

Embedded System Programming

An introduction, Applications and Career Opportunities

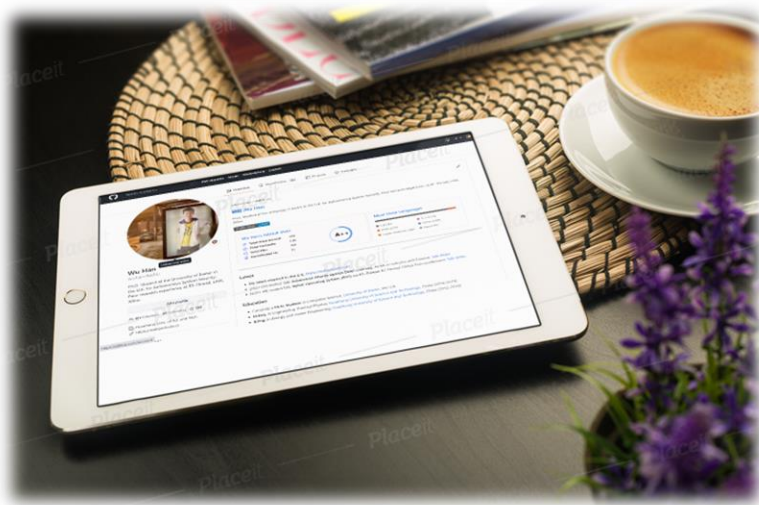


Han Wu

Ph.D. Student at the University of Exeter, the U.K.

[Is Deep Learning secure for Robots?](#)

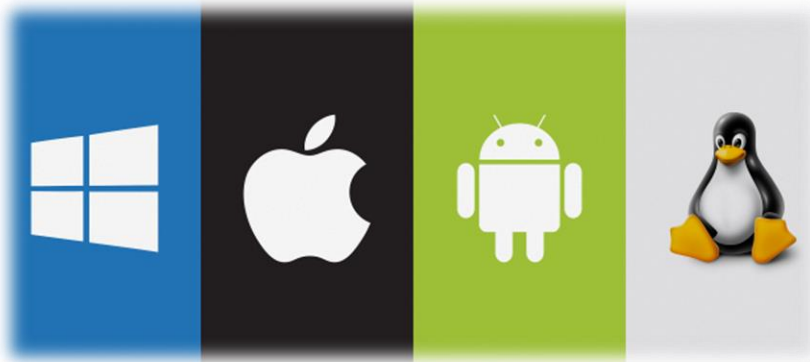
What is Embedded Programming?



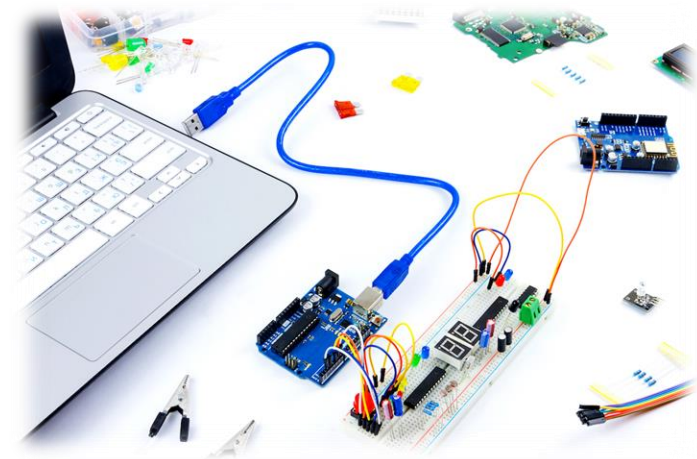
Web Development



App Development



OS Development



We program **Hardware**

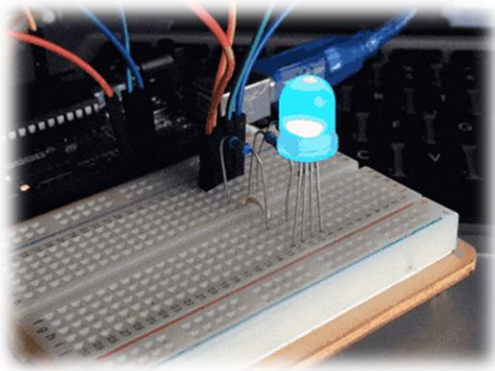
What is Embedded Programming?



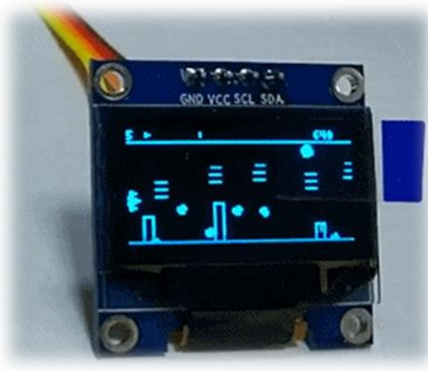
- Achieve a given task set with constrained resources
- Real-time performance



Microcontroller (MCU) & Peripherals



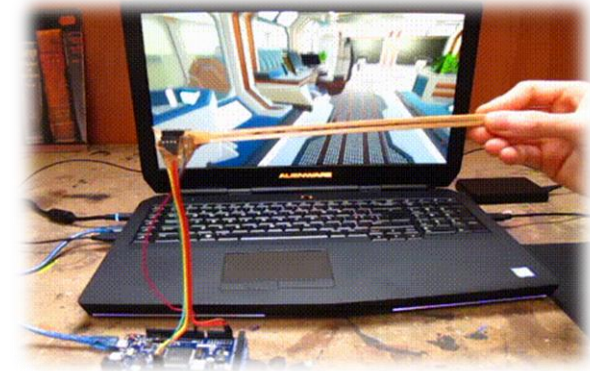
LED



OLED Display



DC Motor



Accelerometer Gyroscope


Is Deep Learning Secure for Robots?

Deep Learning on Embedded Systems


Is Deep Learning Secure for Robots

Adversarial Detection


White-Box attacks against end-to-end detection systems.



Input Image



Object Detection



Perturbation

Clear Patch

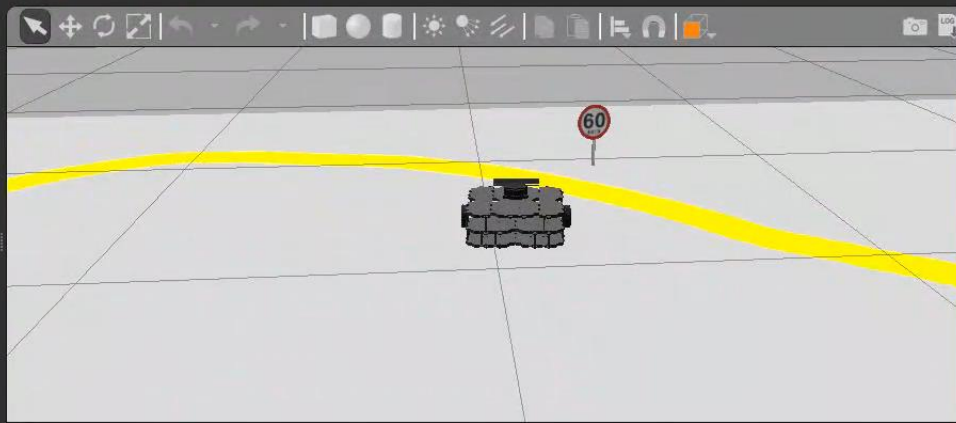
Fix patch

Generating adversarial patch is as easy as drag and drop.

```
wuhanstudio@amil-pc: ~  
process[rosout-1]: started with pid [16726] | detection/client$ ./client  
started core service [/rosout] | Listening on port 3333  
^B^[[C  
5e547e830cc1bb7', 'topic': '/fix_patch', 'type': 'std_msgs/Int32']  
  
60=61.77%  
fps: 25.64  
60=61.78%  
fps: 23.26  
60=61.77%  
fps: 20.41  
60=61.78%  
fps: 29.41  
  
q/z : increase/decrease max speeds by 10%  
w/x : increase/decrease only linear speed by 10%  
e/c : increase/decrease only angular speed by 10%  
  
CTRL-C to quit  
  
currently: speed 0.5 turn 1.0  
  
[1] 0.python* "amil-pc" 22:40 16-Sep-21
```

