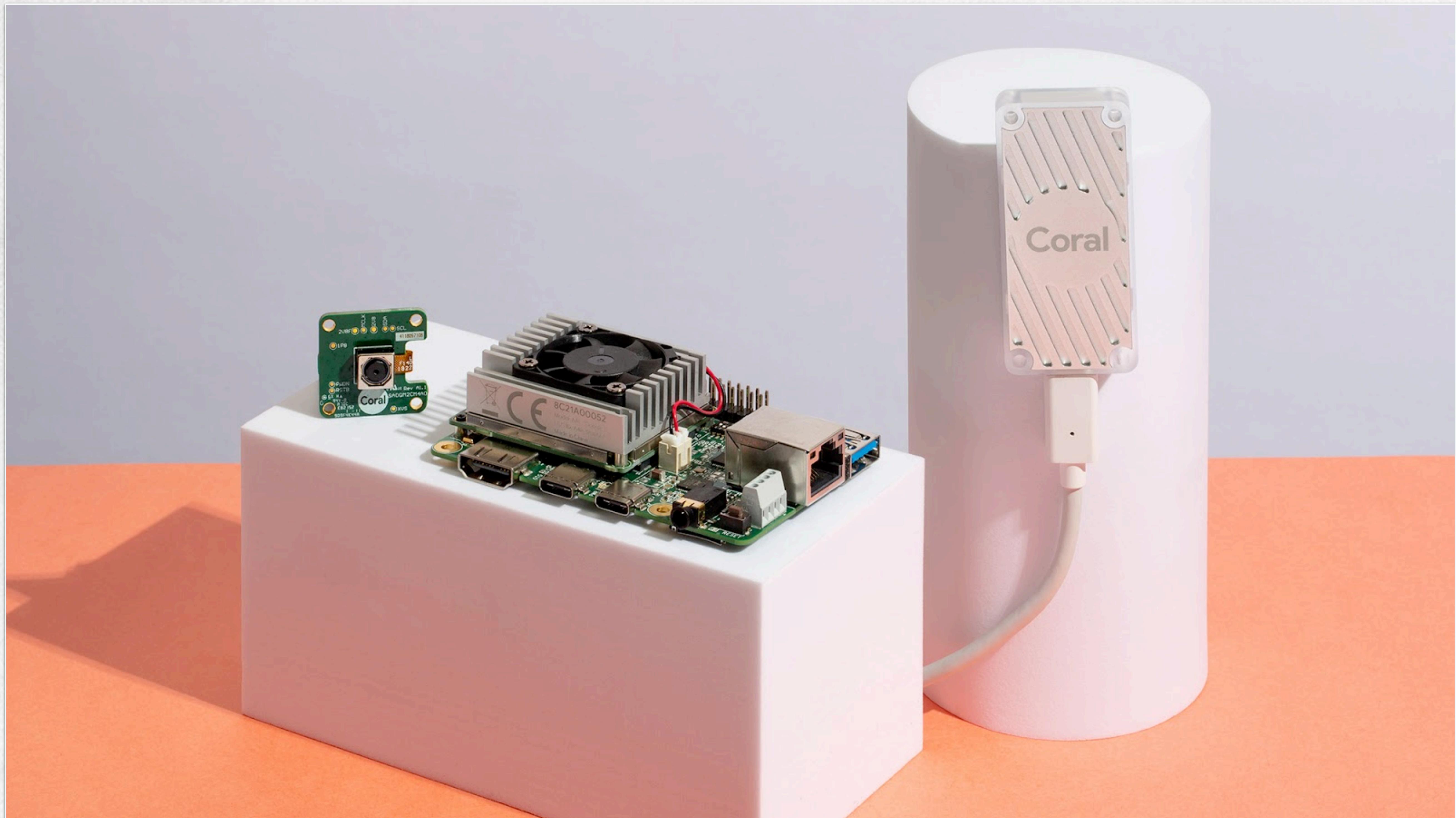
# 3rd Platforms

## INTEL NUC



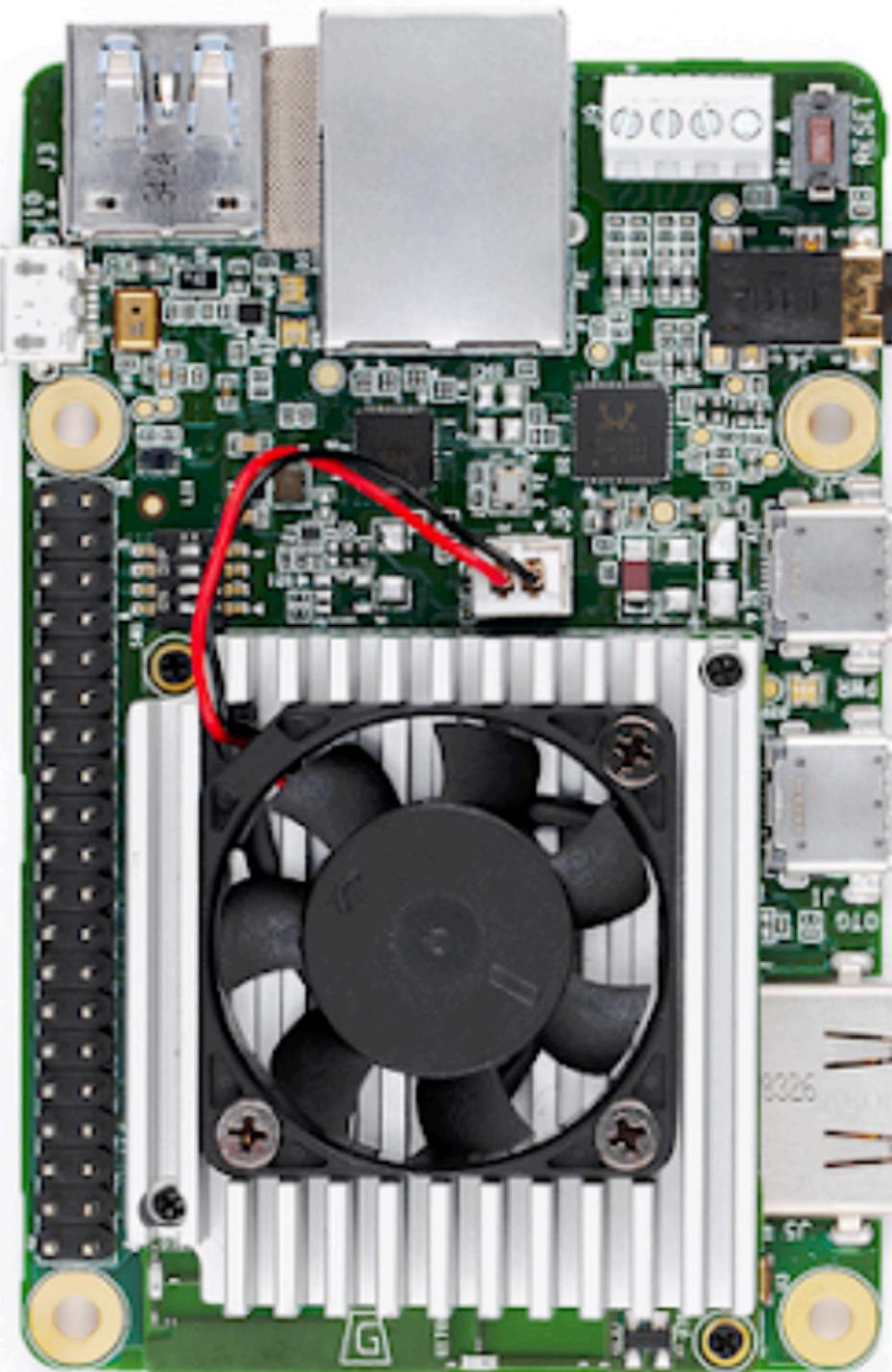
# 3rd Platforms

## Google Coral



## 3rd Platforms

# Google Coral (Visit <https://coral.withgoogle.com/>)



### Dev Board

A single-board computer with a removable system-on-module (SOM) featuring the Edge TPU.

