ESP8266

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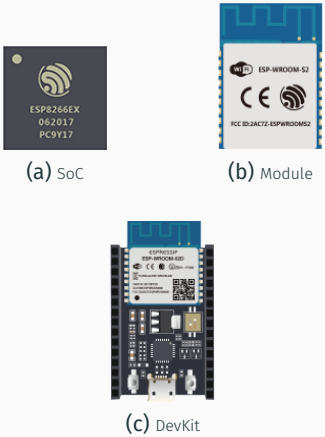
Outline

Introduction

ESP8266?

- WiFi-capable MicroController Unit (MCU)
- Produced by Espressif Systems
- Can be programmed in different languages:
  - Arduino (similar to C++)
  - Python
  - Lua
  - C (for this presentation: RTOS-SDK [4])
  - ...
- Different form factors (see Figure 1)



(a) SoC (b) Module

(c) DevKit

Figure 1: ESP8266 in different configurations

Images from Espressif SoCs and Espressif Modules

ESP32?

- Successor of the ESP8266
- Supports Bluetooth and Bluetooth Low Energy (BLE) additionally to WiFi

Timeline

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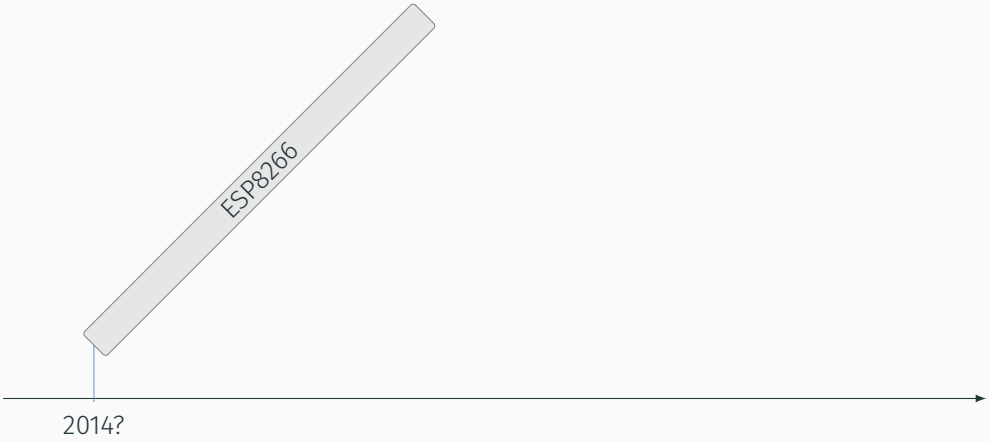

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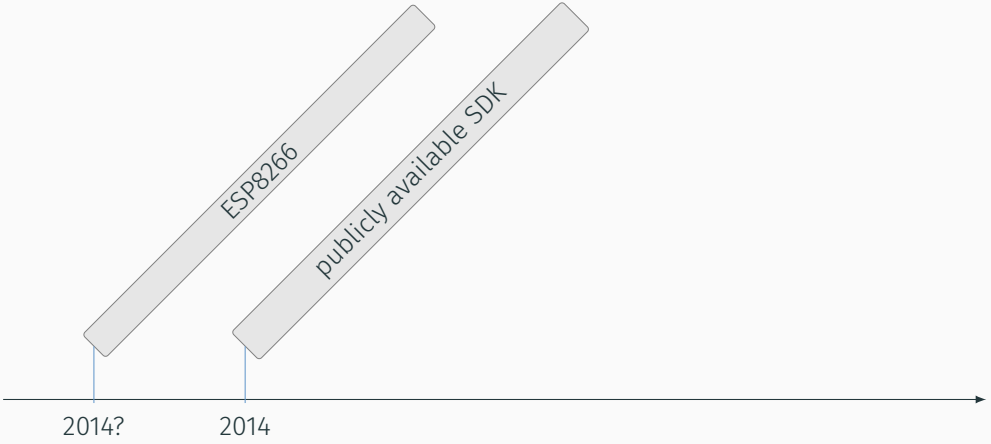