VcXsrv Server - Display LAPTOP-7EE9C57F:0.0

File Edit Camera View Window Help



Real Time Factor: 0.97 Sim Time: 00:00:46:17.198 Real Time: 00:00:40:51.060 Iterations: 2366895 FPS: 2.28

Is Deep Learning Secure for Robots

Adversarial Detection

White-Box attacks against end-to-end detection systems.

Input Image

Adversarial Image

Perturbation

Fix patch

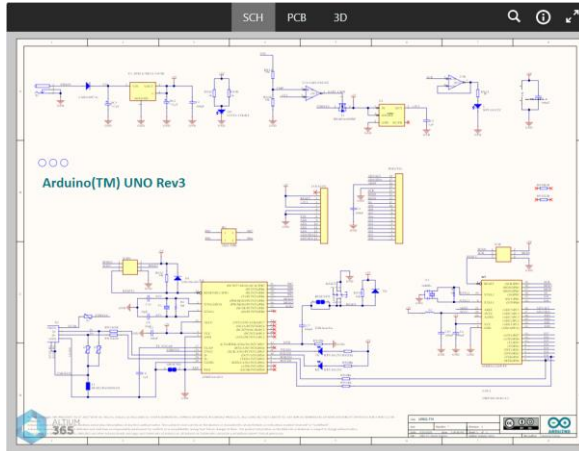
Generating adversarial patch is as easy as drag and drop.

```
wuhanstudio@ubuntu: ~  
2021-08-09 17:07:44+0100 [-] [INFO] [1628525264.876195]: [Client 3] Subscribed to /adv_img  
Listening on port 3333  
-----  
242 0.010690732206861243  
149.80276639344262 -10.197233606557  
376 0.010197233606557375  
150.633521271143 -9.366478728857004  
0.009366478728857005  
151.01688843398156 -8.9831115660184  
37 0.0089831111566018437  
-----  
84  
False  
[2] Stop  
85  
-----  
[0] 0:python3* "ubuntu" 17:50 09-Aug-21
```

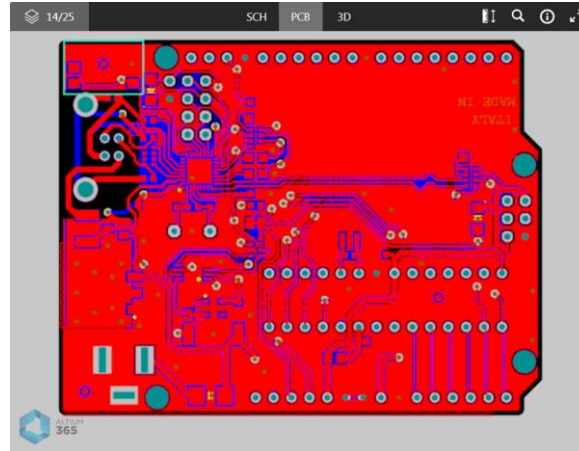
Android Webcam Server

How do we program hardware?

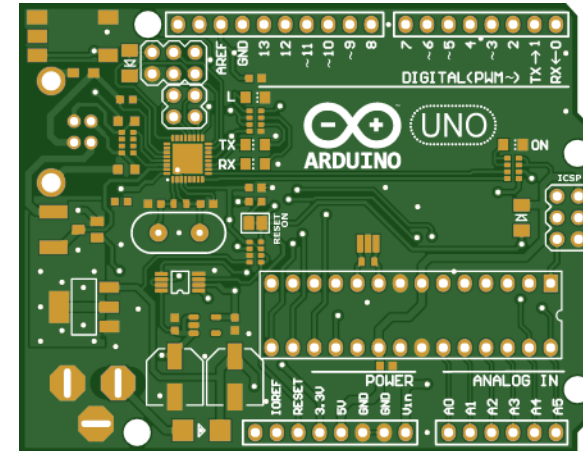
Circuits Design



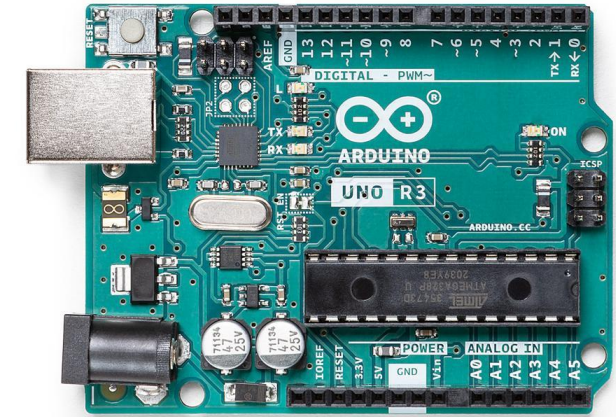
Schematic



PCB Routing



PCB Manufacturing



Development Board

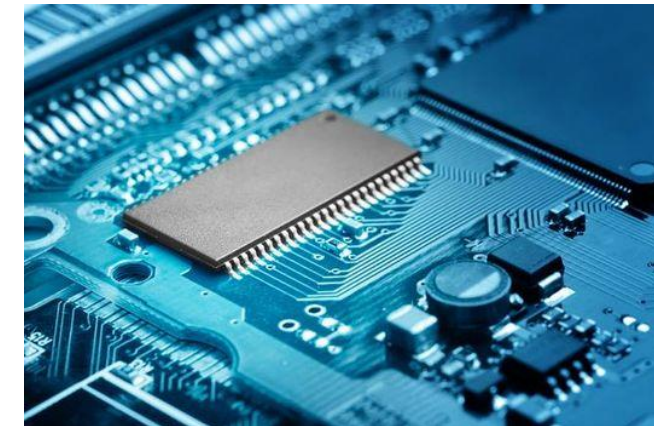
Embedded Programming

```
sketch_dec07a | Arduino 1.8.3
File Edit Sketch Tools Help
sketch_dec07a
void setup() {
  // put your setup code here, to run once:
}
void loop() {
  // put your main code here, to run repeatedly:
}
Arduino/Genuino Uno on COM3
```

① BareMetal



② RT-Thread RTOS

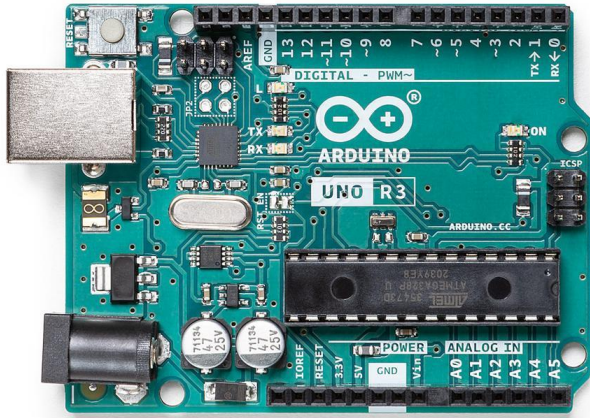


③ Future Career

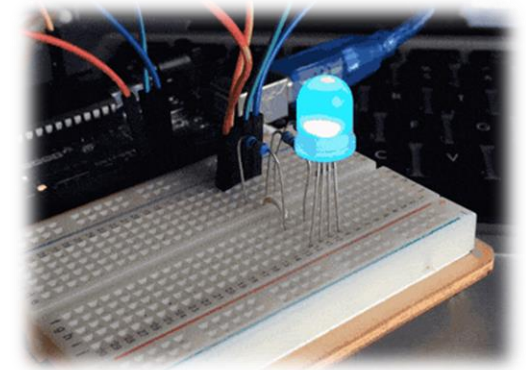
BareMetal Programming

How do we program hardware ?

