IoT Engineering 6: Raspberry Pi as a Local IoT Gateway

Slides: tmb.gr/iot-6

Overview

These slides introduce the *Pi as a local gateway*.

Connecting to, receiving data from BLE devices.

Providing the data to Web servers or clients.

Prerequisites

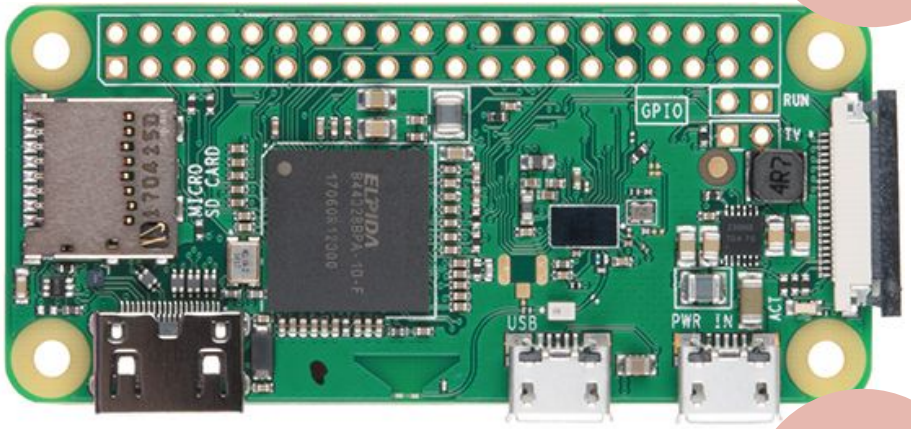
Set up SSH access to the Raspberry Pi, via USB/Wi-Fi:

Check the Wiki entry on Raspberry Pi Zero W Setup.

Submit the Raspberry Pi MAC address via Slack*.

*For simplified Wi-Fi setup.

Raspberry Pi



Single-board computer

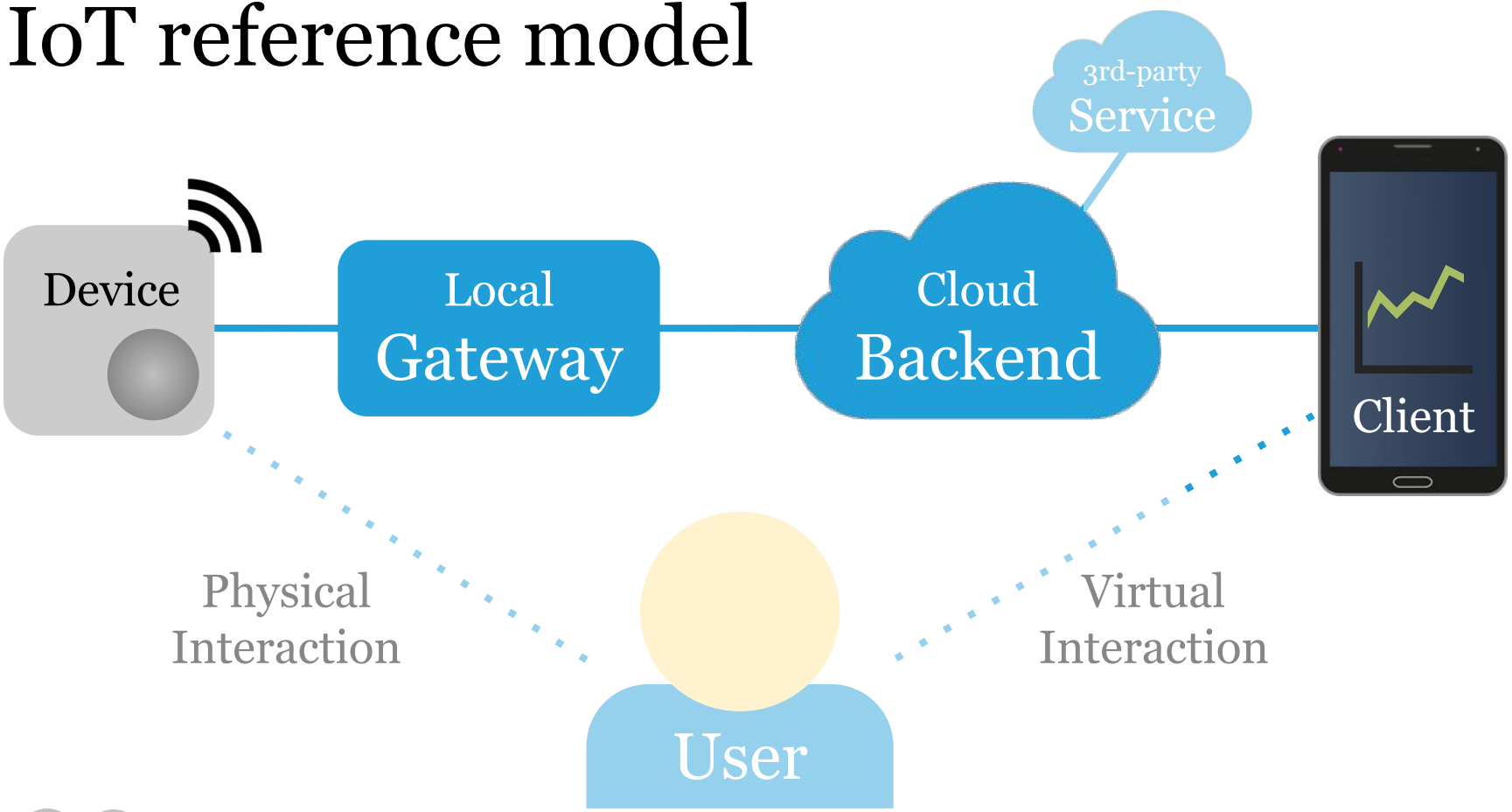
https://raspberrypi.org/products/raspberry-pi-zero-w/

