Sensors

Summary of data collection using remote sensors

v2

Thomas Bryden

9 April 2025

Overview

2 Connections and communication
- 2 power lines (positive & negative)
- 1-4 communication lines

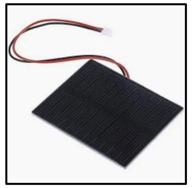
Physical property to measure
- Temperature
- Gas concentration
- Distance
- etc.

1 Sensor

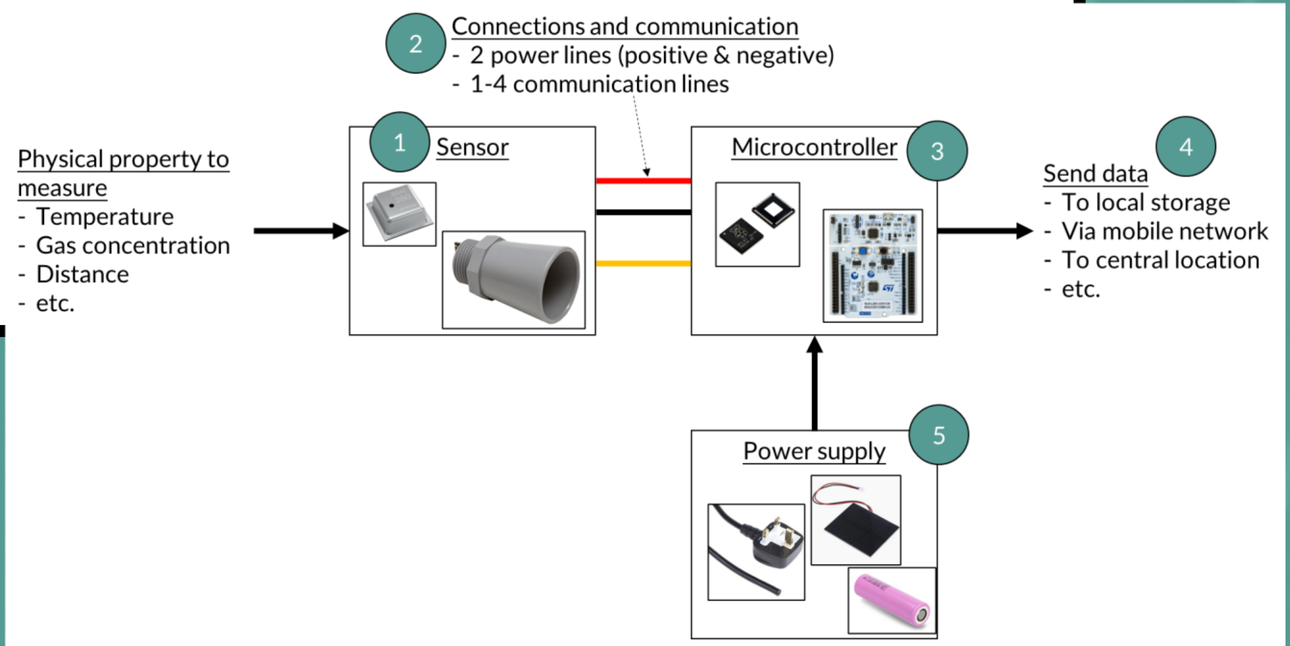
Microcontroller 3

4 Send data
- To local storage
- Via mobile network
- To central location
- etc.

Power supply 5



1. Sensor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1.a Sensor

- → Sensor measures a physical quantity and converts it to a communication protocol (communication protocols are described in slide 2.b)
- → The method of converting physical property to communication protocol varies for every sensor and depends on the physical quantity being measured
- → Each sensor needs to be supplied with power wires (1 positive and 1 negative) and communication wires (see slide 2.a)
- → Small circuits may be required next to the sensor:

Sensor purchased from Bosch

Small circuit next to sensor, in this case made by the company Pimoroni but could be done yourself