- Supported OS: Mendel Linux (derivative of Debian)
- Supported Framework: [TensorFlow Lite](#)
- Languages: Python (C++ coming soon)
- [Datasheet](#)

[Learn More](#)

### USB Accelerator

A USB accessory featuring the Edge TPU that brings ML inferencing to existing systems.

- Supported OS: Debian Linux
- Compatible with Raspberry Pi boards
- Supported Framework: [TensorFlow Lite](#)
- [Datasheet](#)

[Learn More](#)

### 3rd Platforms

## NVIDIA Jetson

(Visit <https://www.nvidia.com/ko-kr/autonomous-machines/embedded-systems/>)

The screenshot shows the top navigation bar with the NVIDIA logo, a search icon, and a user profile icon. Below it, the main menu includes 'AUTONOMOUS MACHINES' (highlighted in white), '업계' (Industry), '제품' (Products), '개발자용' (Developer), and '구매하기' (Buy). The main content area features a large image of three autonomous robots: a large four-wheeled rover-like vehicle in the foreground, a smaller green robot in the middle ground, and another smaller robot in the background. To the left of the image, there is Korean text: '차세대 오토노머스 머신을 위한 임베디드 시스템' (Embedded System for Next-Generation Autonomous Machines) and 'NVIDIA Jetson: 오토노머스를 위한 AI 플랫폼' (AI Platform for Autonomous Machines). Below the image, a detailed description of the Jetson system's capabilities is provided in Korean.

NVIDIA® Jetson™ 시스템은 오토노머스 머신 소프트웨어를 보다 낮은 전력으로 더 빠르게 실행할 수 있는 높은 성능과 전력 효율을 제공합니다. 각각은 CPU, GPU, PMIC, DRAM 및 플래시를 포함하는 완전한 SOM(시스템 온 모듈)이므로 개발 시간과 비용을 절감할 수 있습니다. Jetson은 또한 확장이 가능합니다. 애플리케이션에 적합한 SOM을 선택하고 특정 니즈에 맞는 맞춤형 시스템을 구축하면 됩니다.

# Contents

- Introduction
- OSI 7 Layer
- Open Source Hardwares
- Single Board Computer (SBC)
- Linux

# Father of Linux

## Linus Torvalds



"Hello everybody out there... I'm doing a (free) operating system (just a hobby, won't be anything big and professional like gnu)...it probably will never support anything other than AT-hard disks, as that's all I have..."

August 1991

# Sustainable Ecosystem Linux Foundation



- Since 2000, the Linux Foundation (LF) is dedicated to **building sustainable ecosystems around open source projects** to accelerate technology development and commercial adoption.
- The largest **open source non-profit organization**, it works to promote, protect, and advance Linux and collaborative development and support the "greatest shared technology resources in history."

The screenshot shows the homepage of The Linux Foundation's website. At the top, there is a dark header bar with the 'THE LINUX FOUNDATION' logo on the left and navigation links for Projects, Membership, Events, Training, Resources, and About on the right, along with social media icons for Twitter, Facebook, LinkedIn, YouTube, and Google+.

The main content area features a large banner with a blue background and a network graph pattern. The text 'The Linux Foundation is Creating the Largest Shared Technology Investment in History' is displayed prominently. Below this, there are two blue call-to-action buttons: 'LEARN MORE ABOUT OUR PROJECTS' on the left and 'MEMBERSHIP BENEFITS' on the right. To the right of the banner, a sidebar contains the text 'Our members are developing billion-dollar markets and ensuring society continues to run on open source'. At the bottom of the page, a blue footer bar contains the text 'Open Source Guides for the Enterprise – Learn about best practices for running an open source program office or starting an open source project within your organization.'

# Sustainable Ecosystem Linux Foundation (@2018.12)



## Largest Shared Technology Investment

The Linux Foundation supports the creation of sustainable open source ecosystems by providing financial and intellectual resources, infrastructure, services, events, and training. Working together, The Linux Foundation and its projects form the most ambitious and successful investment in the creation of shared technology.



**16B USD**

Estimated development cost of the 100+ world's leading projects hosted at The Linux Foundation



**25,000**

Technologists attend our events annually, from more than 4,500 companies and 85 countries



**1 Million**

Open source professionals have enrolled in our free open source training courses



**10 / 10**

Largest cloud service providers are Linux Foundation project contributors and members

# Sustainable Ecosystem Linux Foundation (@2018.12)



The Organization of Choice for Building Sustainable Open Source Ecosystems



**Helping the Automotive Industry Innovate**  
AGL lets automakers and suppliers speed innovation and bring new features to market faster. Toyota adopted the AGL platform starting with the best selling car in the world, the 2018 Toyota Camry.

[LEARN MORE ABOUT AGL](#)



**Revolutionizing Networks for 2.5B Mobile Subscribers**  
Mobile service operators representing over 60% of the global market plan to use projects like ONAP and CORD to automate their networks and build innovative next-generation services.

[LEARN MORE ABOUT NETWORKING](#)



**Redefining the nature of trust on the Internet**  
Hyperledger is a global collaboration driven by more than 250 members from the finance, banking, Internet of Things, supply chain, manufacturing, and technology industries.

[LEARN MORE ABOUT HYPERLEDGER](#)



**Home to the World's Most Important Open Source Project**  
The Linux Foundation provides Linux creator Linus Torvalds and lead maintainer Greg Kroah-Hartman a neutral home where Linux kernel development can be protected and accelerated.