BareMetal Programming



MCU Development Board

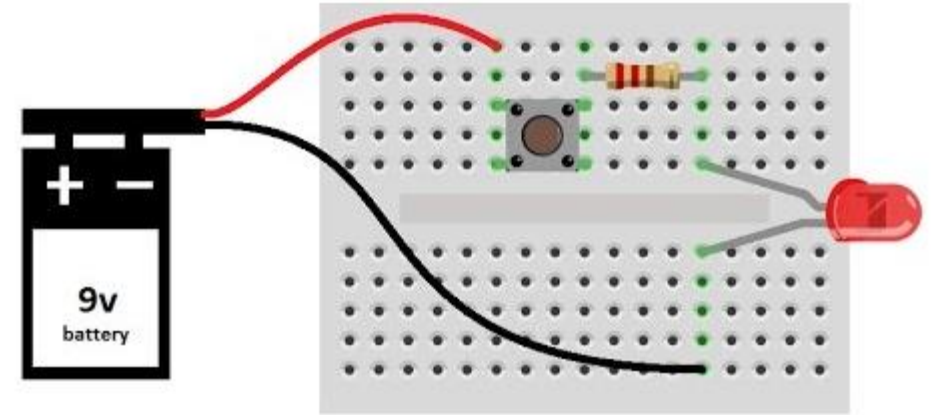
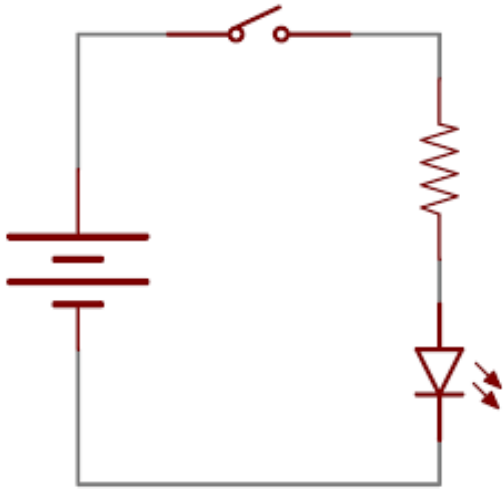


LED 101

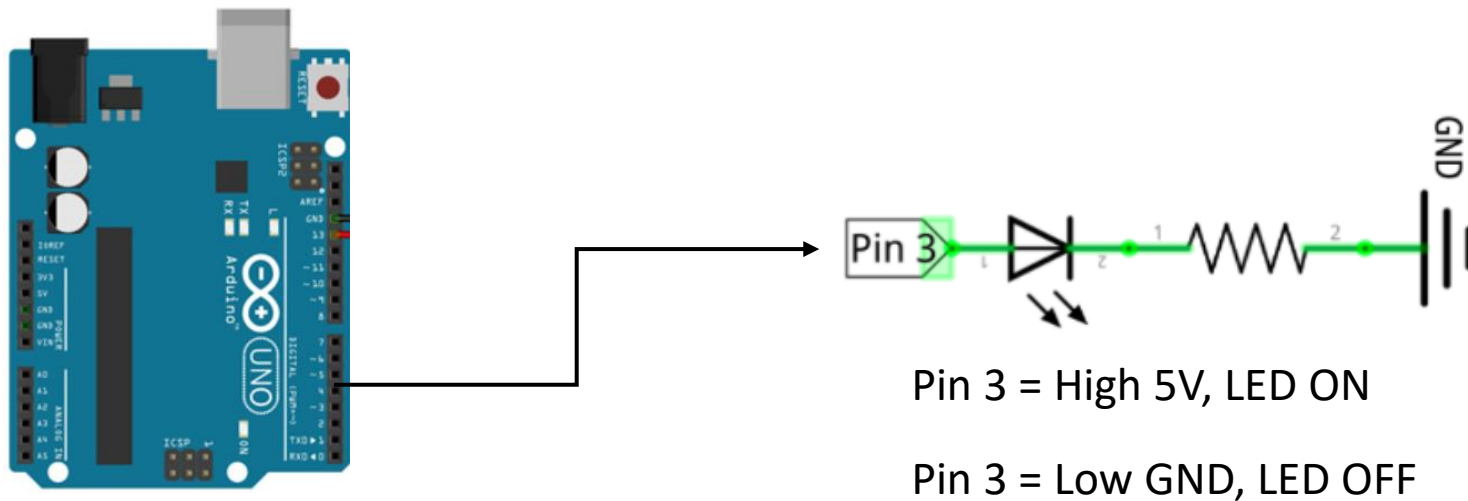
```
sketch_dec07a | Arduino 1.8.3
File Edit Sketch Tools Help
sketch_dec07a
void setup() {
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}
Arduino/Genuino Uno on COM3
```

How to write a C program to control the LED?

