IoT Engineering
3: Sending Sensor Data to IoT Platforms

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Today

⅓ slides,

⅔ hands-on.

Slides, code & hands-on: tmb.gr/iot-3

Prerequisites

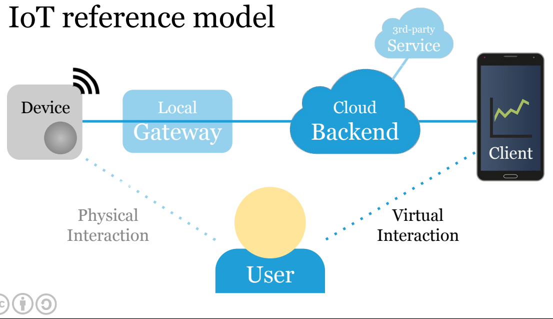
Install the Arduino IDE, set up ESP8266, get Wi-Fi:

Check the Wiki entry on Installing the Arduino IDE.

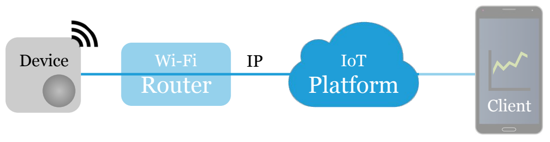
Set up the Feather Huzzah ESP8266 for Arduino.

Get access to a Wi-Fi network without a portal.

IoT reference model



Wi-Fi connectivity



Wi-Fi

Wi-Fi is based on IEEE 802.11/a/b/g/n/... standards.

Uses 2.4 GHz UHF and 5 GHz SHF ISM radio bands.

100 m line-of-sight, many materials absorb/reflect it[1].

Throughput depends on version, 11 Mbps up to Gbps.

Uses more energy than Bluetooth LE, less than 3/4G.

ESP8266 Wi-Fi setup

.ino

```
#include <ESP8266WiFi.h>

void setup() {
  Serial.begin(115200); // for debug output
  WiFi.mode(WIFI_STA); // _AP|_AP_STA|_OFF
  WiFi.begin("SSID", "PASSWORD"); // TODO
  while (WiFi.status() != WL_CONNECTED) {
    delay(100); // keeps watchdog happy
  }
  Serial.println(WiFi.localIP());
}
```

7

MAC address

The MAC address, e.g. 80:7d:3a:58:8a:ef, is a unique identifier assigned to the network interface controller (NIC) for data link layer communications.

Used as a network address for IEEE 802 technology including Ethernet, Wi-Fi and Bluetooth.

The first six digits identify the vendor, e.g. 80:7d:3a.

8

ESP8266 Wi-Fi MAC address

.ino

This code reads the ESP8266 Wi-Fi MAC address:

```
#include <ESP8266WiFi.h>

void setup() {
  Serial.begin(115200);
  Serial.print(WiFi.macAddress());
}
```

Some networks grant access based on MAC address.

9

HTTP Web request

A simple way to put or get data to/from a backend.

To debug HTTP, the cURL client is recommended.

```
$ curl -v tmb.gr/hello.html

> GET /hello.html HTTP/1.1\r\n
> Host: tmb.gr\r\n
> \r\n
```

10

HTTP Web response

```
< HTTP/1.1 200 OK\r\n
< Content-Type: text/html\r\n
< Content-Length: 108\r\n
< \r\n
<!DOCTYPE html><html lang="en">
<head><title>Hello</title></head>
<body><p>Hello, World!</p></body>
</html>
```

11

ESP8266 Wi-Fi client

.ino

```
WiFiClient client;
client.connect(host, port));
client.print(
  "GET /hello.html HTTP/1.1\r\n" \
  "Host: tmb.gr\r\n" \
  "\r\n");
while (client.connected() ||
  client.available()) {
  int ch = client.read(); … }
```

12

Hands-on, 15': Wi-Fi

Build and run the previous Wi-Fi related examples.

Use the *.ino* link on each page to find the source.

The examples are in the course repository.

Make sure to use the ESP8266 board.

Sending sensor data

Here is a simple recipe for "remote sensing".

First, connect the device to the network.

Then, repeat the following steps:

- Read sensor values.
- Add a timestamp.
- Send the data.

Timestamp

Adding a timestamp can happen in two places:

- On the device, when a sensor value is measured.
- On the backend, when a data packet just arrived.