[LEARN MORE ABOUT LINUX](#)

# Sustainable Ecosystem Linux Foundation (@2022.08)

**We're helping open technology projects build world class open source software, communities and companies.**

**1.15 BILLION**

lines of code supporting the most business critical and groundbreaking innovations

**540K+**

developers from the most innovative companies building the future of open technology

**\$54.1B**

total shared value created from the collective contributions of the Linux Foundation community

**19K+**

contributing companies across industries bringing open technology into the enterprise

**100%**

of supercomputers use Linux

**~95%**

of public cloud providers use Kubernetes

**70%**

of global mobile subscribers use devices run on networks built using ONAP

**50%**

of global auto shipments supported by OEMs using Automotive Grade Linux

**50%**

of the Fortune Top 50 enterprise blockchain deployments use Hyperledger

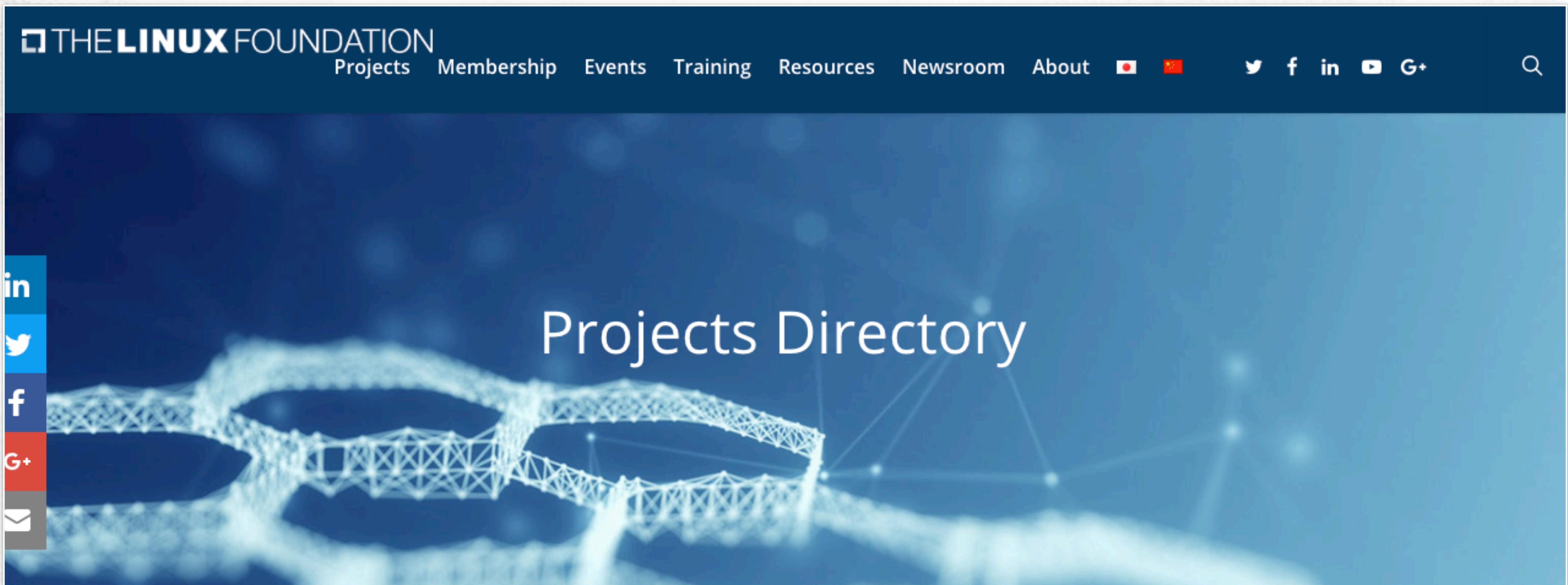
**1 Billion**

security certificates issued by the largest certificate authority in the world: Let's Encrypt

# Sustainable Ecosystem Projects in Linux Foundation



- More than 100+ Open Source Projects ( Let's VISIT NOW )
  - Not only OS itself
  - Cloud, Container, Security, Deep Learning, Networking, Services, ...



The screenshot shows the homepage of The Linux Foundation's Projects Directory. The header features the foundation's logo and navigation links for Projects, Membership, Events, Training, Resources, Newsroom, and About. It includes international flags for Japan and China, and social media links for Twitter, Facebook, LinkedIn, YouTube, and Google+. A search bar is also present. The main visual is a dark blue background with a glowing white network graph of interconnected nodes, overlaid with the text "Projects Directory". On the left, there is a vertical column of social sharing icons for LinkedIn, Twitter, Facebook, Google+, and Email.

Want to get involved in open source? Explore our project directory. The Linux Foundation is home to 100+ open source projects, including some of the most influential and fastest-growing communities across cloud, networking, embedded and IoT, blockchain and data, platforms, security, and open source project management. We welcome your participation.