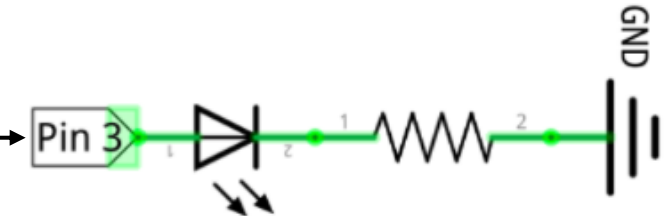
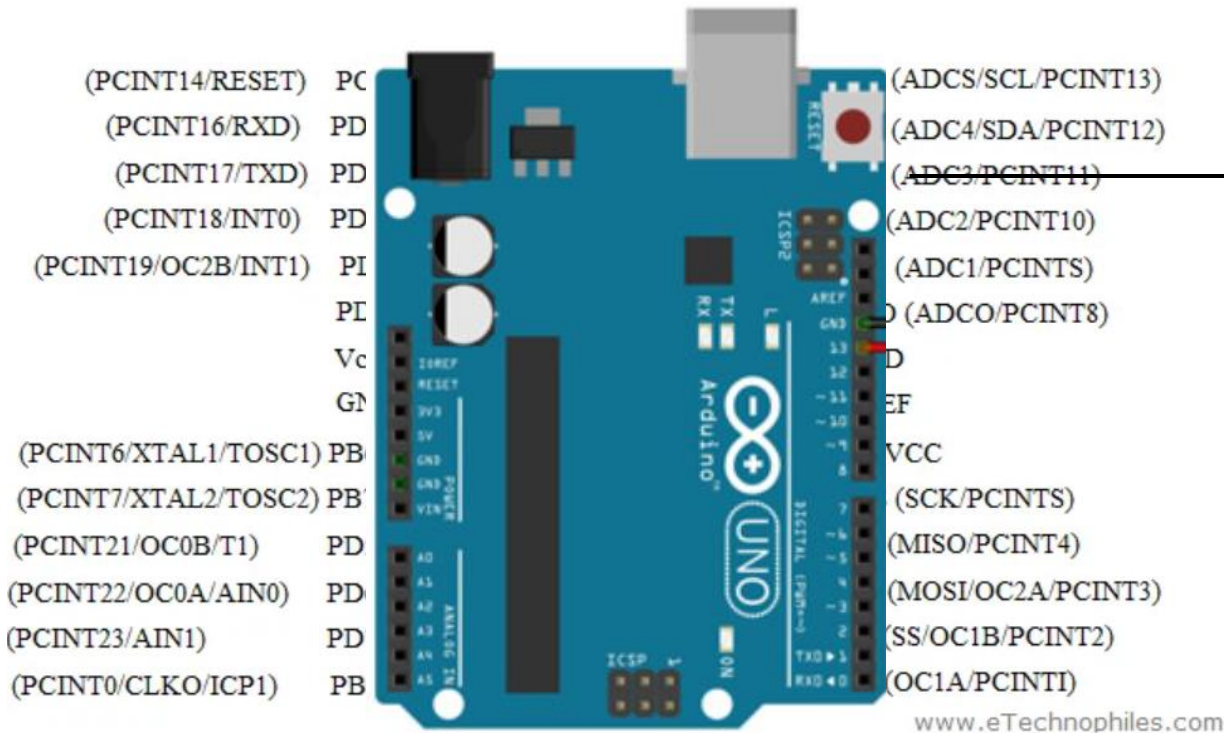
BareMetal Programming



Control the LED using a Switch / Button



BareMetal Programming



Pin 3 = High 5V, LED ON
 Pin 3 = Low GND, LED OFF

13.4.8 PORTD – The Port D Data Register

Bit	7	6	5	4	3	2	1	0	
0x0B (0x2B)	PORTD7	PORTD6	PORTD5	PORTD4	PORTD3	PORTD2	PORTD1	PORTD0	PORTD
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

[ATmega328p Datasheet](#)

C Language (SDK)

```
digitalWrite(3, HIGH); // LED ON
digitalWrite(3, LOW); // LED OFF
```

Assembly Language

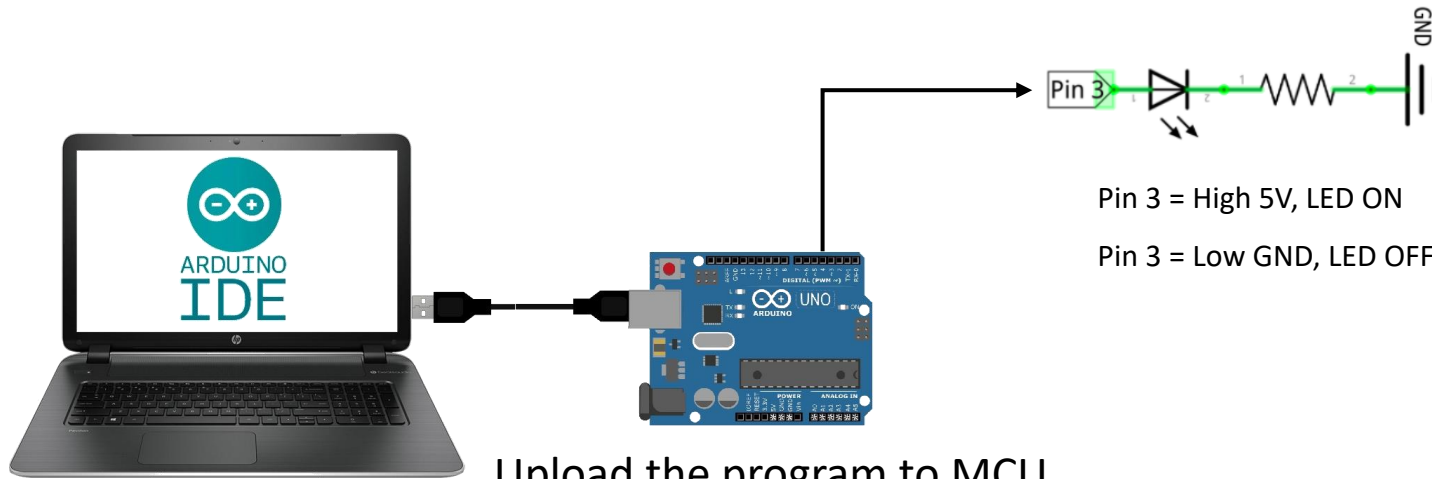
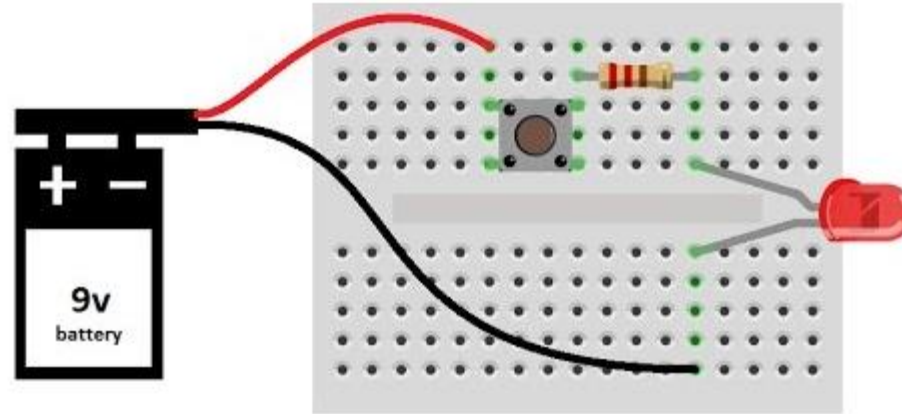
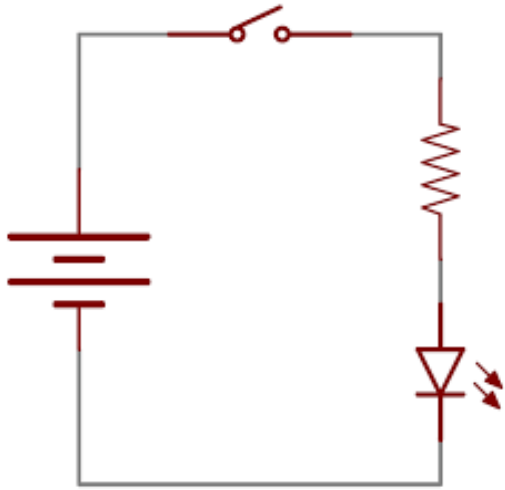
```
SBI PORTD, PIND3 ; 1, HIGH, LED ON
CBI PORTD, PIND3 ; 0, LOW, LED OFF
```

Register (Configurations in MCU)

```
PORTD3 = 1, HIGH, LED ON
PORTD3 = 0, GND, LED OFF
```