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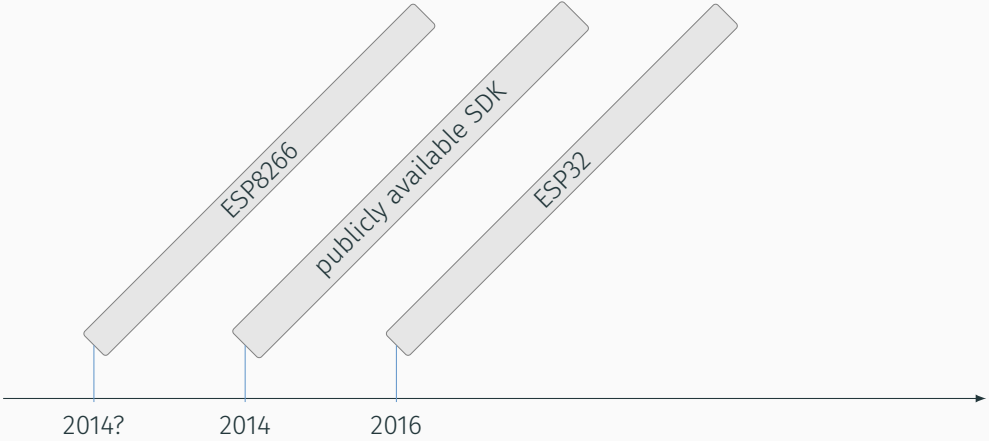

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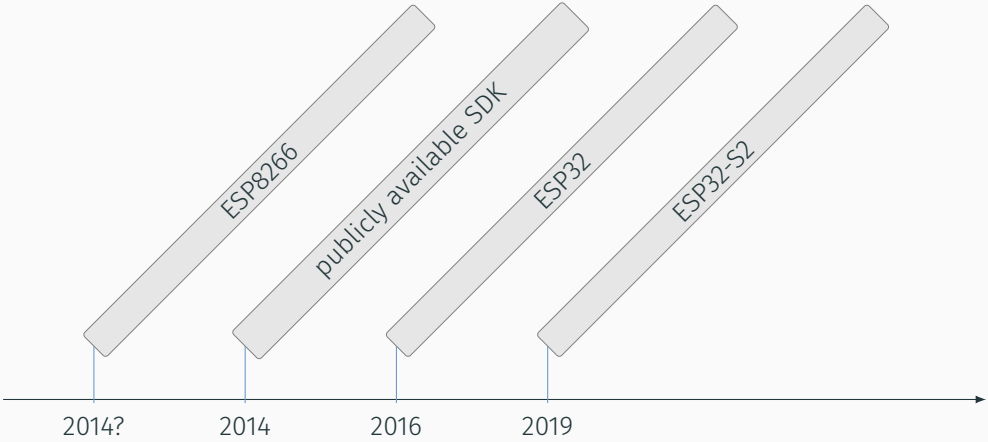
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publicly available SDK
ESP32
ESP32-S2
2014?
2014
2016
2019

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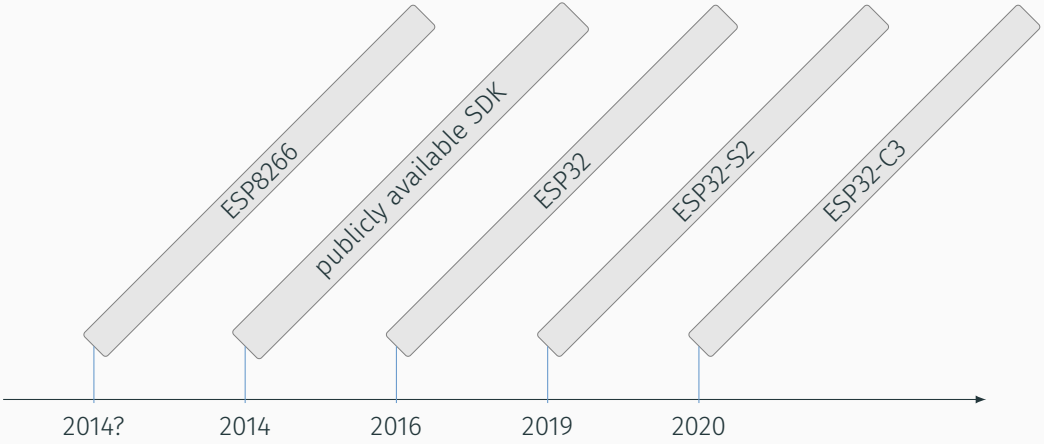
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Comparison: Arduino vs ESP8266

