

IoT Engineering

3: Sending Sensor Data to IoT Platforms

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Slides: tmb.gr/iot-3

Overview

These slides introduce *Wi-Fi connectivity*.

How to connect to a Wi-Fi network.

How to send data to a server.

Prerequisites

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

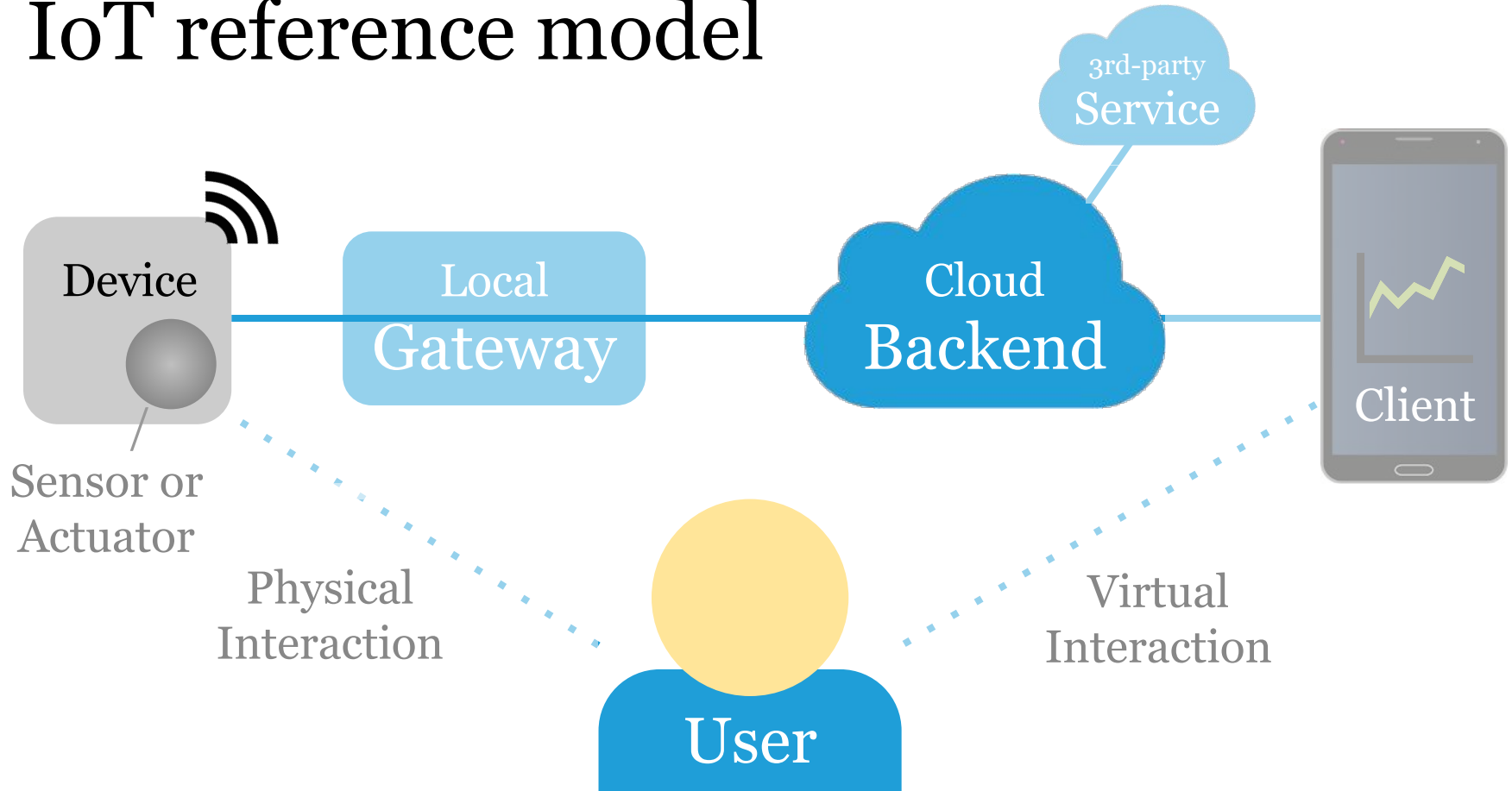
Check the Wiki entry on [Installing the Arduino IDE](#).

[Set up the Feather Huzzah ESP8266](#) for Arduino.