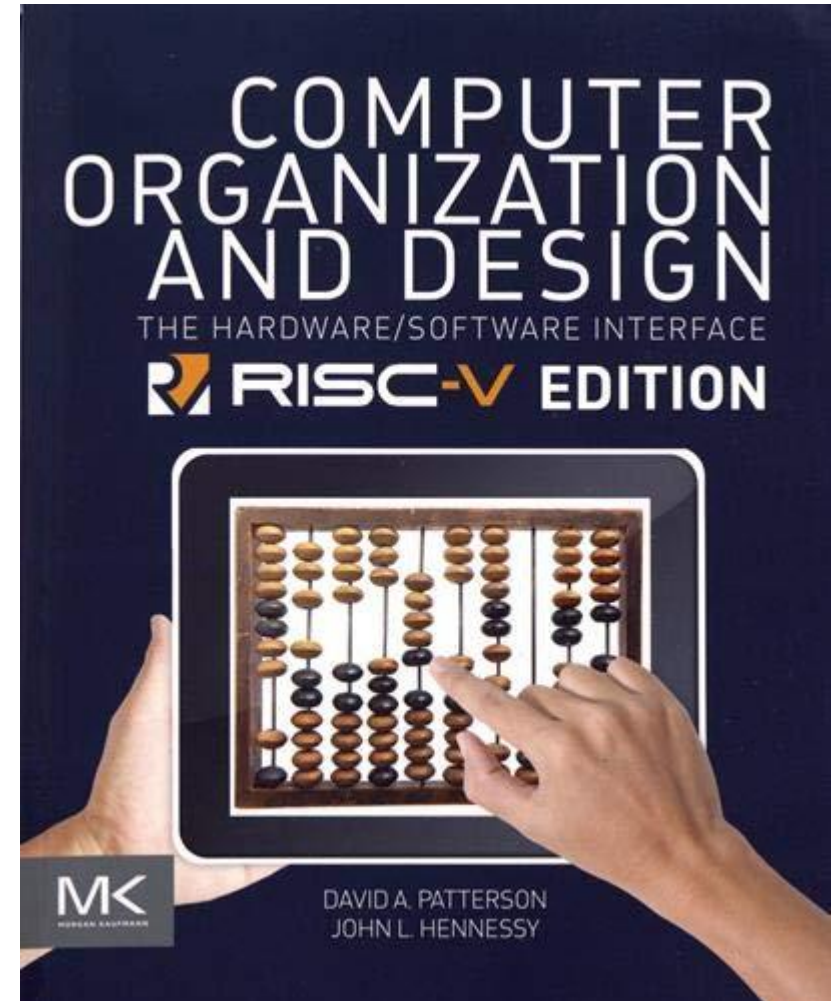
LED 101 Demo

BareMetal Programming



Write a C program

Upload the program to MCU



Introduction to RT-Thread (RTOS)

From BareMetal to Real-Time Operating System

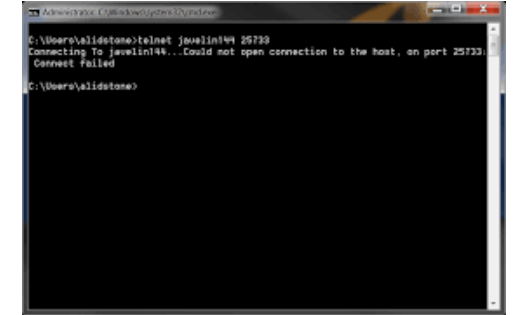
Why do we need RTOS?



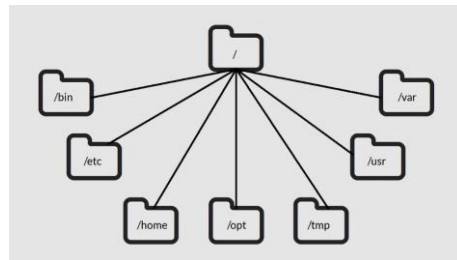
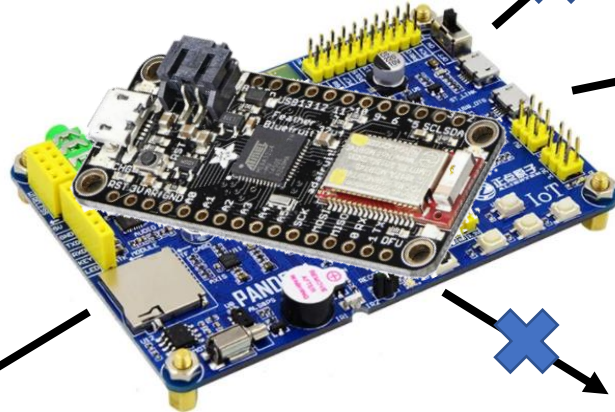
Web Server



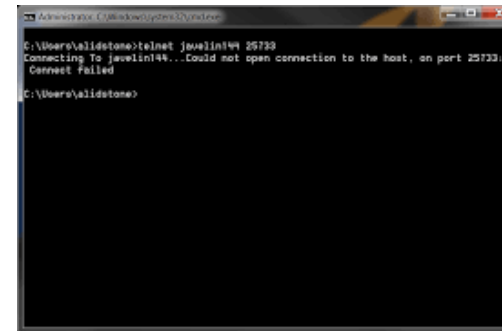
Wireless Network



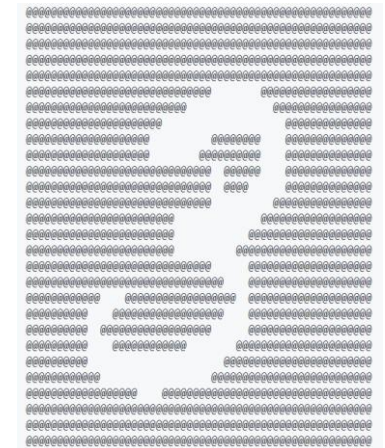
Telnet Server



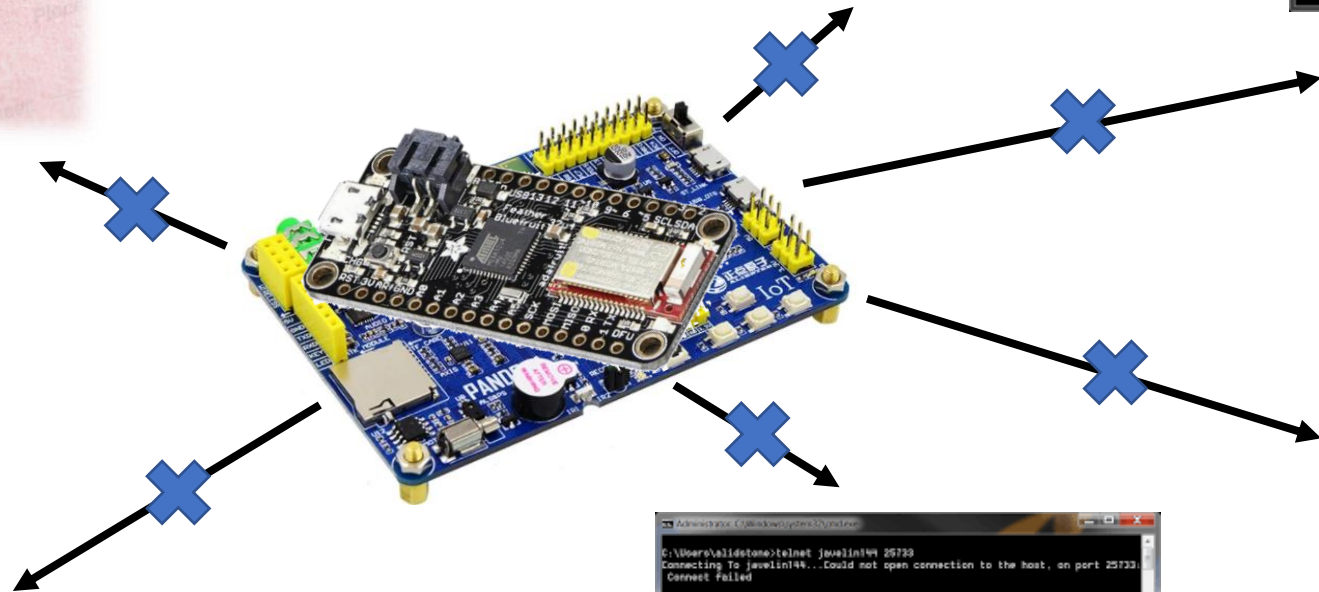
File System



Serial Terminal



Deep Learning



Why do we need RTOS?