1GHz, single core ARM CPU, 512 MB RAM

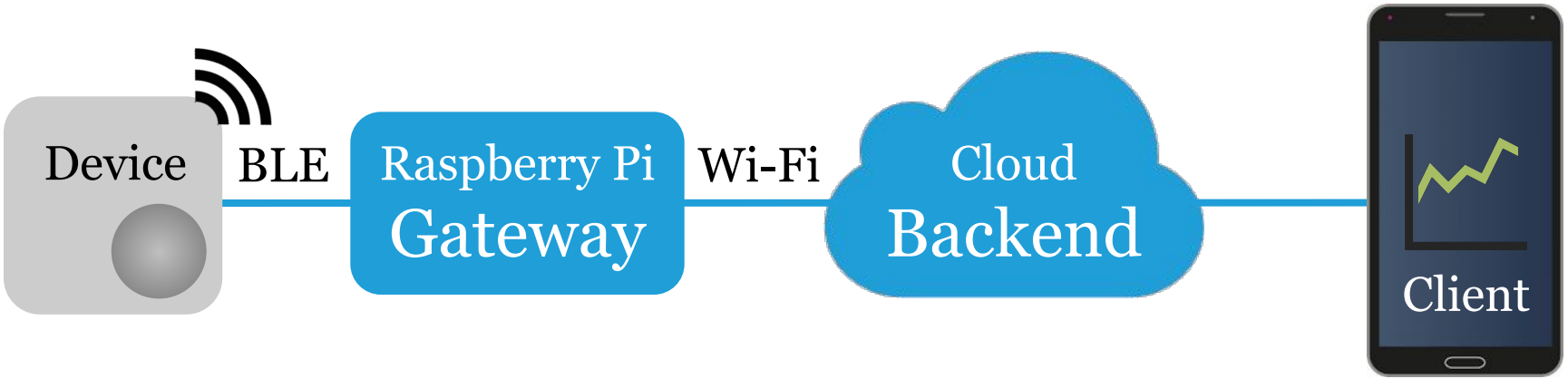
Mini HDMI, USB On-The-Go, Wi-Fi, Bluetooth, etc.

Hold the board at the edge, never touch a chip.

IoT reference model



Local gateway



Connects local devices/network to the backend, e.g. Raspberry Pi as a Bluetooth LE to Wi-Fi gateway.

Push vs. pull

A device (or gateway) can take the following roles:

- *Pushing* data to a service, as a *client*
- *Pulling** data from a service, as a *client*
- *Providing* data to clients, as a *service*
- *Accepting* data from clients, as a *service*

See GSIoT, Fig. 4-5. **Polling*: trying to pull in a loop.