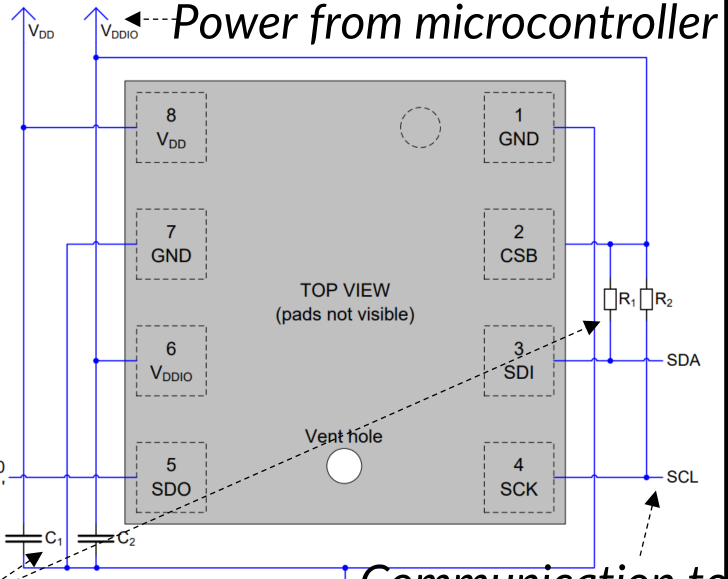
Output to microcontroller

1.b Sensor examples

Bosch BME280

Physical property to measure	Communication protocol to convert to
Humidity, pressure, temperature	I2C

Power from microcontroller



Sensor measuring physical property

Small local circuit

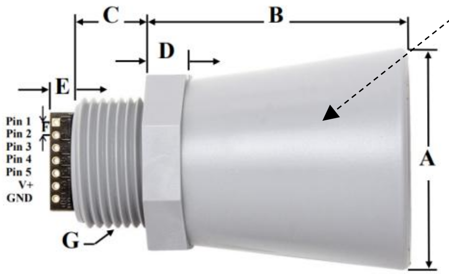
Figure 17: I²C connection diagram

Communication to microcontroller

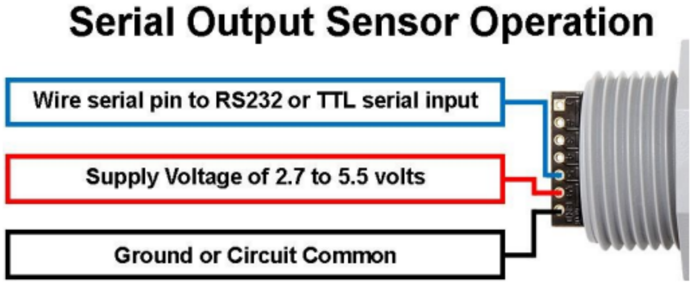
MaxBotix SCXL-MaxSonar-WR

Physical property to measure	Communication protocol to convert to
Ultrasonic distance	RS232

