

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:

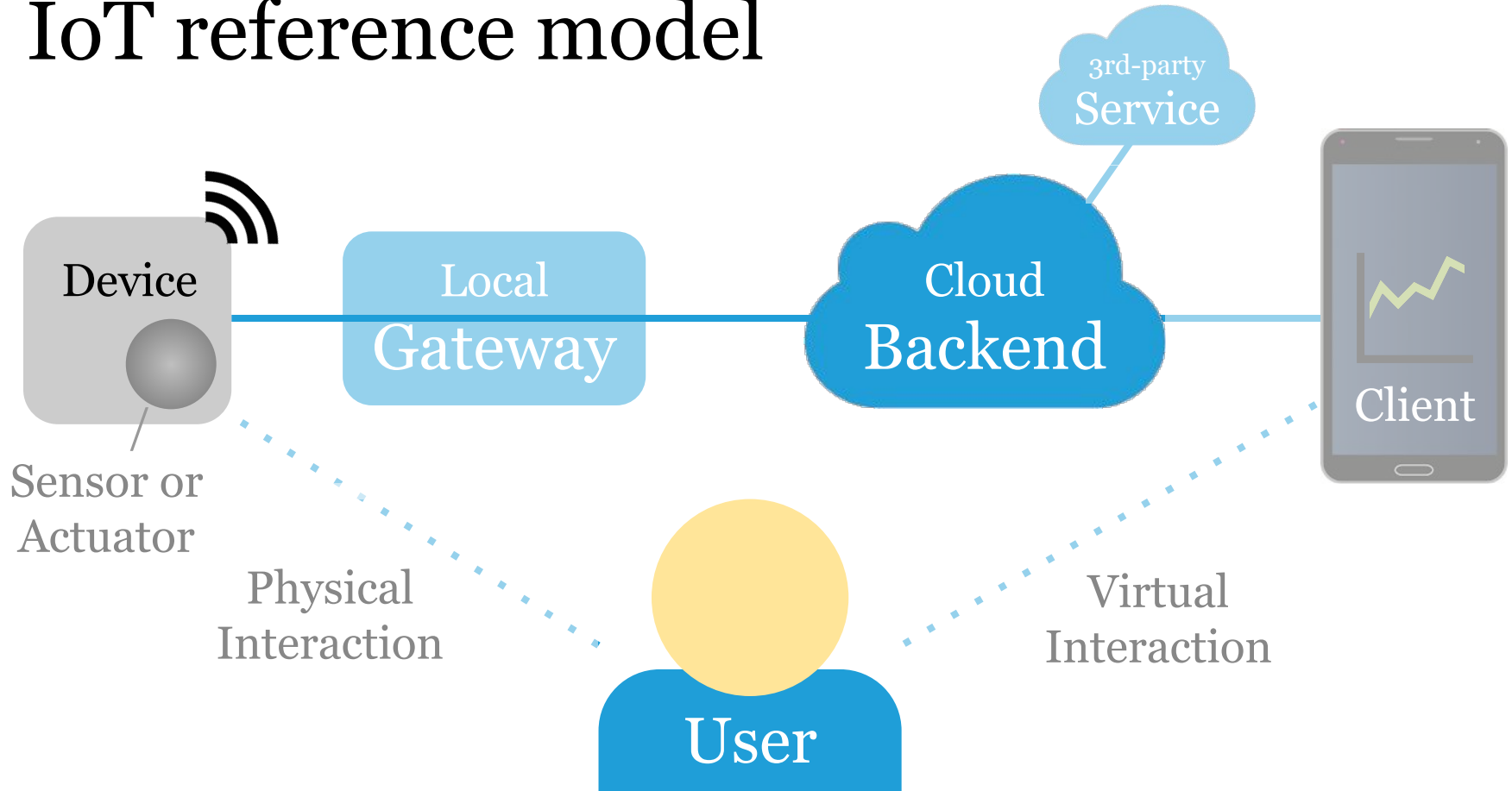
Check the Wiki entry on [Installing the Arduino IDE](#).