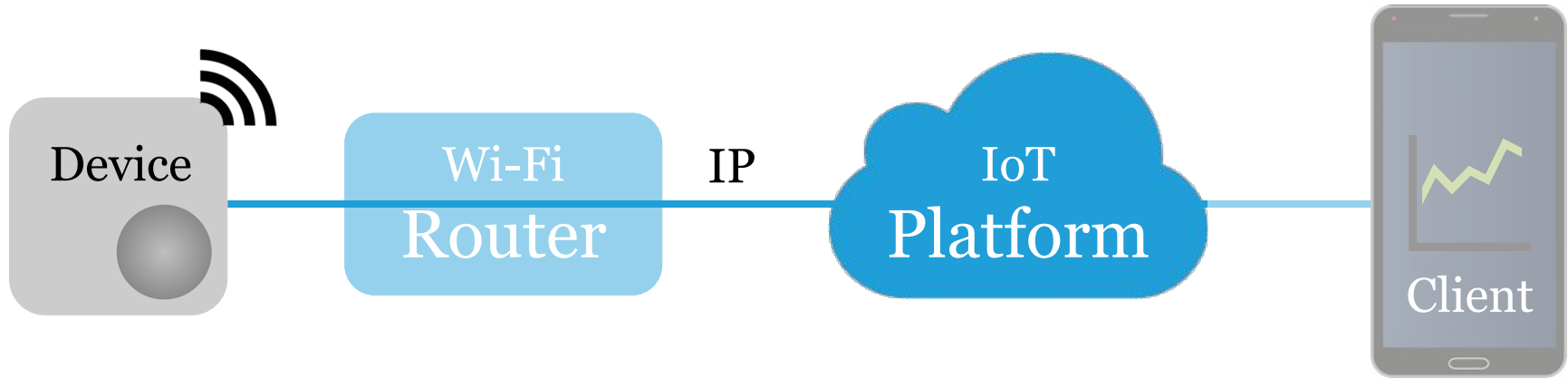
Get access to a Wi-Fi network* without a portal.

*In class, try MY_SSID with MY_PASSWORD.

IoT reference model



Wi-Fi connectivity



The device first connects to the local Wi-Fi network, then it uses an **IP**-based protocol to transport data to a backend server, e.g. an existing IoT platform.

Wi-Fi

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

Uses 2.4 GHz, 5 GHz & 6 GHz radio frequency bands.

100 m line-of-sight, many materials absorb/reflect it¹.

Throughput depends on version, 11 Mbps up to Gbps.

Uses more energy than Bluetooth LE, less than 4/5G.

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("MY_SSID", "MY_PASSWORD"); // TODO
    while (WiFi.status() != WL_CONNECTED) {
        delay(500);
    }
    Serial.println(WiFi.localIP());
}
```

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

HTTP is a TCP/IP-based protocol to transport data.

To test* HTTP (Web) requests, we use the **cURL** tool.

```
$ curl -v tmb.gr/hello.json  
  
> GET /hello.json HTTP/1.1\r\n  
> Host: tmb.gr\r\n  
> \r\n
```

*On your computer, before writing any code.

HTTP Web response

```
< HTTP/1.1 200 OK\r\n
< Content-Type: application/json\r\n
< Content-Length: 32\r\n
< \r\n
{\n
  "message": "Hello, World!"\n
}
```

ESP8266 Wi-Fi client

.ino

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

```

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".

Repeat the following steps in a loop:

- Ensure WiFi is connected
- Read values from sensors
- Add a timestamp (UTC)
- Send data to backend

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>
```

```
const char *host = "www.howsmyssl.com";
```

```
const char *path = "/a/check";
```

```
const int port = 443;
```

```
BearSSL::WiFiClientSecure client;
```


```
client.setInsecure(); // no cert validation
```

```
if (client.connect(host, port)) {
```

```
    // the connection is encrypted
```

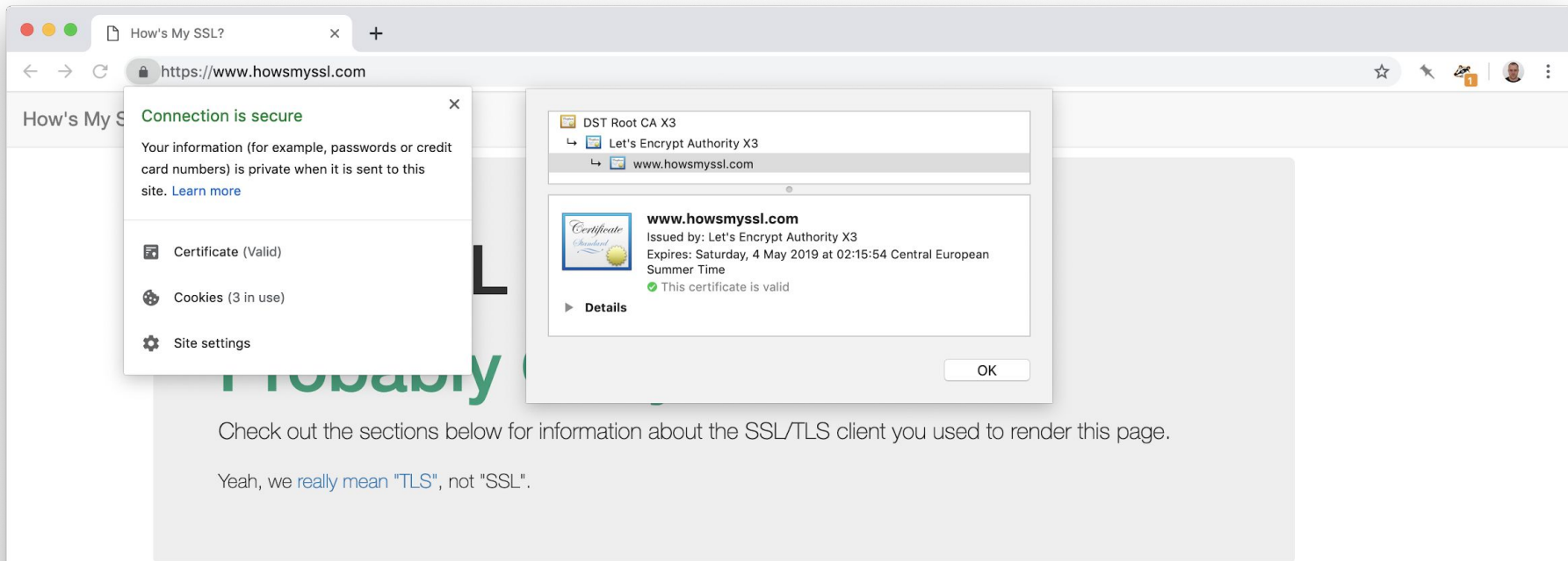

ESP8266 verify host fingerprint

.ino