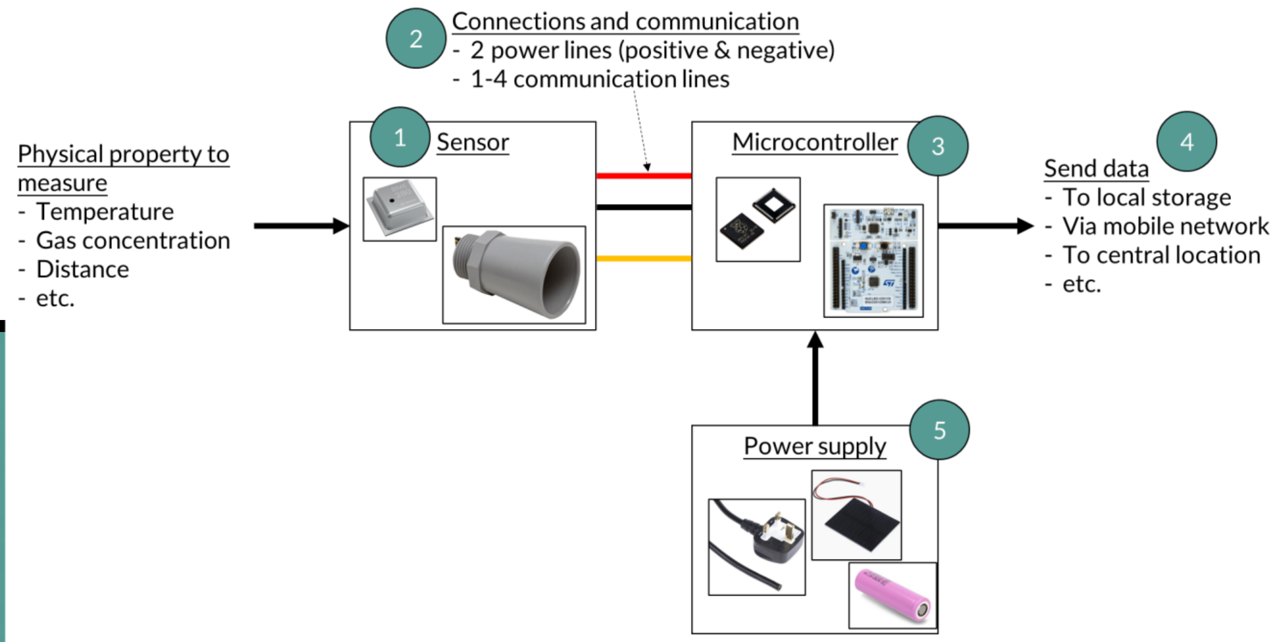
Sensor measuring physical property



Communication and power from microcontroller



2. Connections and communication



2.a Connections and communication

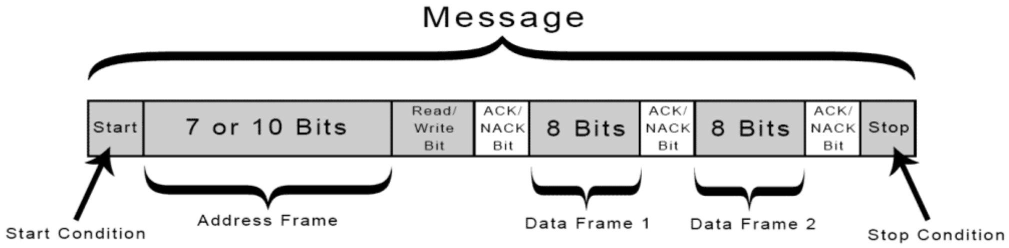
- Sensor needs to be connected to the microcontroller using power and communication wires
- The microcontroller may be located right next to the sensor on the same circuit board, or could be further away and a wire connects the two
- Power wires:
  - Two wires required, one for positive and one for negative
  - If the sensor is low power, it may be powered directly from the microcontroller. If more power (or higher voltage) than the microcontroller can deliver is required, a separate power supply circuit is needed
- Communication, see next slide