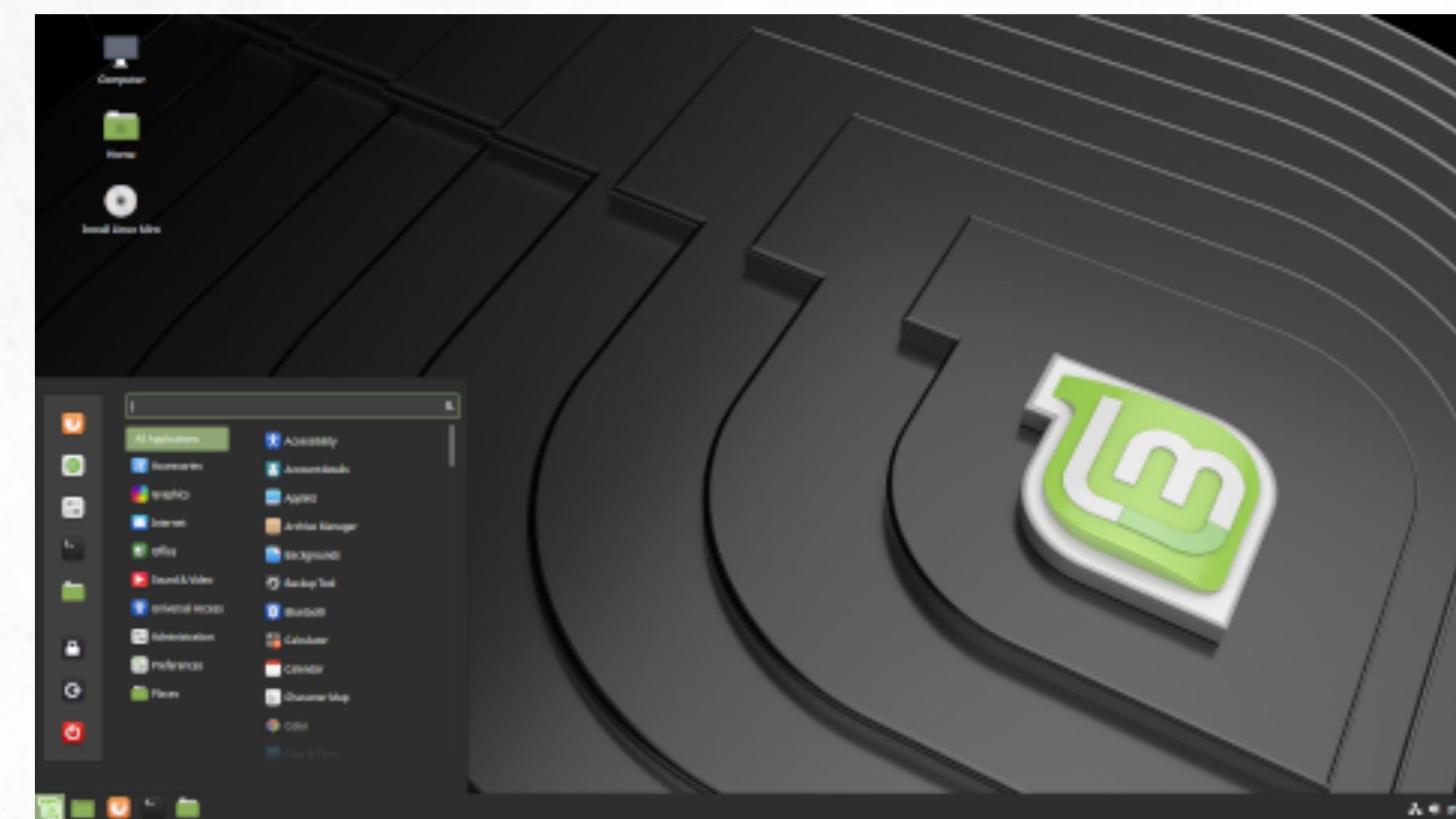
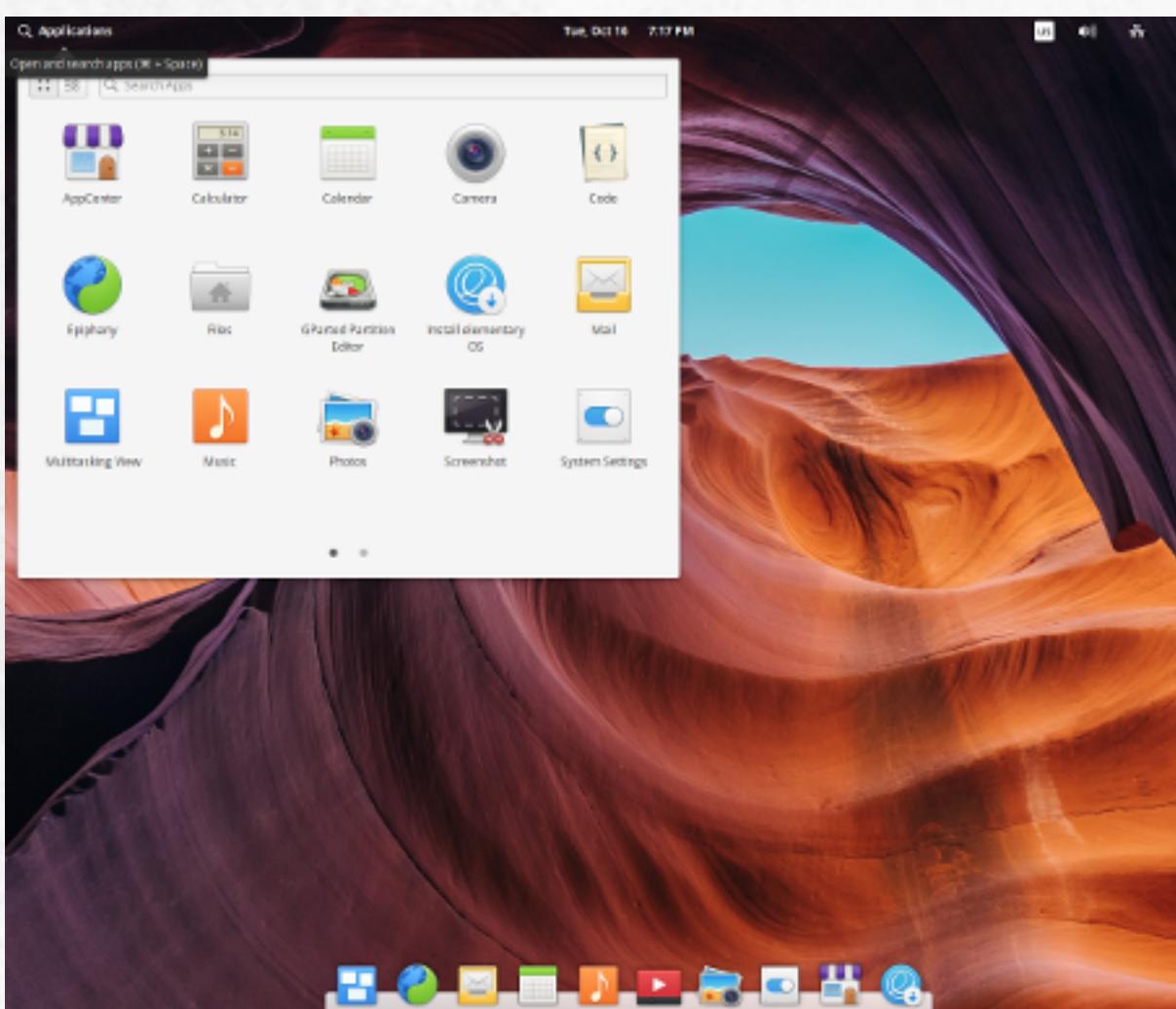