Feature	Arduino Uno [1]	ESP8266 [3]	ESP32 [2]
WiFi	✗	802.11 b/g/n	802.11 b/g/n
Bluetooth	✗	✗	BT 4.2 & BLE
GPIO	✓	✓	✓
CPU	8-bit, 16 MIPS with 16 MHz	32-bit, 160 MHz	32-bit, 200, 400, or 600 MIPS
Memory	2 KiB	160 KiB	520 KiB
Flash	32 KiB	up to 16 MiB external flash	up to 16 MiB external flash
Power consumption	4.5 mW at 4 MHz	264 mW average	500 mW average

Programming examples

GPIO pins – General usage

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1  void app_main(void) {
2    setupGPIO();
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4    ESP_LOGI("main", "Started.");
5    int level;
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7    while(1) {
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GPIOs and physical ports

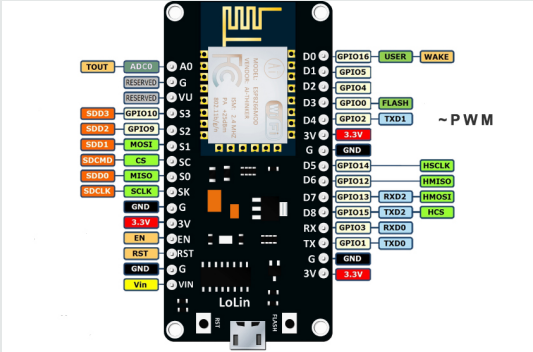

Image from teachmemicro.com

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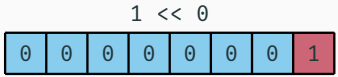

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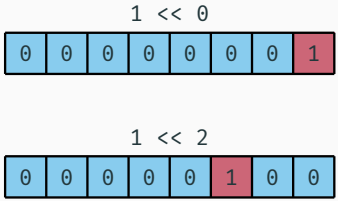

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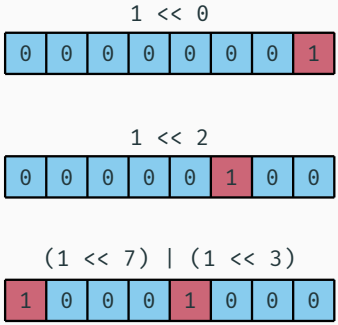

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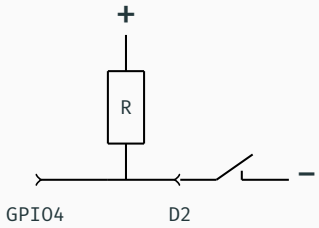

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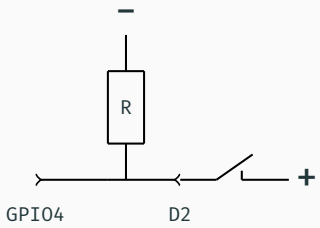