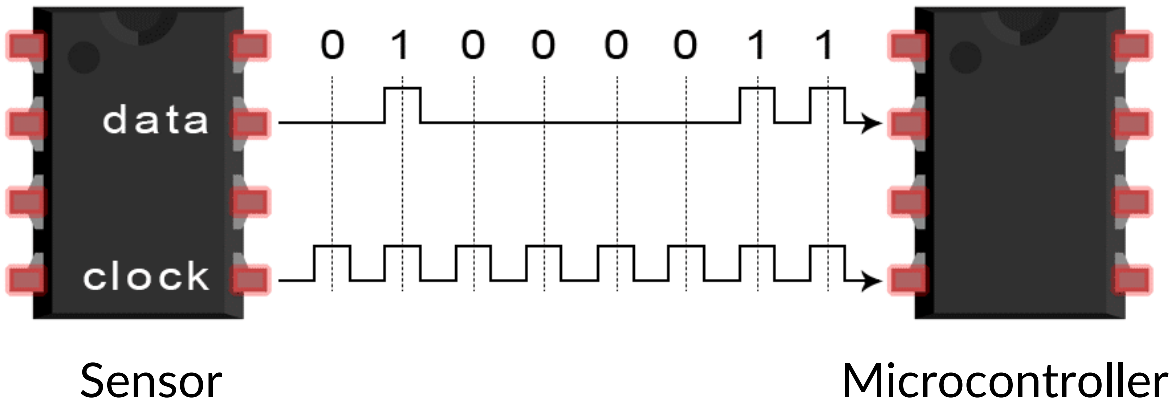
2.b Communication

- Number of communication wires depends on the sensor communication protocol used (which is determined by the sensor manufacturer, see slide 1.b)

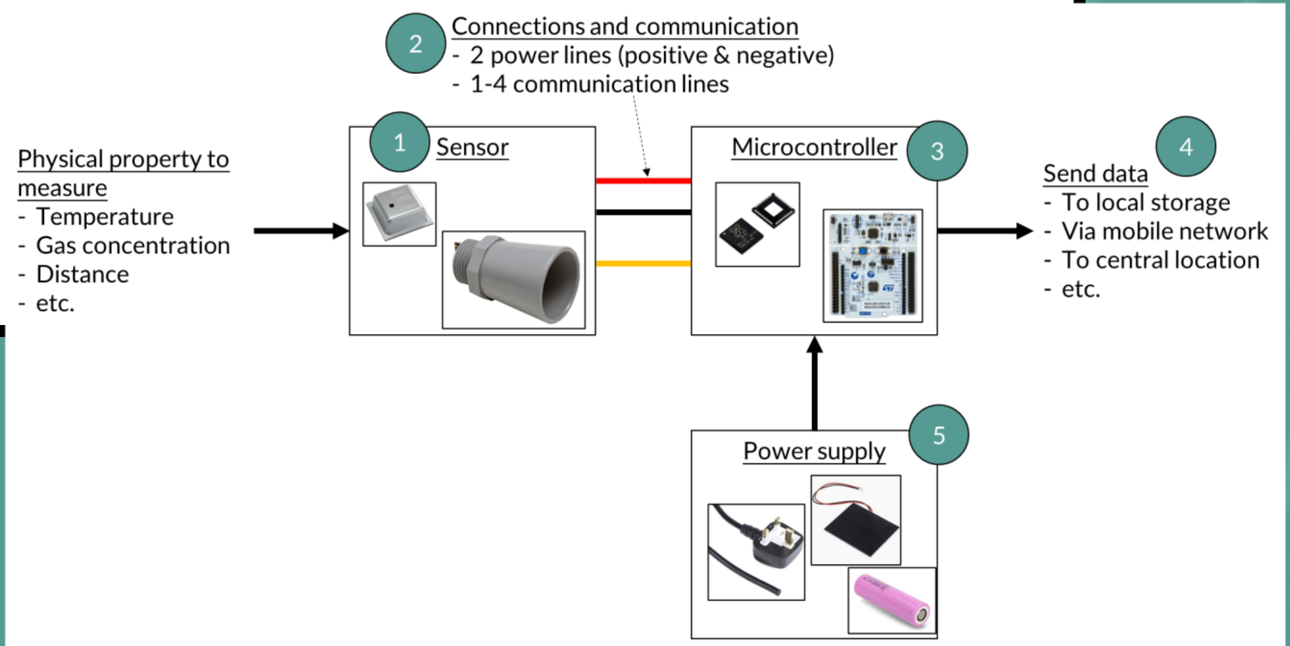
- The physical quantity measured by the sensor is converted to bits by the sensor manufacturer and then the communication protocol determines how these bits are sent to the microcontroller