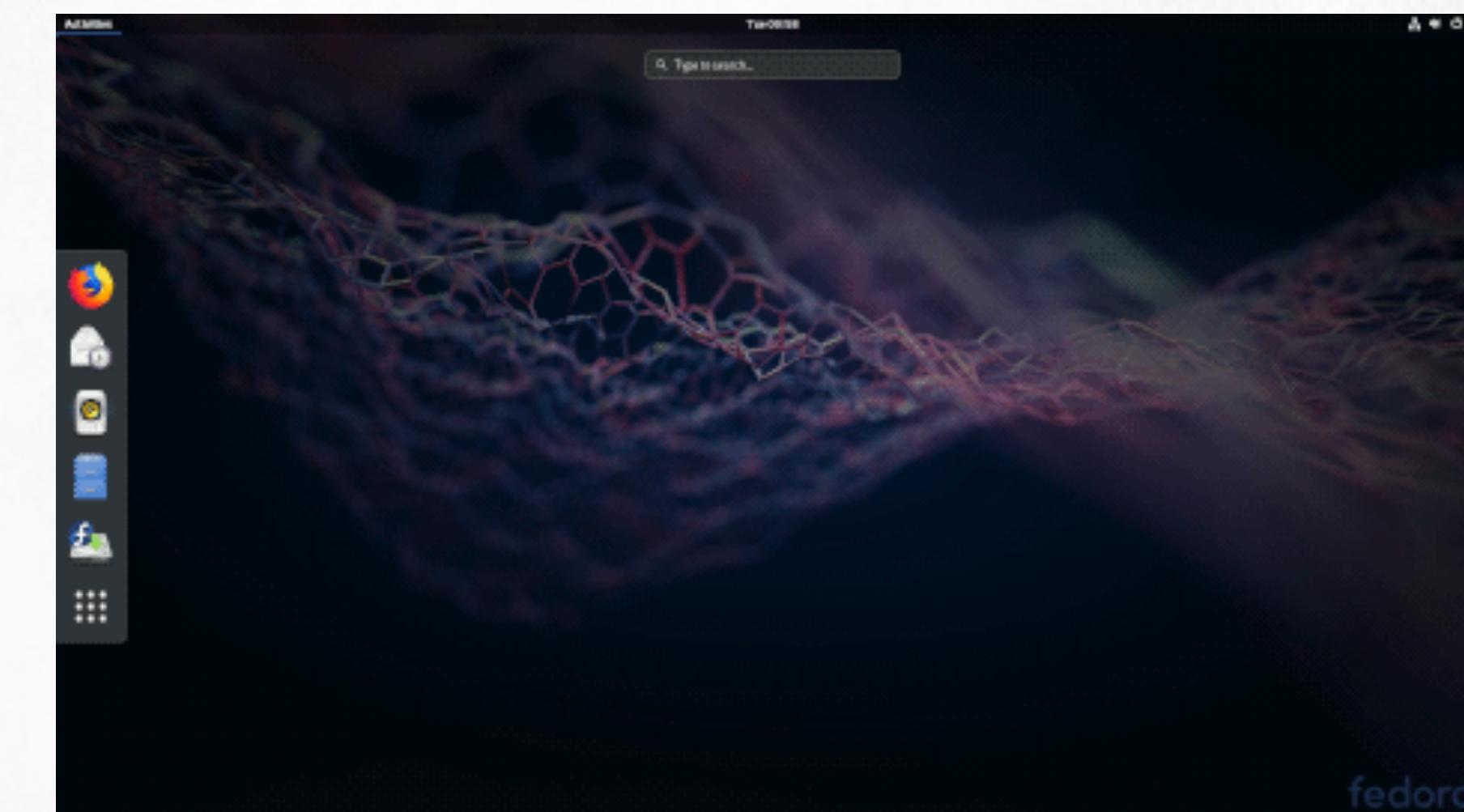
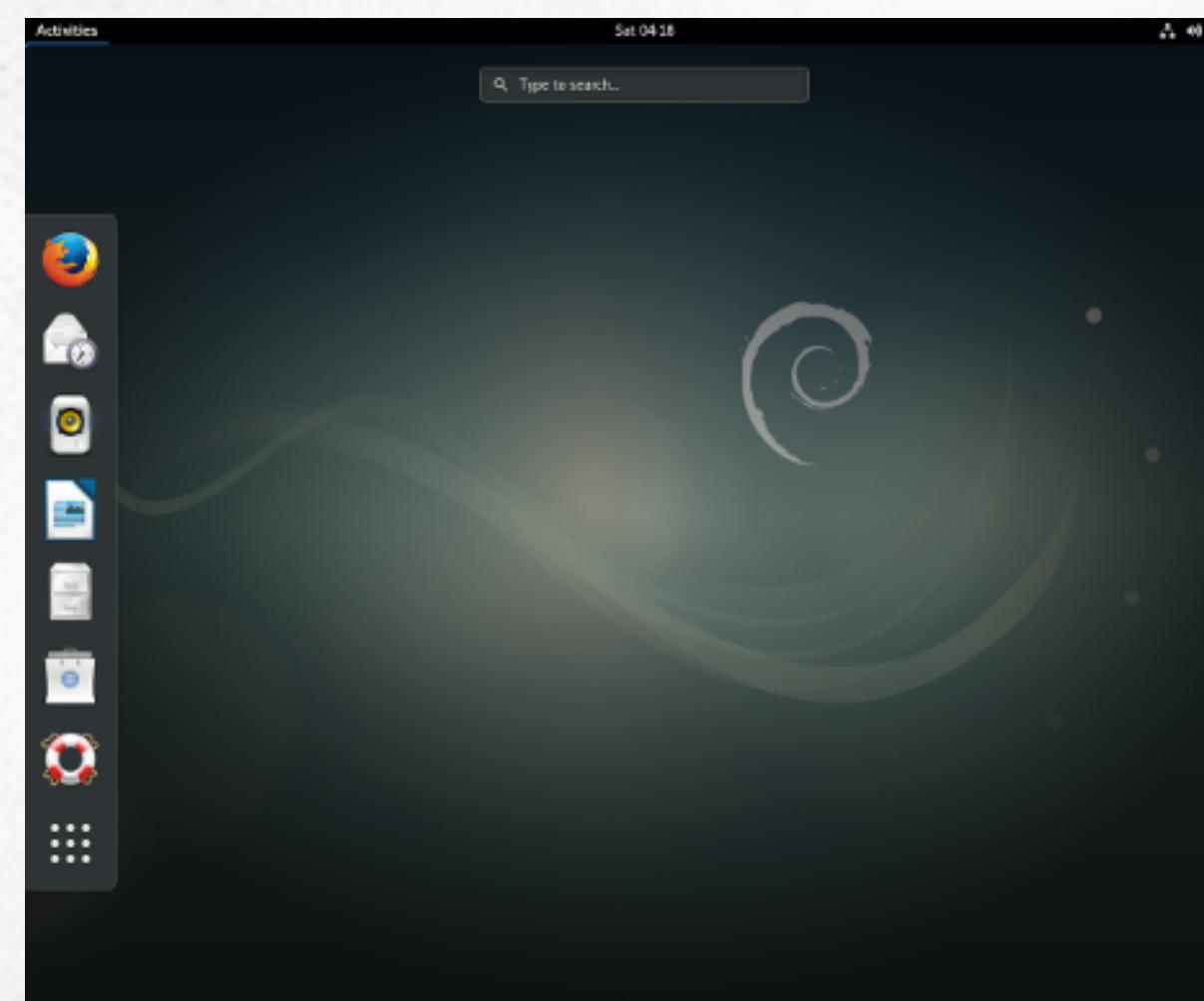