Raspberry Pi BLE to Wi-Fi gateway

As a simple example we build a BLE to Wi-Fi gateway.

Devices are peripherals, the gateway is a BLE central.

The gateway can be either a HTTP client or a service.

We use POST to create, PUT/GET to change/get items.

Peripherals are services, the central is a client.

Use cases

Our BLE to Wi-Fi gateway supports these use cases:

Discovery — display a list of BLE device addresses*.

Remote sensing — get sensor values from an address.

Remote control — write command values to an addr.

*The result of a BLE scan or a preconfigured list.

Discovery .png

Device ← Gateway (Scan) ← … ← Client (GET)

Client can be local or remote, via backend, e.g.

```
$ curl -v https://LOCAL_IP/devices?uuid=…
{
  "devices": [
    {"bt_addr":"2c-41-a1-14-2e-b1"},
    {"bt_addr":"d7-76-54-22-b4-b1"}
  ]
}
```

Remote sensing .png

Device ← Gateway (Read) ← … ← Client (GET)

Client can be local or remote, via backend, e.g.

```
$ curl -v https://LOCAL_IP/devices\
/d7-76-54-22-b4-b1/0x180d/0x2a37/value
{
  "value": 180
}
```

Remote sensing

2.png, 3.png

Gateway is *polling* devices, *pushing* data to backend:

Device ← Gateway (Read, POST) → Backend

Or, device is *pushing* and gateway is *pushing* again:

Device (Notify) → Gateway (POST) → Backend

Remote control .png

Device ← Gateway (Write) ← … ← Client (PUT)

Client can be local or remote, via backend.

```
$ curl -vX PUT https://LOCAL_IP/devices\
/d7-76-54-22-b4-b1/0x180d/0x2a37/value \
--data '{"value": … }'
```

Implementing the use cases

How to implement the above use cases on the Pi?

We'll need a BLE central to scan, read, write, notify.

As well as Web client and Web service functionality.

And the gateway should start up when plugged in.

Let's look at these building blocks, in Node.js.

Node.js

Install Node.js, a runtime for server-side JavaScript:

```
$ wget https://nodejs.org/dist/v10.15.3\
/node-v10.15.3-linux-armv6l.tar.gz
$ tar -xzf node-v10.15.3-linux-armv6l.tar.gz
$ cd node-v10.15.3-linux-armv6l/
$ sudo cp -R * /usr/local/
$ node -v
```

New to JavaScript? Read Eloquent JavaScript.

Node.js BLE with *noble*

Install noble, a Node.js library to build a BLE central:

```
$ sudo apt-get update
$ sudo apt-get install bluetooth bluez \
libbluetooth-dev libudev-dev
$ npm install @abandonware/noble
```

To use BLE from the command line, use *bluetoothctl*:

```
$ sudo bluetoothctl
[bluetooth]# scan on | scan off | help | quit
```

Node.js BLE scan .js

Scan for BLE devices advertising e.g. a HRM service:

```
const noble = require("@abandonware/noble");

noble.on("discover", function(peripheral) {
  console.log("found:", peripheral);
});

noble.startScanning(["180d"], true); // HRM
```

Node.js BLE read

.js

```
p.connect((err) => { // peripheral connected
  p.discoverServices(["180d"], (err, svs) => {
    svs[0].disc…Cha…(["2a37"], (err, chs) => {
      chs[0].read((error, data) => {
        const value = data.readUInt8(0);
      });
    });
  });
});
```

Node.js BLE write

.js

```
p.connect((err) => { // peripheral connected
  p.discoverServices(["180d"], (err, svs) => {
    svs[0].disc…Cha…(["2A39"], (err, chs) => {
      const data = new Buffer(1);
      data.writeUInt8(value, 0);
      chs[0].write(data, noRes, (err) => {…});
    }); // noRes = write without response
  });
});
```

Node.js BLE notify

.js

```
p.connect((err) => { // peripheral connected
  p.discoverServices(["180d"], (err, svs) => {
    svs[0].disc…Cha…(["2a37"], (err, chs) => {
      chs[0].subscribe((error, data) => {…});
      chs[0].on("data", (data, isNoti) => {
        const value = data.readUInt8(0); });
    });
  });
});
```

Hands-on, 20': Bluetooth LE

Run the previous Bluetooth LE examples on the Pi.