Operating System manages things for you

Your Application

Real-Time Operating System (RTOS)

File System

Networking

POSIX

Shell

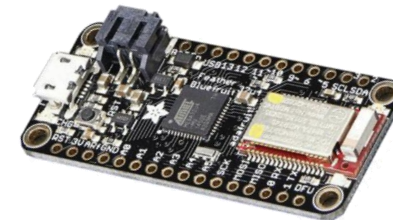
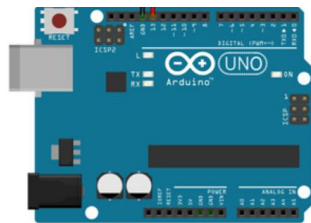
Hardware Abstraction Layer (HAL)

AVR

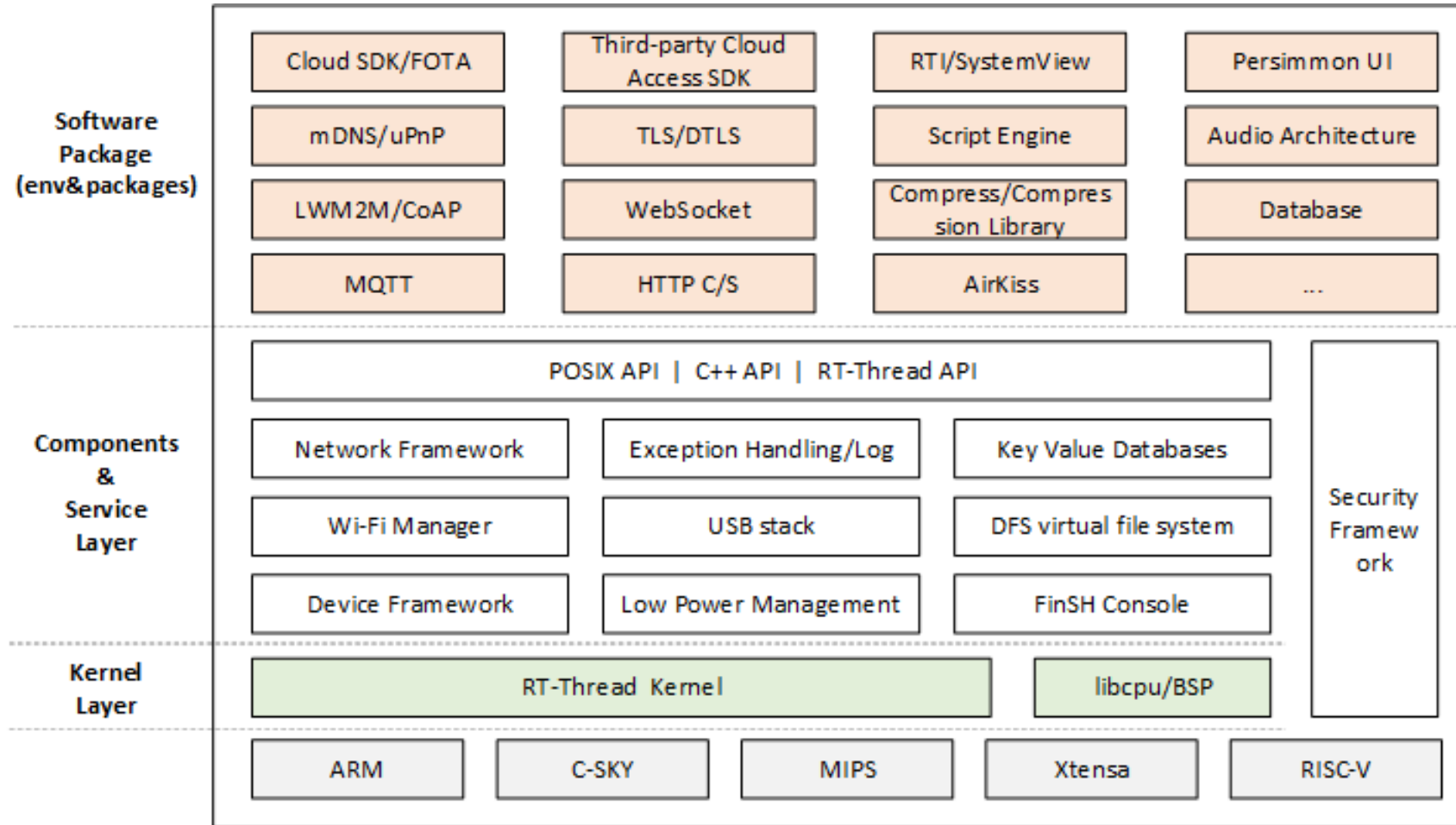
STM32

ESP32

RISC-V



Open Source RTOS



FreeRTOS



RT-Thread



Zephyr



Nuttx

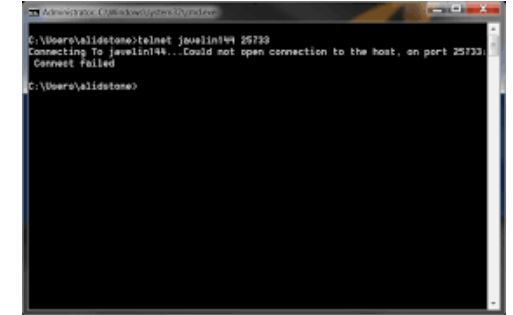
Why do we need RTOS?