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

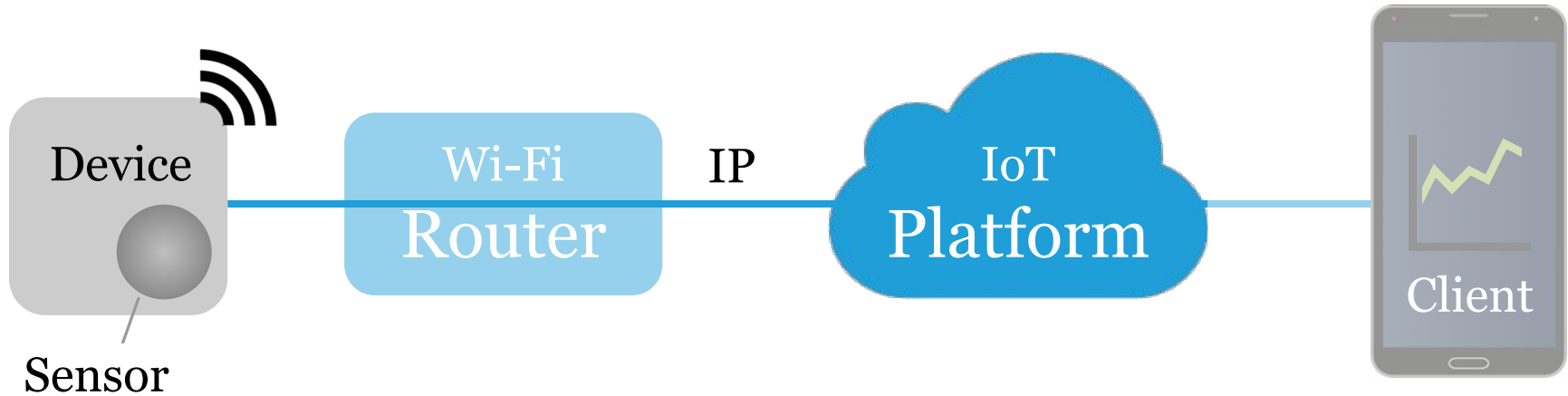
Get access to a Wi-Fi network* without a portal.

*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 it.

Throughput depends on version, 11 Mbps up to Gbps.

Uses more energy than Bluetooth LE, less than 4G/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
```

...

ESP8266 check certificate

.ino

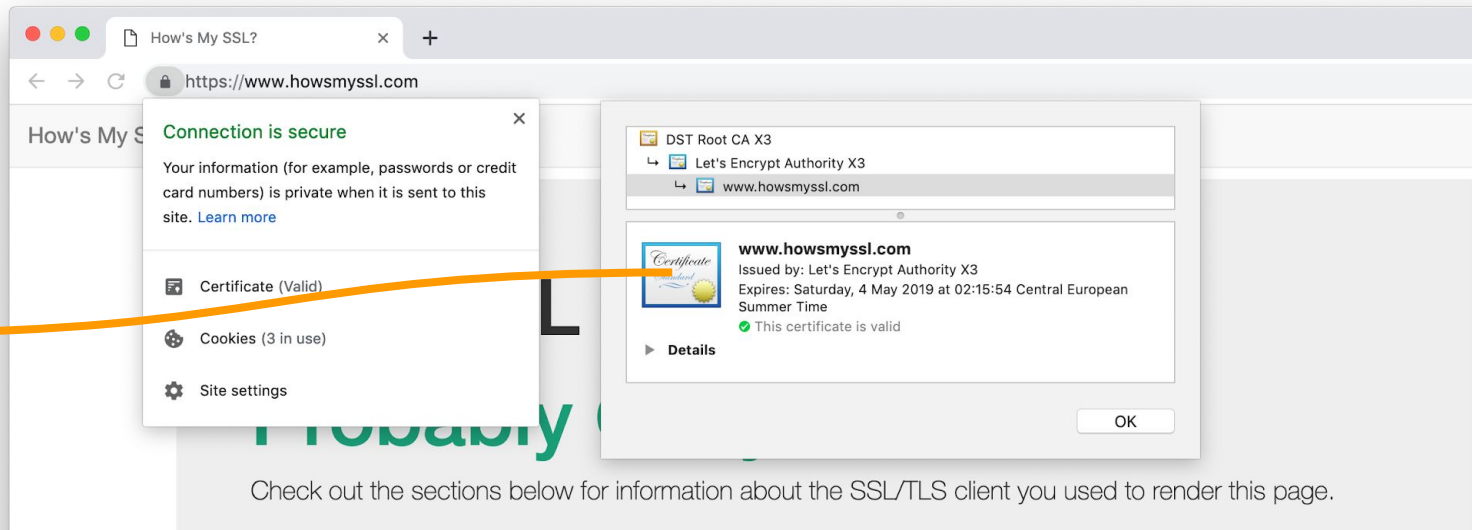
```
char cert_pem [] PROGMEM = R"CERT(...)CERT";  
X509List cert(cert_pem); // CA or server cert  
  