Make sure Node.js, *npm* and *Noble* are all installed.

Use the *.js* link on each page or check the main repo.

To run a Node.js program *my.js*, type `$ node my.js`

Use the nRF5280 HRM BLE Peripheral for testing.

Node.js Web client .js

```
const http = require("http");

http.get("http://tmb.gr/hello.html", (rsp) => {
  let data = "";
  rsp.on("data", (chunk) => { data += chunk; });
  rsp.on("end", () => { console.log(data); });
}).on("error", (err) => {
  console.log(err.message);
});
```

Node.js secure Web client .js

```
const https = require("https"),
  qs = require("querystring"); // for POST body

let reqData = qs.stringify({ "value": 42 });
let options = { hostname: "postb.in", path:
  "/MY_POSTBIN_ID", method: "POST", headers: {
    "Content-Type": …, "Content-Length": … }};
let req = https.request(options, (res) => { … });
req.write(reqData); // write request body
req.end(); // sends the request
```

Node.js Web service .js

```
const http = require("http");
const server = http.createServer((req, res) => {
  res.statusCode = 200;
  res.setHeader("Content-Type", "text/plain");
  res.end("It works!\n");
});
server.listen(8080, "0.0.0.0", () => {
  console.log("Server running ...");
});
```

Node.js secure Web service .js

```
const fs = require("fs"),
  https = require("https");

const options = {
  key: fs.readFileSync("./key.pem"),
  cert: fs.readFileSync("./cert.pem"),
}
const server = https.createServer(
  options, (req, res) => {…});
server.listen(443, "0.0.0.0", () => {…});
```

Hands-on, 20': Web client & service

Run the previous Web client and service examples.

Use the *.js* link on each page or check the main repo.

To run a Node.js program *my.js*, type: `$ node my.js`

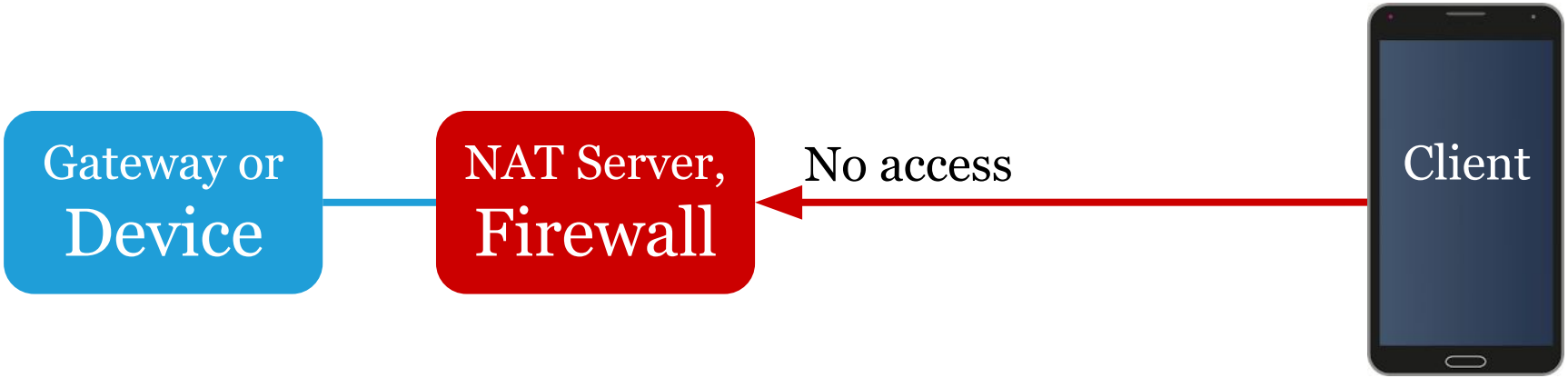
To display the IP address on the Pi, type: `$ ifconfig`

Then access http://IP:8080/ or https://IP:4443/

Remote access challenges

Devices behind a firewall or NAT are not accessible.

They usually have no public or no static IP address.