- Common communication protocols include:
  - I2C https://circuitbasics.com/basics-of-the-i2c-communication-protocol/
  - SPI https://www.circuitbasics.com/basics-of-the-spi-communication-protocol
  - UART https://www.circuitbasics.com/basics-uart-communication/



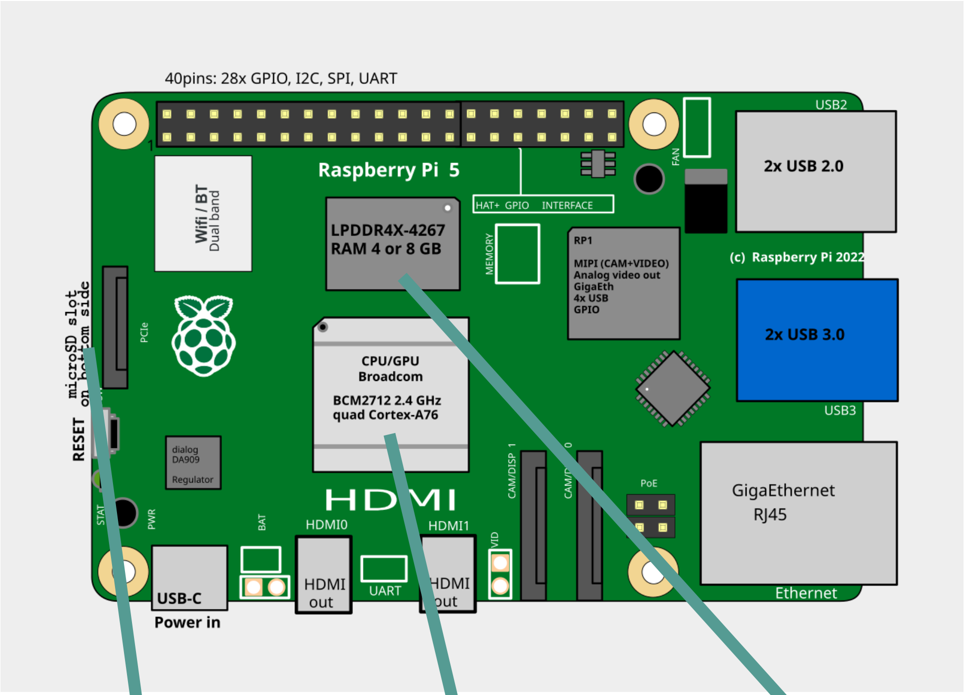


3. Microcontroller



3.a Microcontroller

- Contain all components on single chip
- Cons: Less powerful than full computer
- Pros: Smaller, cheaper, uses far less power
- Well suited for remote sensing applications

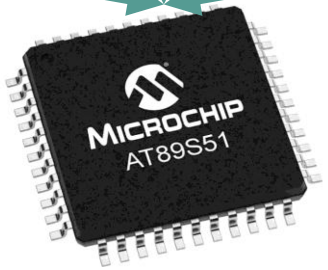


Full Computer

Permanent memory (SSD)

CPU

Temporary memory (RAM)



Microcontroller

3.a Microcontroller use

- Microcontroller program is written on a regular computer and then uploaded to the microcontroller where it runs in a loop

- Remote connections*:
  - Cannot remotely connect whenever you want, as listening for remote connections uses microcontroller power
  - When the microcontroller wakes up it can check if anyone wants to connect, or check for program updates