The first allows caching of measurements, the second requires sending immediately or discarding values.

Trade-off: accuracy & completeness vs. simplicity.

Time

The time on a microcontroller is reset to 0 at startup.

Timestamps use Coordinated Universal Time (UTC).

There are different ways to get and keep UTC time:

- Get time from a standard Web server, using HTTP.
- Get time from a network time server, using NTP.
- Set and keep time with a real time clock (RTC).

ESP8266 Web-based time client .ino

```
> HEAD / HTTP/1.1\r\n
> Host: google.com\r\n
> \r\n
< HTTP/1.1 301 Moved Permanently\r\n
< Location: http://www.google.com/\r\n
< Content-Type: text/html\r\n
< Date: Sat, 02 Mar 2019 17:10:20 GMT\r\n
< \r\n
```

Network Time Protocol

Network Time Protocol (NTP) is a network protocol for clock synchronization between computer systems[1].

Synchronizes participating computers to within a few milliseconds of Coordinated Universal Time (UTC)[1].

Implementations send and receive timestamps using the User Datagram Protocol (UDP) on port 123[1].

See [1]Wikipedia.

ESP8266 built-in NTP client .ino

```
configTime(timezone * 3600, dst_offset,
  "pool.ntp.org", "time.nist.gov");
// wait for time() being adjusted
while (time(NULL) < 28800 * 2) {
  delay(500);
}
// time() is set
time_t now = time(NULL);
```

Hands-on, 15': ESP8266 NTP clients

Build, run and compare the following NTP clients:

The Web-based time client and built-in NTP client.

Arduino > Examples > ESP8266WiFi > NTPClient.

Bonus: Read the code of this low memory version.

Which one would you use, and why?

Transport Layer Security

Transport Layer Security (TLS) allows a device to:

- Encrypt a communication channel, for privacy.
- Verify that it talks to the right backend server.

Trust is based on certificates issued by authorities.

HTTPS relies on TLS to secure HTTP connections.

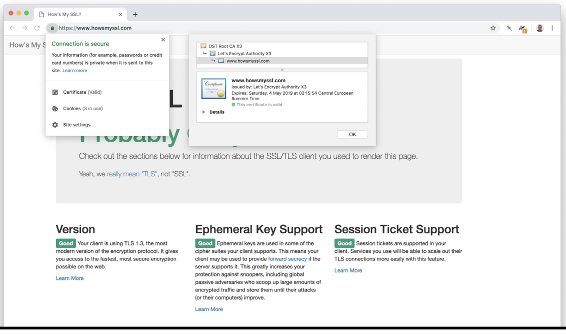
See this video by @spiessa for an introduction.

ESP8266 secure Wi-Fi client .ino

```
#include <ESP8266WiFi.h>
#include <WiFiClientSecure.h>

const char *host = "www.howsmyssl.com";
const char *path = "/a/check";
const int port = 443;

WiFiClientSecure client;
if (client.connect(host, port)) {
  // the connection is encrypted
```

ESP8266 verify host fingerprint .ino

```
// Browser > 🔒 > Certificate > Fingerprint
const char *fingerprint = "67 FF 3D BC D3
59 E2 C0 BD 04 3B 8A 57 CB 72 7C 0A 20 F5
E4"; // SHA-1, not really secure anymore

if (client.verify(fingerprint, host)) {
  Serial.println("certificate verified");
} else {
  Serial.println("certificate mismatch");
}
```



Connection is secure

Your information (for example, passwords or credit card numbers) is private when it is sent to this site. Learn more

Certificate (Valid)

Cookies (3 in use)

Site settings

DST Root CA X3
Let's Encrypt Authority X3
www.howsmyssl.com

www.howsmyssl.com
Issued by: Let's Encrypt Authority X3
Expires: Saturday, 4 May 2019 at 02:15:54 Central European Summer Time
This certificate is valid

Details

Check out the sections below for information about the SSL/TLS client you used to render this page.

Yeah, we really mean "TLS", not "SSL".

Version

Good Your client is using TLS 1.3, the most modern version of the encryption protocol. It gives you access to the fastest, most secure encryption possible on the web.

Learn More

Ephemeral Key Support

Good Ephemeral keys are used in some of the cipher suites your client supports. This means your client may be used to provide forward secrecy if the server supports it. This greatly increases your protection against snoopers, including global passive adversaries who scoop up large amounts of encrypted traffic and store them until their attacks (or their computers) improve.