// make sure time() is set, see NTP client  
BearSSL::WiFiClientSecure client;  
client.setTrustAnchors(&cert);  
if (client.connect(host, port)) {  
    // certificate chain verified  
    ...  
}
```

Getting a server's certificate in Chrome

Drag &
drop...



Convert:



```
tamberg@mac Desktop % openssl x509 -inform der -in www.howsmyssl.com.cer -out cert.pem
tamberg@mac Desktop % cat cert.pem
-----BEGIN CERTIFICATE-----
MIIEjzCCA3egAwIBAgISBJ1bFpXEv5L7HobG8ytsWpA1MA0GCSqGSIb3DQEBCwUA
MDIx CzA JBgNVBAYTA1VTMRYwFAYDVQQKEw1MZXQncyBFbmNyeXB0MQswCQYDVQQD
FwJSMzAeFw0vMTA4MjIwMTA5MTA5MTA5MTA5MTA5MTA5MTA5MTA5MTA5MTA5MTA5
MTA5MTA5MTA5MTA5MTA5MTA5MTA5MTA5MTA5MTA5MTA5MTA5MTA5MTA5MTA5MTA5
```

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

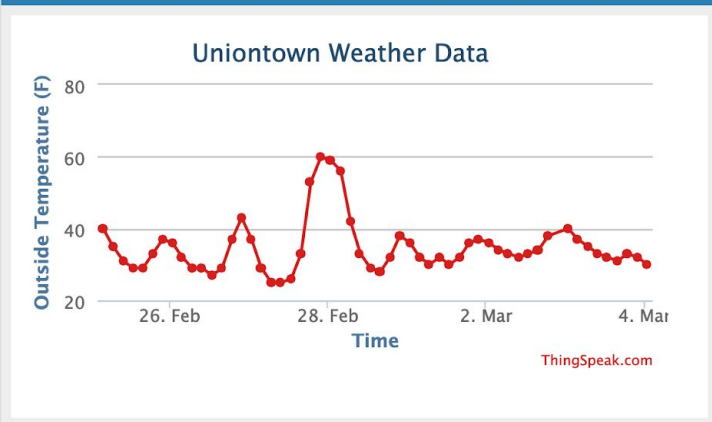
Author: [iothans](#)

Access: Public

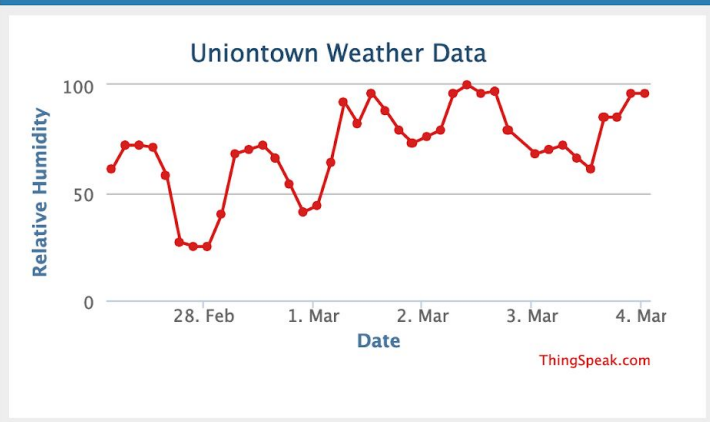
Weather data from Uniontown, PA

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

Field 1 Chart



Field 2 Chart



Timestamps

Adding a timestamp can happen in two places:

- In 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:

Web-based time client and built-in NTP client and
Arduino > Examples > ESP8266WiFi > NTPClient.

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 your IoT platform data feed URL* to Teams.

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 Teams or email

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Thanks for your time.