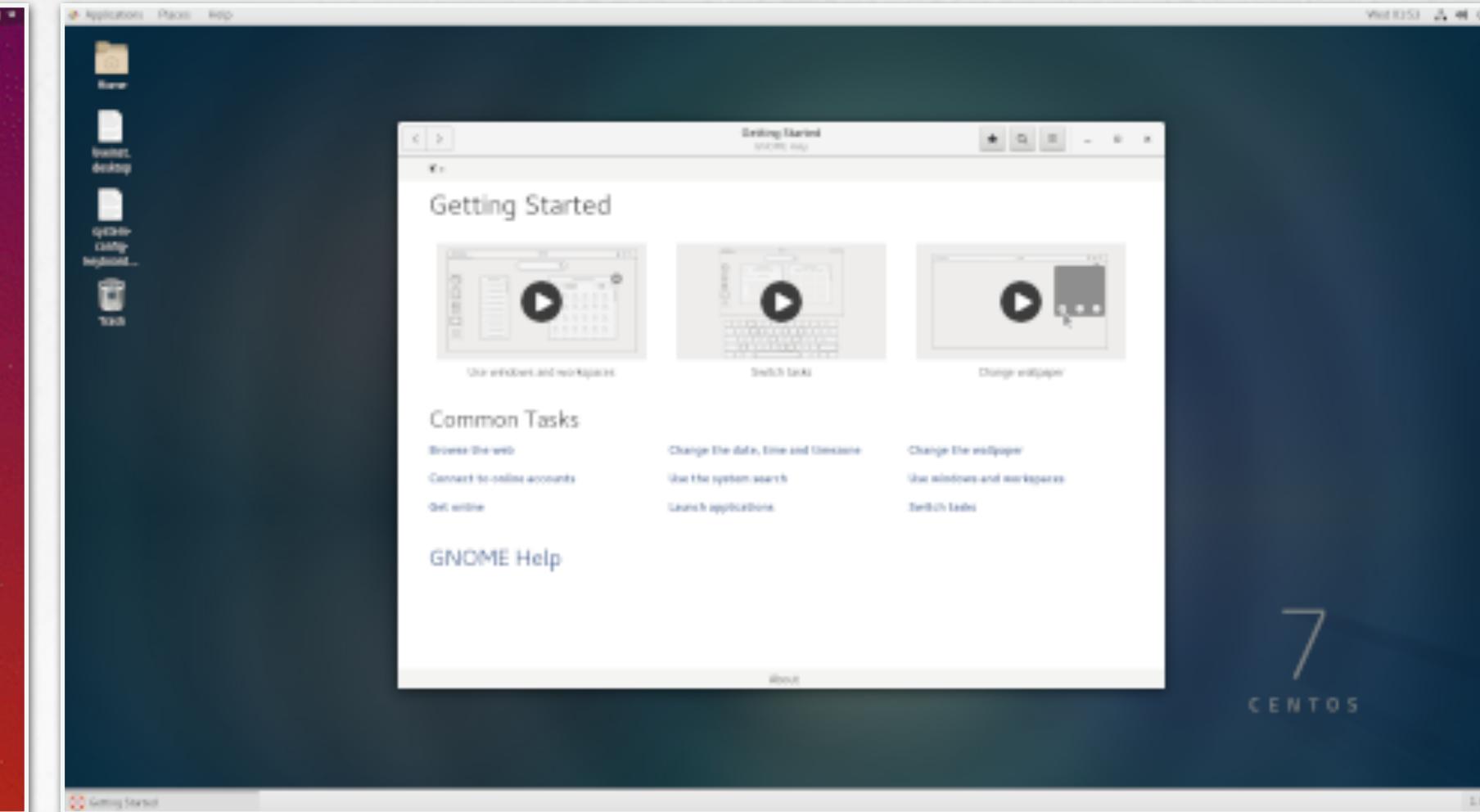
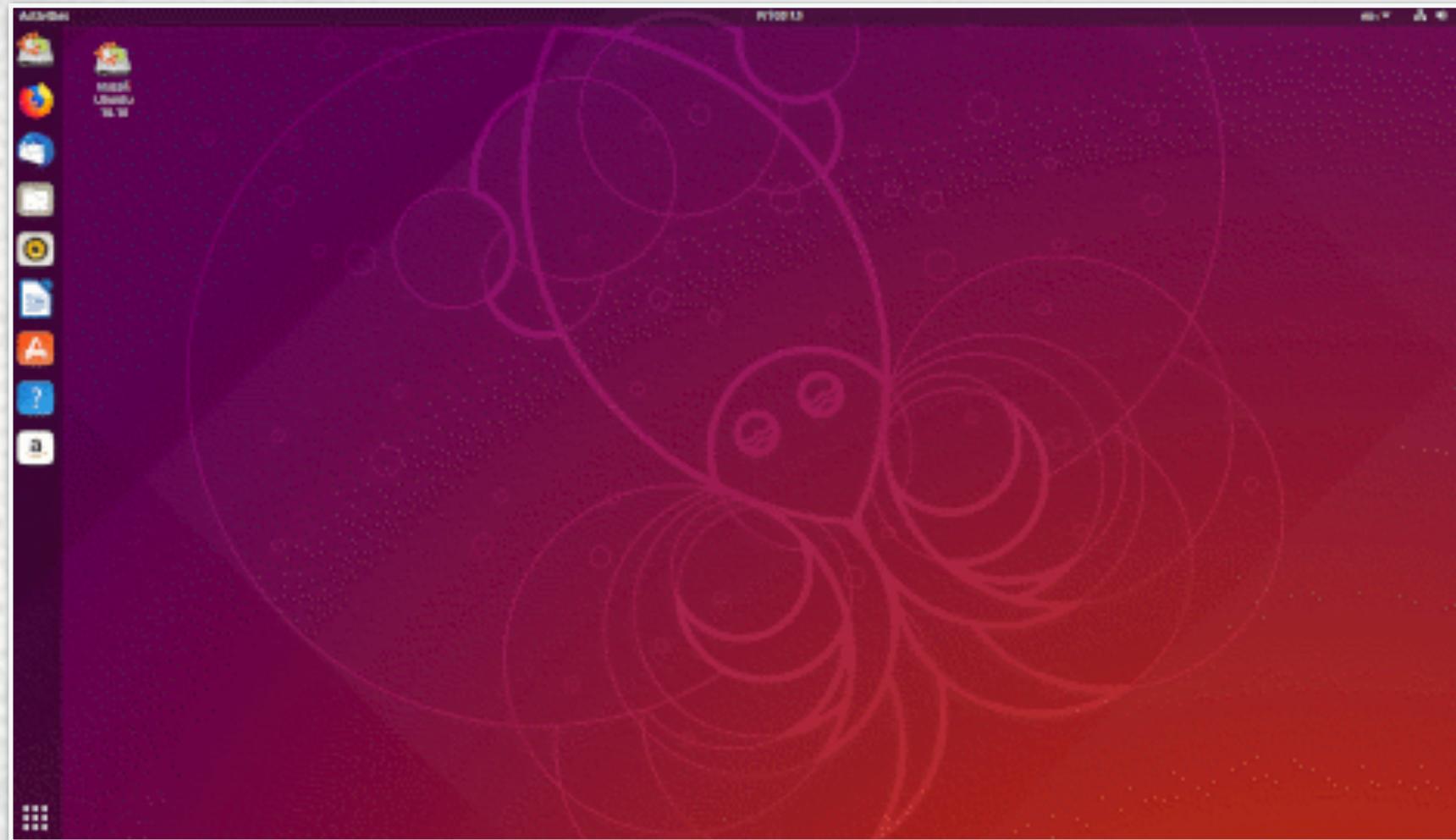
Distro?