Learn More

Session Ticket Support

Good Session tickets are supported in your client. Services you use will be able to scale out their TLS connections more easily with this feature.

Learn More

ESP8266 check CA certificate .ino

```
extern const unsigned char caCert[] PROGMEM;
extern const unsigned int caCertLen;
```

```
// make sure time() is set, see NTP client
WiFiClientSecure client; // use TLS
if (client.setCACert_P(caCert, caCertLen)) {
  if (client.connect(host, port)) {
    if (client.verifyCertChain(host)) {
      …
```

25

Hands-on, 15': ESP8266 TLS clients

Build, run and compare the following TLS clients:

Secure Wi-Fi client, with fingerprint, with CA check.

Locate/download the CA certificate in your browser.

Locate the SHA-1 fingerprint of the host certificate.

Bonus: Try to change the host to another Website.

26

IoT platforms

IoT platforms enable storing/displaying sensor data.

There are many examples, we start with these two:

Dweet.io stores name/value pairs in JSON format.

ThingSpeak stores sensor data and displays graphs.

Both receive data through HTTP POST requests.

27

Dweet.io

Dweet.io stores name/value pairs in JSON format.

```
Host: dweet.io
Port: 443
```

```
POST /dweet/for/THING_NAME?name=value
POST /dweet/for/THING_NAME?x=23&y=42&t=…
GET /get/dweets/for/THING_NAME
```

Or POST any valid JSON data in the request body.

28

Hands-on, 15': Dweet.io

Dweet.io works without an account, data is public.

Use your ESP8266 MAC address as THING_NAME.

On the ESP8266, read the analog pin A0, then POST its value to `/dweet/for/THING_NAME?a0=value`

Use cURL or your browser to read stored data from `https://dweet.io/get/dweets/for/THING_NAME`

29

ThingSpeak

ThingSpeak stores sensor data and displays graphs.

```
Host: api.thingspeak.com
Port: 80 or 443
```

```
POST /update?key=WRITE_API_KEY&field1=42
GET /channels/CHANNEL_ID/feed.json?
key=READ_API_KEY
```

30

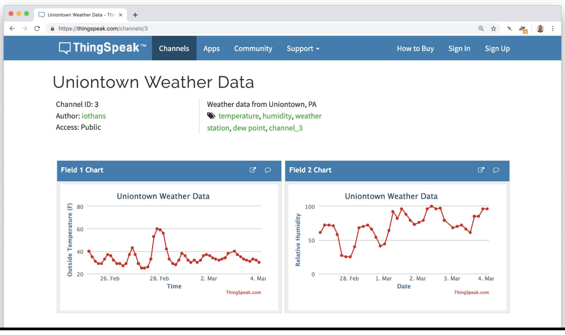
Hands-on, 15': ThingSpeak

Get an account to create channels and get API keys.

Add the Arduino library with *Sketch > Include Library > Manage Libraries... >ThingSpeak > Install*

Try the example code *File > Examples > ThingSpeak > ESP8266 > WriteMultipleFields.ino*

Make sure values arrive in your ThingSpeak channel.



https://thingspeak.com/channels/3

Uniontown Weather Data

Channel ID: 3
Author: iothans
Access: Public

Weather data from Uniontown, PA
temperature, humidity, weather station, dew point, channel_3

Hands-on, 15': Temperature sensor

Design a connected temperature sensor as specified:

Gets current time and date in ISO 8601 UTC format.

Gets temperature & humidity from a DHT11 sensor.

Connects* to api.thingspeak.com port 443 with TLS.

Posts sensor values, timestamp every 30 seconds.

*) And robustly reconnects, if disconnected.

Summary

We learned to connect a device to a Wi-Fi network.

We looked at ways to get UTC time on a controller.

We sent sensor measurements to an IoT platform.

These are the basics of remote sensing.

Next: Internet Protocols, HTTP and CoAP.

Homework, max. 3h

Implement or finish the temp. sensor you designed.

Post the IoT platform data feed URL* to the Slack.

Commit the Arduino code to the hands-on repo.

Measure the temperature for at least 24 hours.

*) Ideally public, we'll take a look together.

Feedback?

Find me on https://fhnw-iot.slack.com/

Or email thomas.amberg@fhnw.ch

Slides, code & hands-on: tmb.gr/iot-3