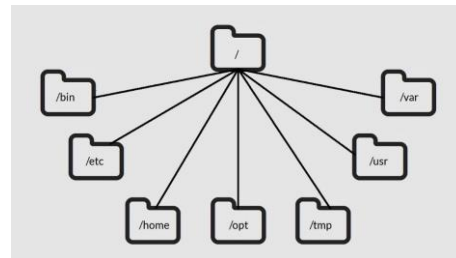
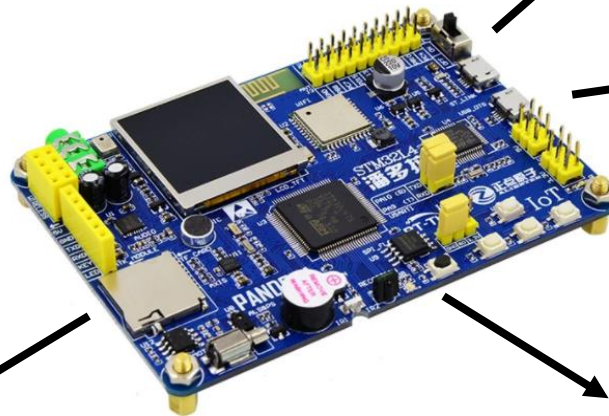
Software Packages
(Web Server)



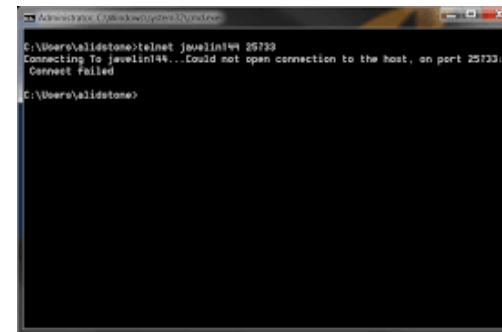
Networking



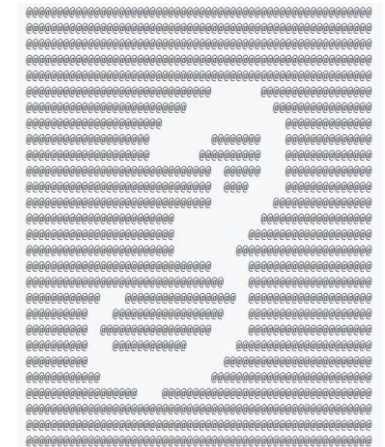
Software Packages
(Telnet)



File System

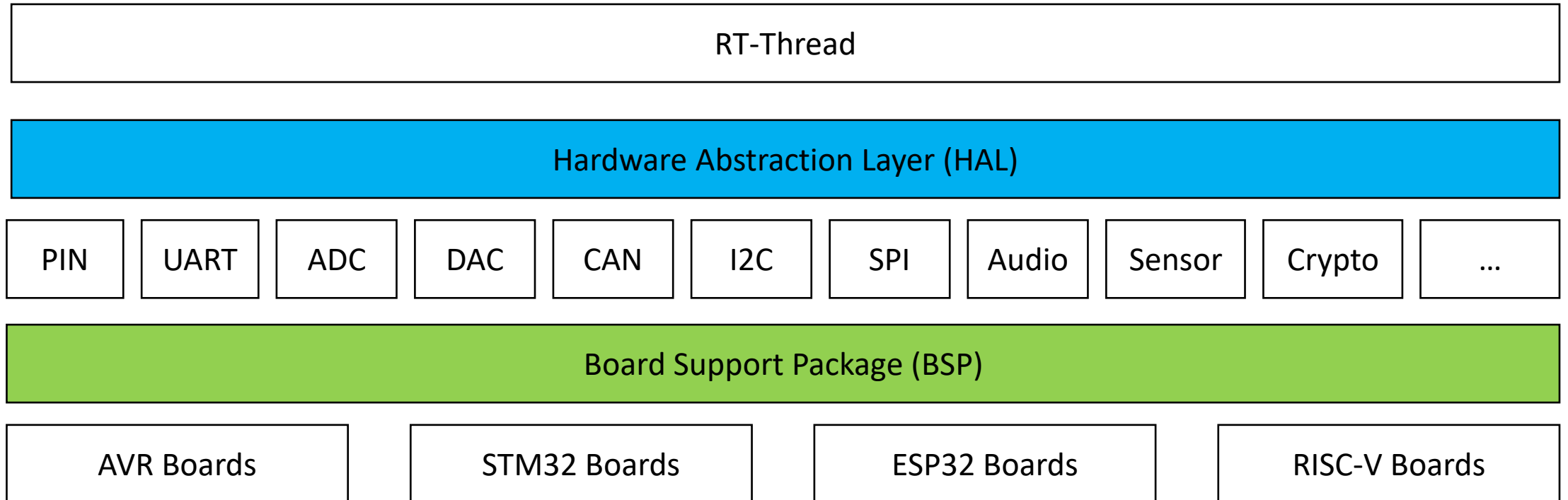


HAL (UART, I2C ...)