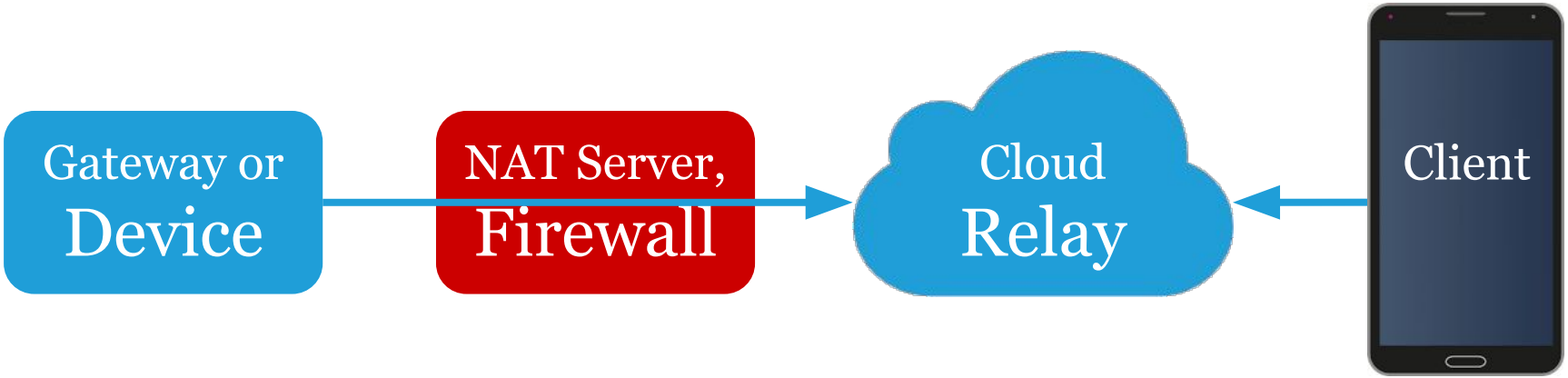


Opening incoming ports is not recommended.

Remote access via relay service

Relay services provide a public endpoint for access.

Based on an outgoing TCP connection to the relay.



E.g. Ngrok, Pagekite or Yaler (I'm a founder).

Why not just use VPN?

VPN extends the "local" network to clients — but also:

One compromised device can expose many devices.

VPN requires substantial resources on the device.

Managing VPNs can be a challenge at scale.

See Is VPN a false friend? by @clemensv.

Hands-on, 10’: Remote access

Install a Ngrok, Pagekite or Yaler relay service dæmon.

Configure it to publish the secure Node.js Web service.

Submit the URL to access your Web service via Slack.

Creating a *systemd* service

```
$ sudo wget -O /lib/systemd/system/my.service \
https://raw.githubusercontent.com/tamberg/ \
fhnw-iot/master/06/Bash/my.service
```

Edit *my.service* to run your Node.js command line:

```
$ sudo nano /lib/systemd/system/my.service
```

```
…
WorkingDirectory=/home/pi/fhnw-iot/06/Nodejs/
ExecStart=/usr/bin/node my.js
…
```

Using the service with *systemctl*

To start/stop/remove the systemd service, type:

```
$ sudo systemctl daemon-reload
$ sudo systemctl enable my.service
$ sudo systemctl start my.service

$ sudo systemctl stop my.service

$ sudo rm /etc/systemd/system/multi-user.\
target.wants/my.service
$ sudo rm /lib/systemd/system/my.service
```

Hands-on, 30': Putting it all together

Choose one of the BLE to Wi-Fi gateway use cases.

Implement it combining the above building blocks.

For the backend, use a relay service or ThingSpeak*.

Make it work end-to-end first, then make it robust.

*Depending on the use case you chose.

Summary

We used the Raspberry Pi as a BLE to Wi-Fi gateway.

Use-cases are discovery, remote sensing and control.

We looked at architectural patterns & involved roles.

Clients push or pull, services accept or provide data.

We saw challenges of & solutions for remote access.

Next: Messaging Protocols and Data Formats.

Homework, max. 3h

Start sketching some ideas for your team project, take the topics of upcoming lessons into account.

Here are some examples: IoT Gauge (Servo, Wi-Fi), Voodoo Sonic (DIY fabric switch, LEDs, LoRaWAN), Smart Homer (Infrared receiver, IR LED, Ethernet), Connected Foosball (PIR sensor, Wi-Fi, beamer)

A few servos, PIR and tilt sensors are available.

Feedback or questions?

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

Or email thomas.amberg@fhnw.ch

Thanks for your time.