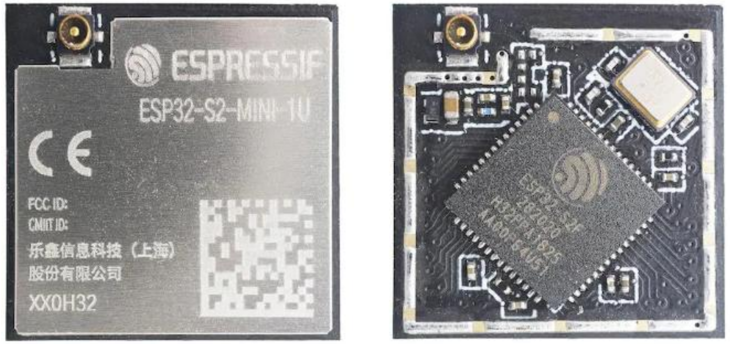
Typical microcontroller program structure

1. Connect to sensor and read data, see slide 2.b
2. Connect to internet
3. Send API POST request, containing sensor measurement, to website
4. Check website to see if any updates to program are available, if yes, download updates
5. Go to sleep for a set amount of time

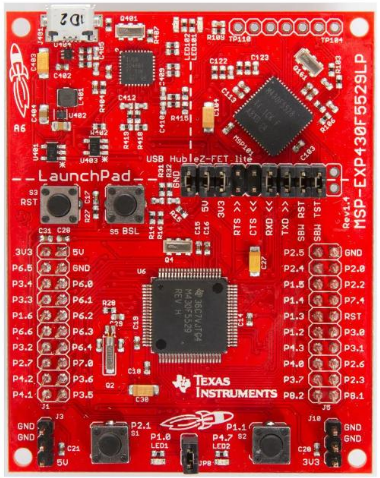
*This is my experience, not sure on how this works in industry