# Linux Variants



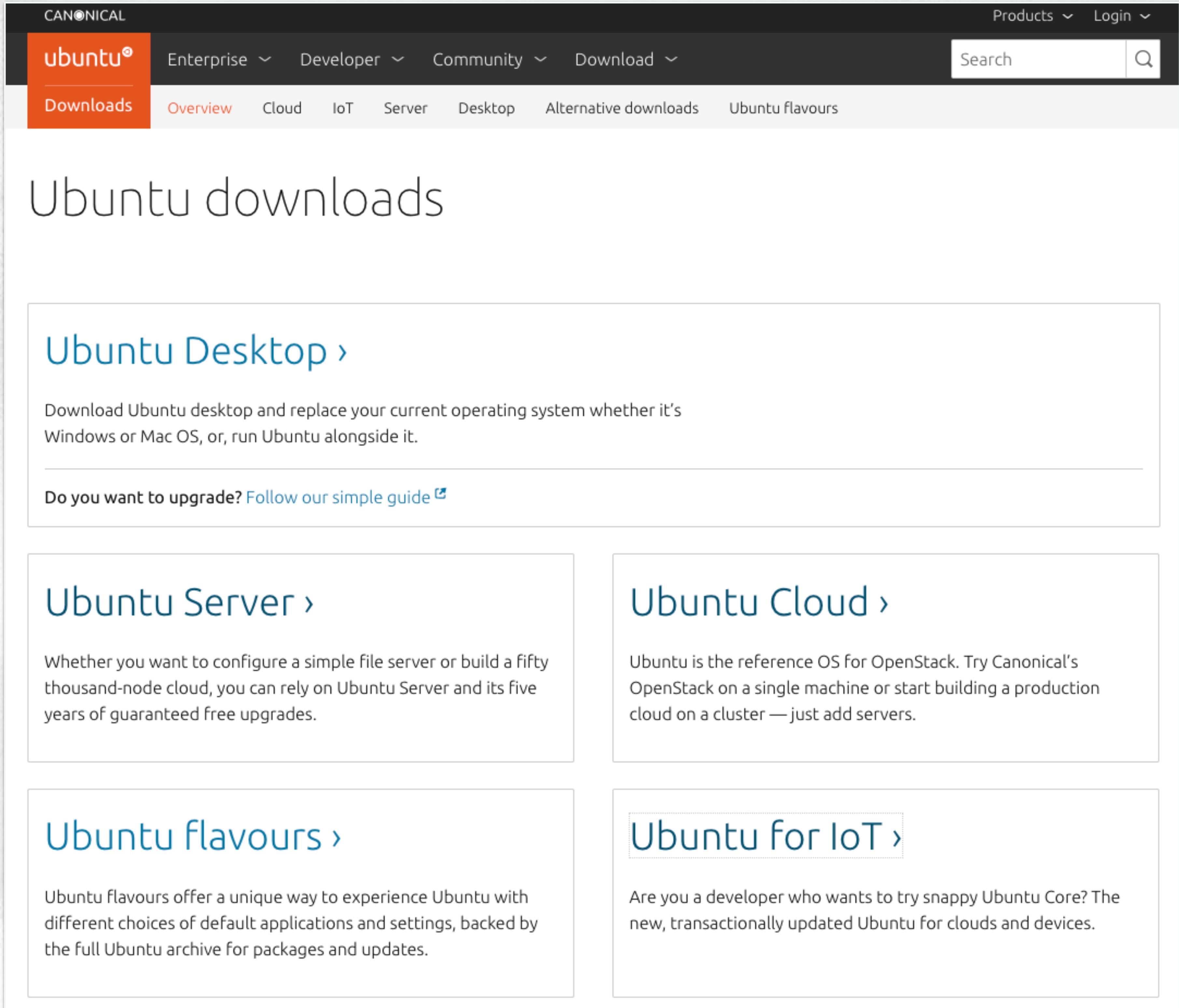
# Linux Variants

## Linux for Desktop



# Linux Variants

# Ubuntu Linux for Server, Cloud & IoT



The screenshot shows the Canonical Ubuntu Downloads page. The header includes the Canonical logo, a navigation bar with links for Enterprise, Developer, Community, Download, and a search bar. Below the header, there's a secondary navigation bar with links for Downloads, Overview, Cloud, IoT, Server, Desktop, Alternative downloads, and Ubuntu flavours. The main content area features five sections: 'Ubuntu desktop', 'Ubuntu Server', 'Ubuntu flavours', 'Ubuntu Cloud', and 'Ubuntu for IoT'.

**Ubuntu desktop ›**  
Download Ubuntu desktop and replace your current operating system whether it's Windows or Mac OS, or, run Ubuntu alongside it.  
Do you want to upgrade? [Follow our simple guide ↗](#)

**Ubuntu Server ›**  
Whether you want to configure a simple file server or build a fifty thousand-node cloud, you can rely on Ubuntu Server and its five years of guaranteed free upgrades.

**Ubuntu flavours ›**  
Ubuntu flavours offer a unique way to experience Ubuntu with different choices of default applications and settings, backed by the full Ubuntu archive for packages and updates.

**Ubuntu Cloud ›**  
Ubuntu is the reference OS for OpenStack. Try Canonical's OpenStack on a single machine or start building a production cloud on a cluster — just add servers.

**Ubuntu for IoT ›**  
Are you a developer who wants to try snappy Ubuntu Core? The new, transactionally updated Ubuntu for clouds and devices.

## Ubuntu Linux for Lightweight & Special Purpose

### Ubuntu flavours

Ubuntu flavours offer a unique way to experience Ubuntu, each with their own choice of default applications and settings. Ubuntu flavours are backed by the full Ubuntu archive for packages and updates.



#### Kubuntu ↗

Kubuntu offers the KDE Plasma Workspace experience, a good-looking system for home and office use.



#### Lubuntu ↗

Lubuntu is a light, fast, and modern Ubuntu flavor using LXQt as its default desktop environment. Lubuntu used to use LXDE as its default desktop environment.



#### Ubuntu Budgie ↗

Ubuntu Budgie provides the Budgie desktop environment which focuses on simplicity and elegance. It provides a traditional desktop metaphor based interface utilising a customisable panel based menu driven system.



#### Ubuntu Kylin ↗

The Ubuntu Kylin project is tuned to the needs of Chinese users, providing a thoughtful and elegant Chinese experience out-of-the-box.



#### Ubuntu MATE ↗

Ubuntu MATE expresses the simplicity of a classic desktop environment. Ubuntu MATE is the continuation of the GNOME 2 desktop which was Ubuntu's default desktop until October 2010.



#### Ubuntu Studio ↗

Ubuntu Studio is a multimedia content creation flavor of Ubuntu, aimed at the audio, video and graphic enthusiast or professional.



#### Xubuntu ↗

Xubuntu is an elegant and easy to use operating system. Xubuntu comes with Xfce, which is a stable, light and configurable desktop environment.

# Linux Variants

## Linux for Smartphone, Wear, Tablet, TV, Auto

The screenshot shows the Android Source website interface. At the top, there is a navigation bar with links: Source, Set up, Design, Secure, Develop, Configure, and 참조 (References). To the right of the navigation bar are a search bar with a magnifying glass icon and the text "검색" (Search), a "코드로 이동" (Go to code) button, and a "로그인" (Login) button. Below the navigation bar, a green header bar contains the text "Android unites the world! Use the open source Android operating system to power your device." and a "GET SOURCE" button.

**9 interfaces and architecture**

Port the latest Android platform using simple HIDL interfaces to create compelling devices for your customers.

[LEARN TREBLE](#)

**Securing Android is essential**

Find out how the Android security program works and learn how to implement the latest features.

[IMPLEMENT SECURITY](#)

**Design compatible devices**

Offer a consistent experience with other Android-powered devices and get the ability to include more apps.