```
// Browser >  > Certificate > Fingerprint  
const char *fingerprint = "CB 4D 0A 4F E5  
0A DA 76 68 A4 33 37 BC 9A F9 C5 47 DD 5D  
F6"; // SHA-1, not really secure anymore
```

```
BearSSL::WiFiClientSecure client;  
client.setFingerprint(fingerprint);  
if (client.connect(host, port)) {  
    // certificate fingerprint matched
```

...



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

```
#include "certs.h" // generated with cert.py
X509List cert(cert_ISRGRoot_X1);

// make sure time() is set, see NTP client
BearSSL::WiFiClientSecure client;
client.setTrustAnchors(&cert);
if (client.connect(host, port)) {
    // certificate chain verified
    ...
}
```

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.

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.

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`

See Wiki for [Dweet.io cURL examples](#).

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

ThingSpeak

ThingSpeak stores sensor data and displays graphs.

Host: `api.thingspeak.com`

Port: 80 or 443

POST `/update?api_key=WRITE_API_KEY&field1=3`

GET `/channels/CHANNEL_ID/feed.json?`

`api_key=READ_API_KEY`

See Wiki for **ThingSpeak cURL examples**.

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.

Uniontown Weather Data

Channel ID: 3

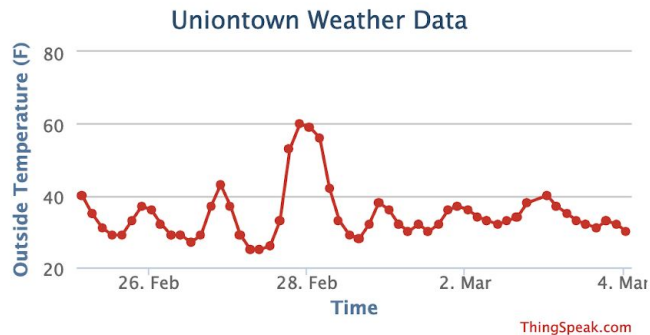
Author: [iothans](#)

Access: Public

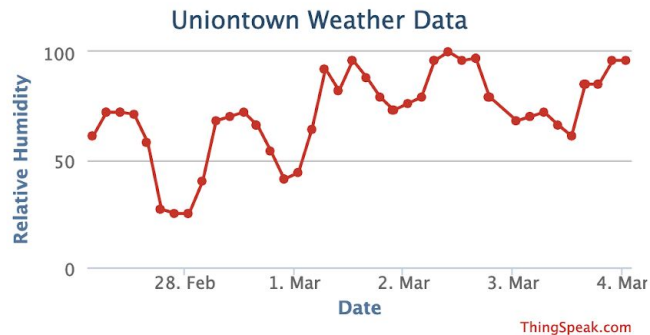
Weather data from Uniontown, PA

🔑 [temperature](#), [humidity](#), [weather station](#), [dew point](#), [channel_3](#)

Field 1 Chart



Field 2 Chart



Timestamps

Adding a timestamp can happen in two places:

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

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

Trade-off: simplicity vs. accuracy & completeness.

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 systems¹.

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

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

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?

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 sent sensor measurements to an IoT platform.

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

These are the basics of remote sensing.

Next: Internet Protocols, HTTP and CoAP.

Challenge

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 or questions?

Write me on <https://fhnw-iot.slack.com/>

Or email thomas.amberg@fhnw.ch

Thanks for your time.