3.b Microcontroller examples

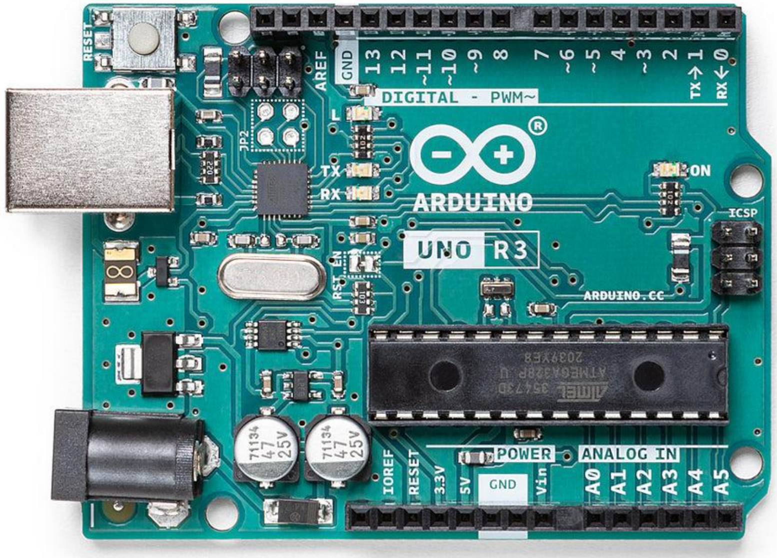
ESP32



Texas Instruments



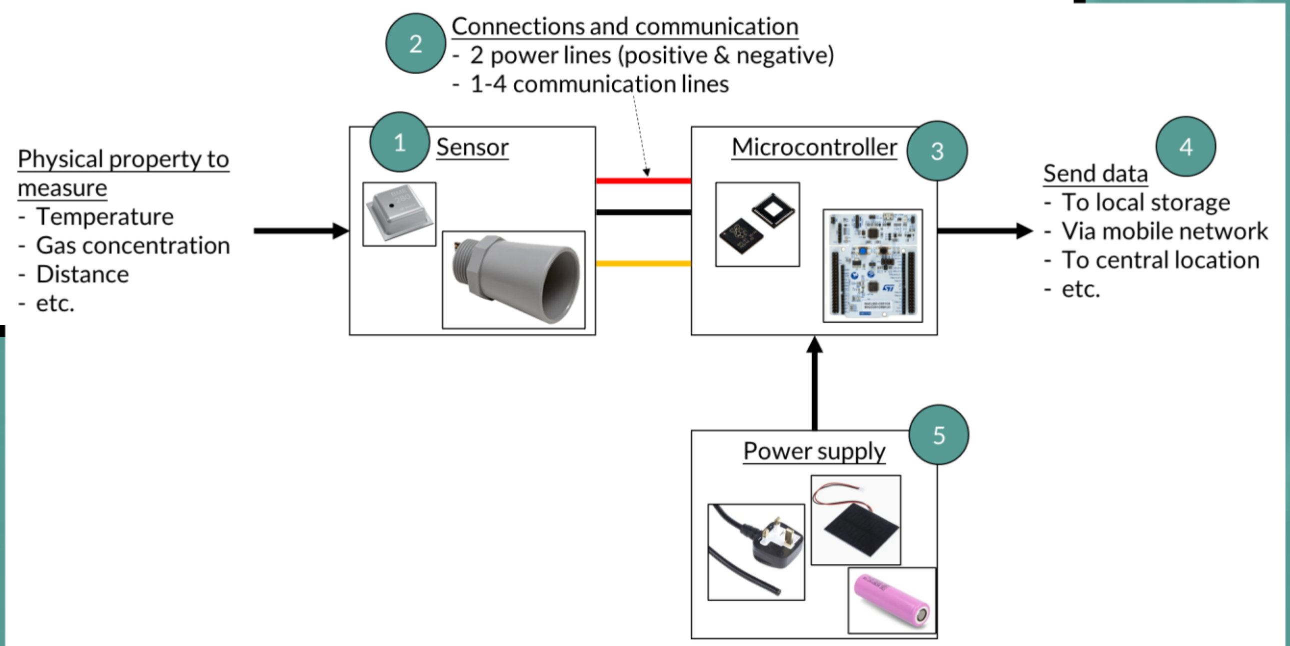
Arduino



STMicroelectronics

Whereas a Raspberry Pi is a full computer, not a microcontroller, requires more power

4. Send data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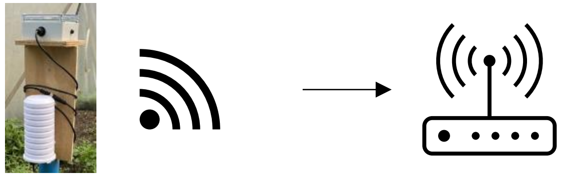
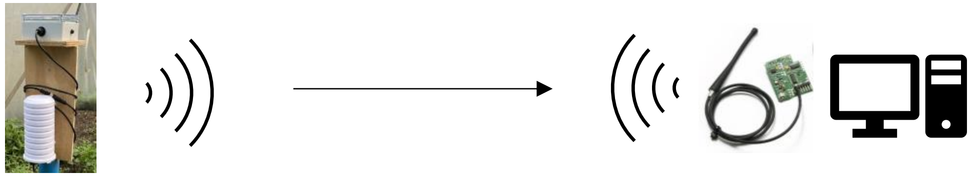
4.a Send data

→ Depends on location and available connections

1. Store locally on memory card		Need to physically collect data
2. Transmit via Wi-Fi		May not be a Wi-Fi connection available
3. Transmit via mobile network		Requires signal and mobile network usage costs
4. Transmit via radio frequency		Requires computer in another location to receive data

4.b Send data POST request

→ How I send data from the sensor to the database, may be different in industry

Microcontroller

Standard POST request:

bespokesensors.com/databases/post-sensor.php?api_key=XXX&temperature=21.26&humidity=85

```
String httpRequestData =
"api_key=" + apiKeyValue +
"&temperature=" +
String(temperat) + "&humidity="
+ String(humidity) + "";
```