[TEST DEVICES](#)



# Linux as Main Machine

## Still, why Linux?

The screenshot shows a ZDNet article page. At the top, the ZDNet logo is on the left, followed by a search icon. The navigation bar includes links for CLOUD, INNOVATION, CXO, HARDWARE, MORE, NEWSLETTERS, ALL WRITERS, and a user profile icon. A red banner at the top of the main content area reads "MUST READ: AT&T 5G: Behind the scenes in Texas as the new mobile network goes live". The main headline is "Linux totally dominates supercomputers". Below it, a sub-headline states "It finally happened. Today, all 500 of the world's top 500 supercomputers are running Linux." The author's photo and name, Steven J. Vaughan-Nichols, are listed, along with the publication date, November 14, 2017, and the topic, Innovation. A social sharing bar below the author information includes counts for 35 comments, 20 Facebook likes, LinkedIn, Twitter, Email, and a bell icon. To the right of the main article, there is a sidebar for the North American International Auto Show 2019 Detroit Cobo Center, featuring a button to "LET YOUR MIND WANDER." and a link to www.naias.com. Another sidebar on the right is titled "THE ROAD TO AUTONOMOUS DRIVING" and features a button to "Download our Trend Paper". At the bottom of the page, there is a section titled "MORE FROM STEVEN J. VAUGHAN-NICHOLS" with links to other articles: "Enterprise Software" and "Linux Mint 19.1: The better-than-ever Linux desktop" (with a thumbnail of a Linux desktop interface), and "Government: US IRS Linux move delayed by" (with a thumbnail of a computer monitor displaying a Linux terminal window).

# Software is eating up the world\*

August 20, 2011



\* Marc Andreessen  
in Wall Street Journal

5



**Mark Andreessen**  
founder of Netscape,  
renowned Venture Capitalist  
Andreessen-Horowitz

**Software is eating the world, in all sectors**

In the future every company will become a **software** company

# Linux as Networker's OS

## Linux Eating the Networking Industry

### Open Source Networking Landscape Linux Foundation hosts 9/10 Top projects

Services

Application Layer / App Server

Network Data Analytics

Orchestration, Management, Policy

Cloud & Virtual Management

Network Control

Operating Systems

IO Abstraction & Data Path

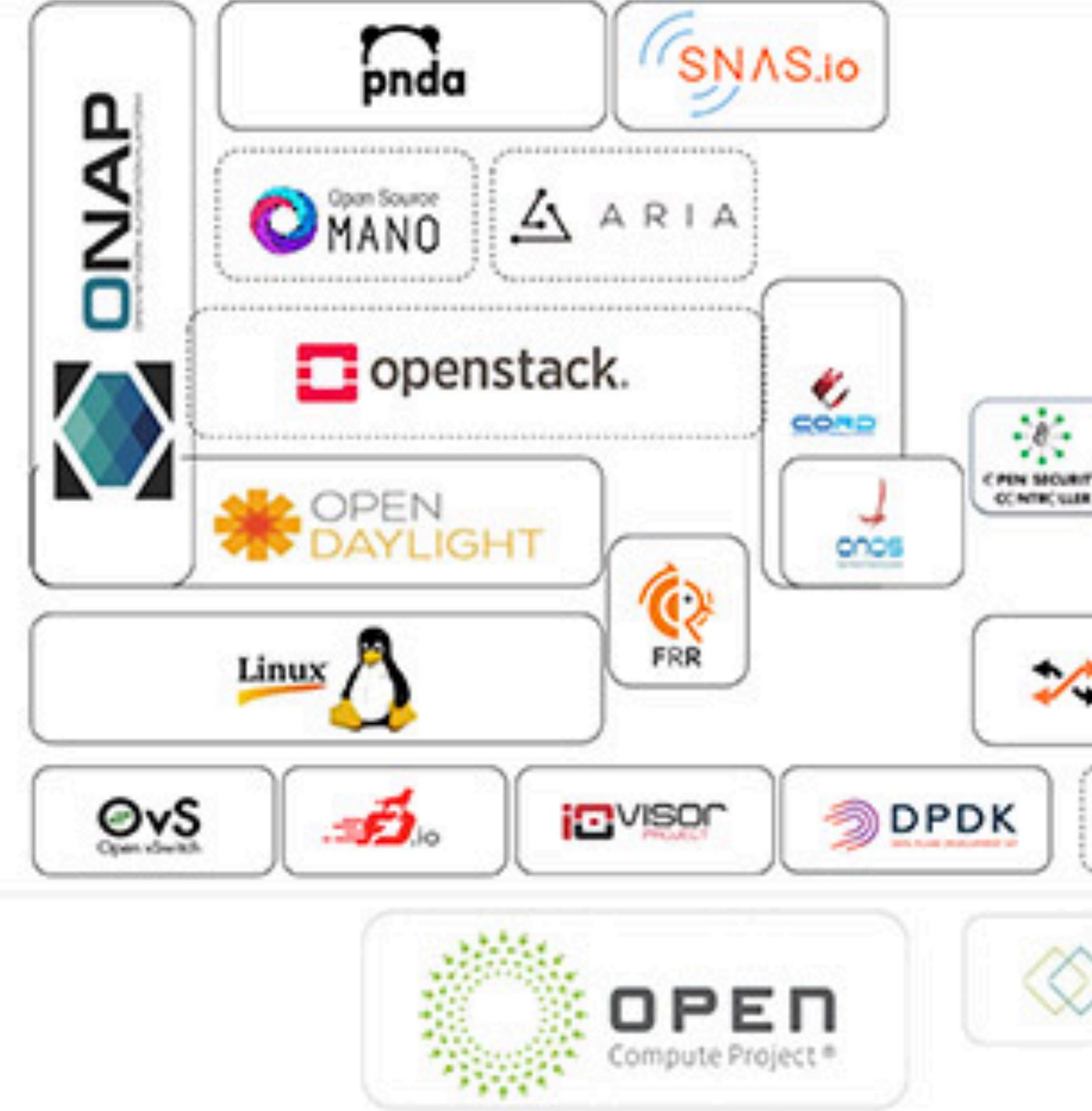
Disaggregated Hardware

THE LINUX FOUNDATION

OPNFV System Integration & Test Automation

CI/CD

Product, Services & Workloads



Linux Foundation Hosted

Outside Linux Foundation

CLOUD FOUNDRY

Standards

tmforum



MEF NIST

OIF



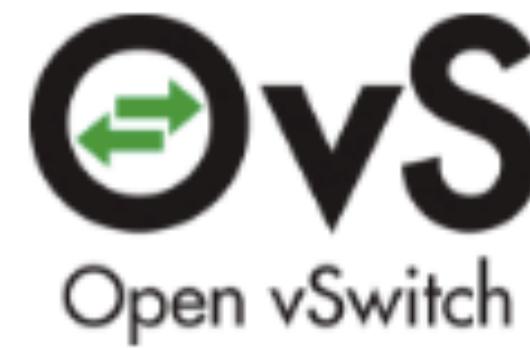
IEEE 802 CableLabs

3GPP OIF

Automation of Network + Infrastructure + Cloud + Apps + IOT

# Linux as Networker's OS

## Linux Eating the Networking Industry



CLOUD FOUNDRY





# Thank you