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Demo 1

GPIO example

WiFi Station – Setup

```
void initWifi() {
  tcpip_adapter_init();
  esp_event_loop_create_default();

  wifi_init_config_t cnf = WIFI_INIT_CONFIG_DEFAULT();
  esp_wifi_init((const wifi_init_config_t *)(&cnf));

  esp_event_handler_register(WIFI_EVENT, ESP_EVENT_ANY_ID, &handler, NULL);
  esp_event_handler_register(IP_EVENT, IP_EVENT_STA_GOT_IP, &handler, NULL);

  wifi_config_t wcnf;
  setIntArr(wcnf.sta.ssid, "myssid");
  setIntArr(wcnf.sta.password, "mypassword");
  wcnf.sta.threshold.authmode = WIFI_AUTH_WPA2_PSK;

  esp_wifi_set_mode(WIFI_MODE_STA);
  esp_wifi_set_config(ESP_IF_WIFI_STA, &wcnf);
  esp_wifi_start();
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WiFi Station – Setup

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WiFi Station – Event handling

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void handler(void *arg, esp_event_base_t base, int32_t eventId, void *data) {
  if(base == WIFI_EVENT && eventId == WIFI_EVENT_STA_START) {
    ESP_LOGI("WiFi", "Connecting to AP...");
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  }
  else if (base == WIFI_EVENT && eventId == WIFI_EVENT_STA_DISCONNECTED) {
    wifi_event_sta_disconnected_t *event = (wifi_event_sta_disconnected_t*)data;
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    esp_wifi_connect();
  }
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Demo 2

Connecting to a WiFi AP as Station

WiFi AP

- Basically the same as WiFi station
  - Initialize tcpip adapter
  - Implement event handlers and register them
  - Create and initialize configuration data structure
  - Set mode to Access point
  - Start WiFi

Webserver

- Initialize webserver
- Add handlers for different methods and paths
  - Load the query string to a buffer
  - Do some application logic (e.g. checking if a parameter has a specified value, blink a LED, etc.)
  - Send response
- Start the server

Demo 3

Controlling LED over WiFi

Aspects of information security

How trustworthy is the ESP?

- Trust in hardware that might not be trustworthy
- Bugs in SDKs, libs, etc. -> update frequency?
- Bugs in own implementation -> update frequency?

Idea: How to improve overall security

- **Basic approach**: Reduce attack surface
  - Put them in an additional network
  - Access from the outside only with a proxy
- **Awareness**: Be aware of the risks
  - Confidentiallity
  - Integrity
  - Availability

Project ideas related to IoT

Web-controllable LED-Strip

- Setup a webserver that processes requests
- Control a WS2812-based LED strip based on the submitted requests
- Works with matrices, cubes, etc. as well

Controller for 3D-Snake

- Part of the project “3D-Snake” created in the scope of the bachelor program
- Controllers have photoelectric barrier and detect motion based on them
- Movements are interpreted as gestures and submitted to the main component (Raspberry Pi) via Bluetooth
- Idea: Add other controller types (e.g. accelerometer, etc.)

Project ideas not related to IoT

WiFi Deauthentication

- Security of WiFi ist not as good as it should be
- There is the possibility to deauthenticate a client by spoofing its MAC address

WiFi Deauthentication

- **Idea**: Deauthenticate all clients from a given SSID
  - If a client connects, its connection is deauthenticated again
  - Impact on Availability

WiFi Deauthentication

- **Idea**: Deauthenticate all clients from a given SSID and provide a network with the same SSID
  - Clients connect to the attackers network
  - Impact on Integrity/Confidentiallity

WiFi Deauthentication

- **Idea**: Deauthenticate clients and let them connect again
  - Sniff the WPA 4-Way handshake
  - Crack the WPA key after enough handshakes are sniffed

Conclusion

Conclusion

- Small programmable device with WiFi capability
- Programmable in different languages
- Documentation from vendor not satisfying, but many 3rd party resources
- Think about risks related to security/safety of your projects

Questions?

References i

[1] *ATmega328P Datasheet*. 2015. URL: http://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-7810-Automotive-Microcontrollers-ATmega328P_Datasheet.pdf (visited on 03/24/2021).

[2] *ESP32 Datasheet*. 2021. URL: https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf (visited on 03/24/2021).

[3] *ESP8266 Datasheet*. 2020. URL: https://www.espressif.com/sites/default/files/documentation/0a-esp8266ex_datasheet_en.pdf (visited on 03/24/2021).

[4] *ESP8266 RTOS Software Development Kit*. 2021. URL: https://github.com/espressif/ESP8266_RTOS_SDK (visited on 05/16/2021).