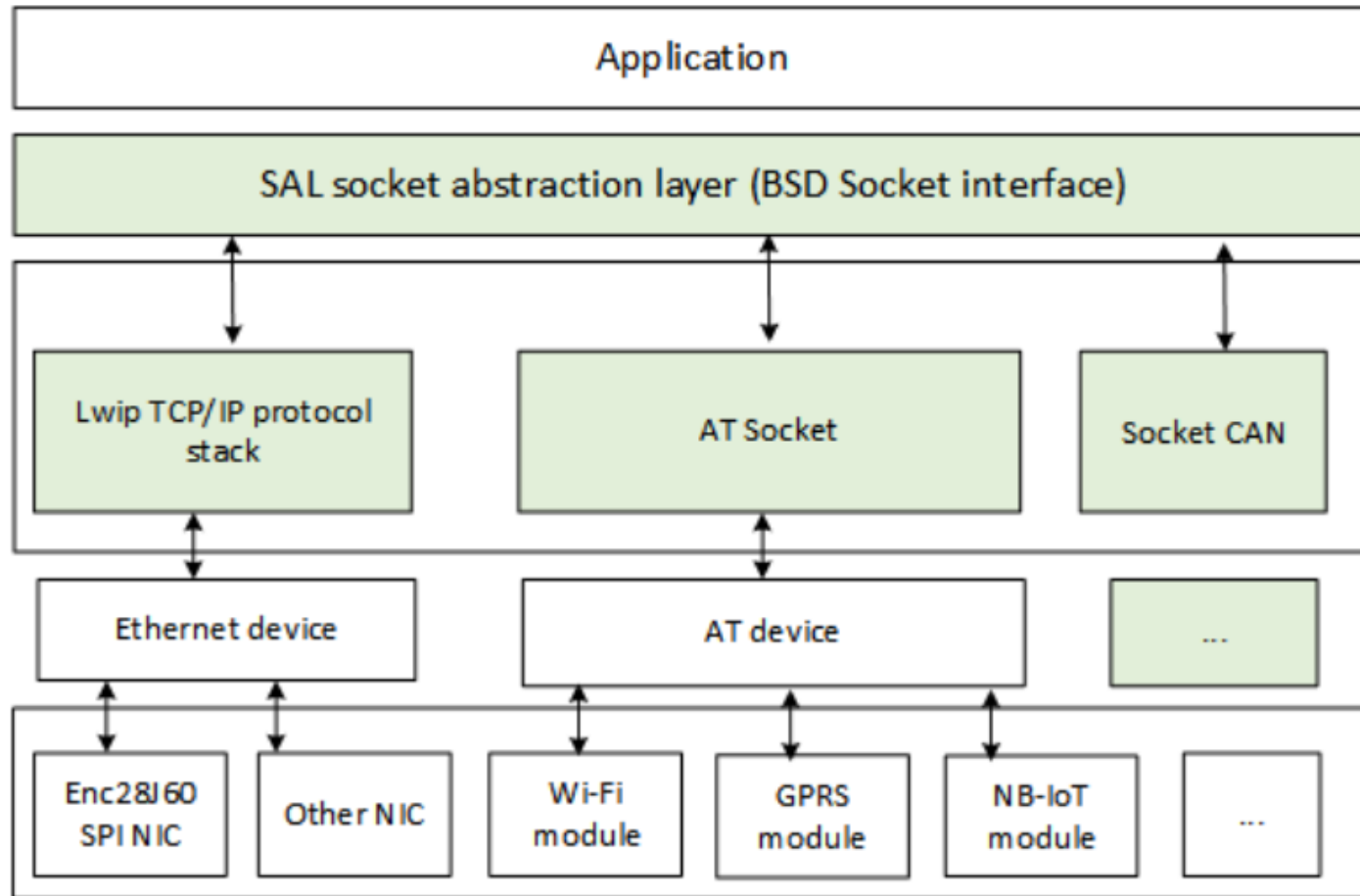
POSIX Layer

RT-Thread HAL



The same code runs on different hardware

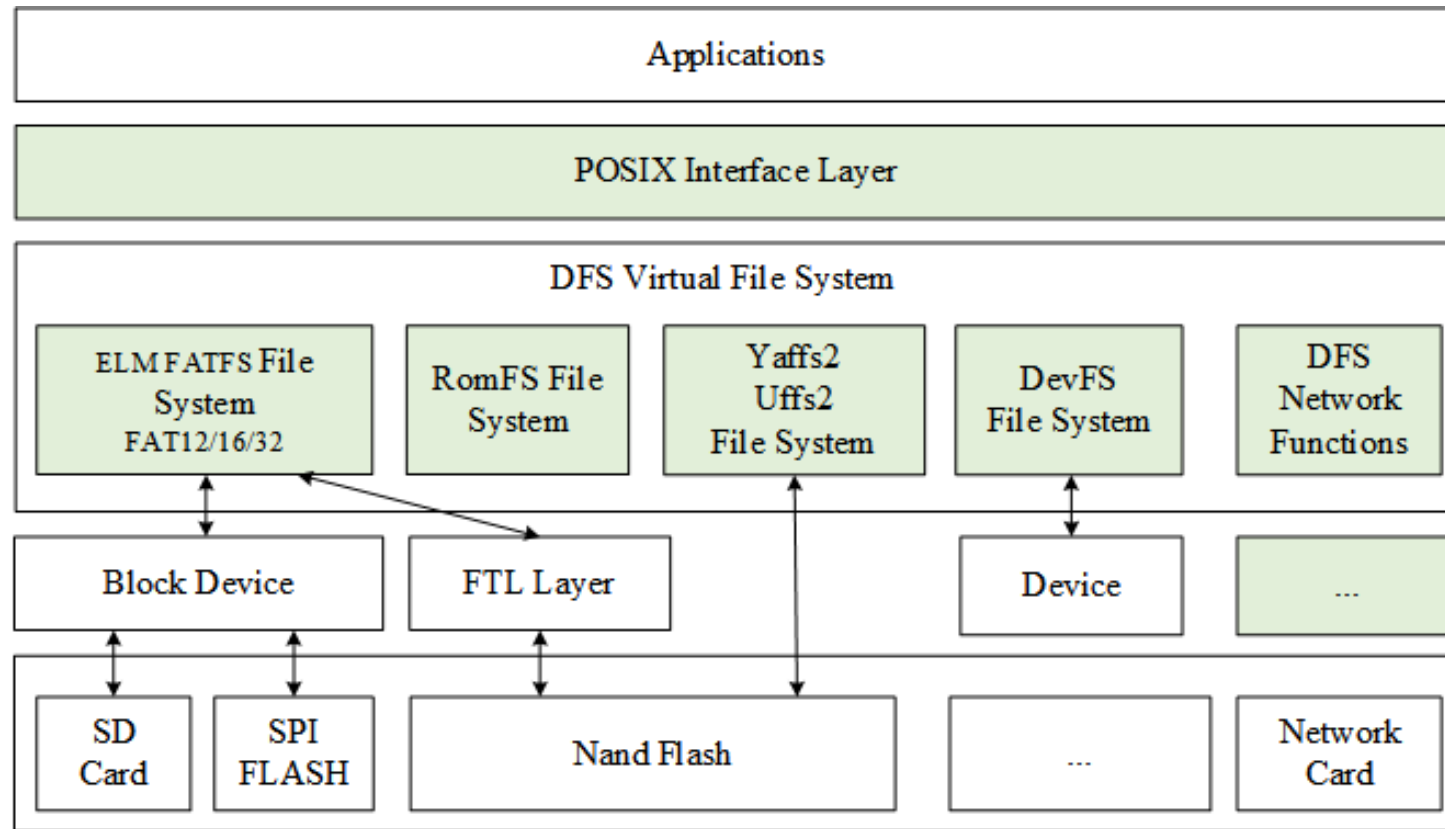
RT-Thread Networking



MSH Command

- > list_device
- > wifi scan
- > wifi status
- > ifconfig
- > dns
- > ping
- > telnet

RT-Thread File System



MSH Command

- > list_device
- > pwd
- > ls
- > mkdir
- > cd
- > rm
- > cat
- > echo

RT-Thread POSIX

- **POSIX = Portable Operating System**
 - Standard Enforced by IEEE
 - The purpose of POSIX was to **improve portability**. When your source code follows the standard, you can compile and **run the code on a different machine easily**.
- **Thread management**: Thread creating, detaching, joining, and setting and querying thread attributes.
- **Mutex**: Abbreviation for "mutual exclusion", which restricts thread access to shared data and protects the integrity of shared data. This includes creating, destroying, locking, and unlocking mutex and some functions for setting or modifying mutex properties.
- **Condition variable**: Communication between threads used to share a mutex. It includes functions such as creation, destruction, waiting condition variables, and sending signal.
- **Read/write locks and barriers**: including the creation, destruction, wait, and related property settings of read-write locks and barriers.

The same code runs on different Operating Systems

RT-Thread Packages

RT-Thread Software Package

Search Packages

RT-Thread software package is a common code base running on top of RT-Thread IoT operating system platform. Here is the package open platform, you can find all kinds of the latest and the most popular packages.

Easy to use [Find the package](#)










Easy to master [Check the documents](#)

380 Packages

6,453,729 Downloads

128 Contributors

Software Package Category

 IOT IoT-related packages, including network-related packages, cloud access packages, etc.	 Peripherals Packages related to the underlying peripheral hardware, sensor packages.	 System System and software packages, behavior monitoring system packages, and other file systems, etc.
 Programming language Various programming languages, scripts or interpreters that can be run on the terminal board.	 Tools Tool packages for assisted use.	 Unclassified category Some unclassified packages, demos, and samples, etc.
 Multimedia Audio and video packages.	 Security Crypton&Decryption algorithms and transport layer security.	 AI RT-Thread embedded AI software package.

Future Career

Embedded System Developer

Embedded Linux



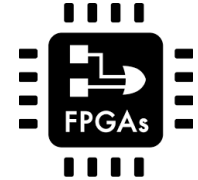
Rust Lang



Security



FPGA



From BareMetal to RTOS



FreeRTOS



RT-Thread

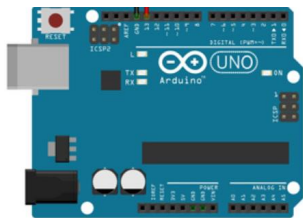


Zephyr™
Zephyr



Nuttx

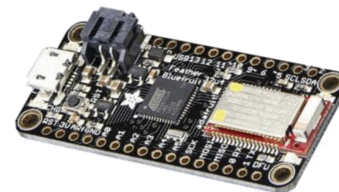
BareMetal Programming



Arduino



STM32



ESP32



RISC-V

Thanks



 [@wuhanstudio](https://github.com/wuhanstudio)

<https://wuhanstudio.cc>