→

Hosted webpage

bespokesensors.com/databases/post-sensor.php

1. Extract api_key and sensor data from POST
2. Use api_key to work out which table to insert sensor data into
3. Generate SQL query to insert data into table
4. Execute SQL query, data stored in database

```
if ($_SERVER["REQUEST_METHOD"] == "POST") {
…
$sensor_sql_init = "INSERT INTO " . $table . " (";
…
…
if ($sensor_conn->query($sensor_sql) === TRUE) {
```

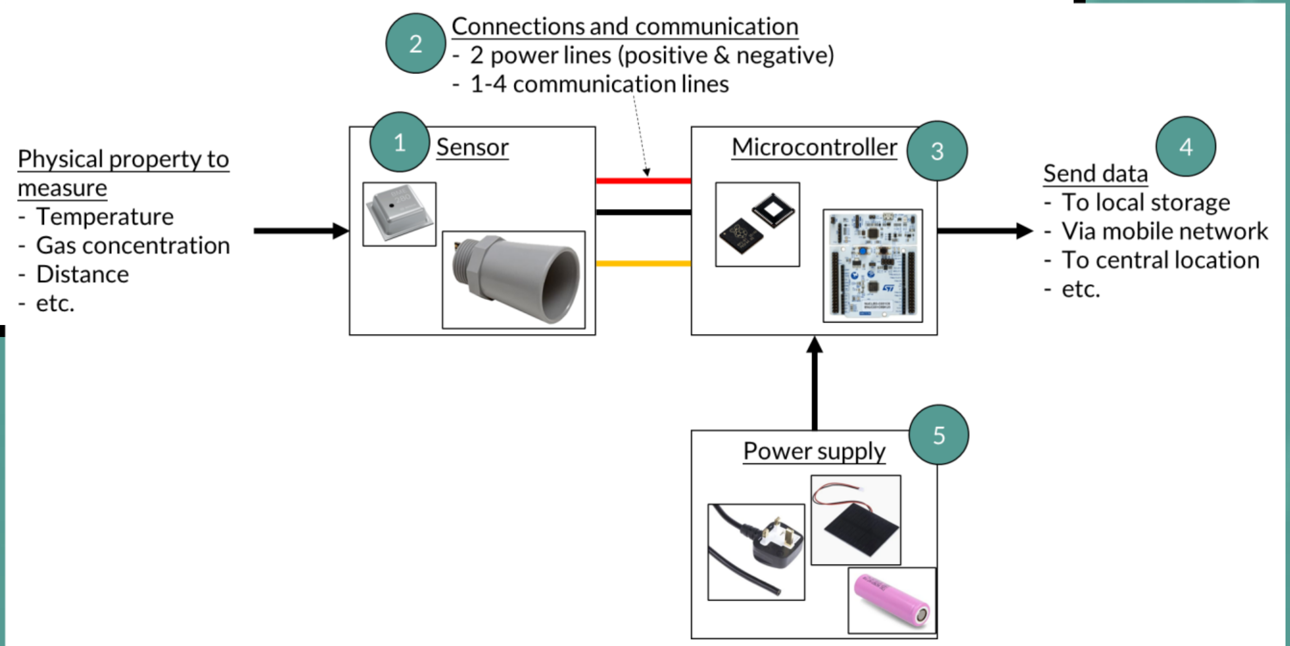
4.c Send data via radio frequency

- Radio frequency has the lowest power requirements, can be transmitted relatively long distances (typically up to 10 km in rural locations) and does not cost for data usage

- However, radio frequency requires another computer (a gateway) to receive the transmitted data, the gateway computer has a radio frequency receiver and is in a building with power and internet. The gateway computer uploads the received data to the database.

- The Things Network https://www.thethingsnetwork.org/ THE THINGS NETWORK
  - Creating a network of gateway computers around the world (LoRaWAN®)
  - My understanding is then you just use a nearby LoRaWAN® gateway instead of requiring your own gateway computer
  - Unsure how much this is used in industry

5. Power supply

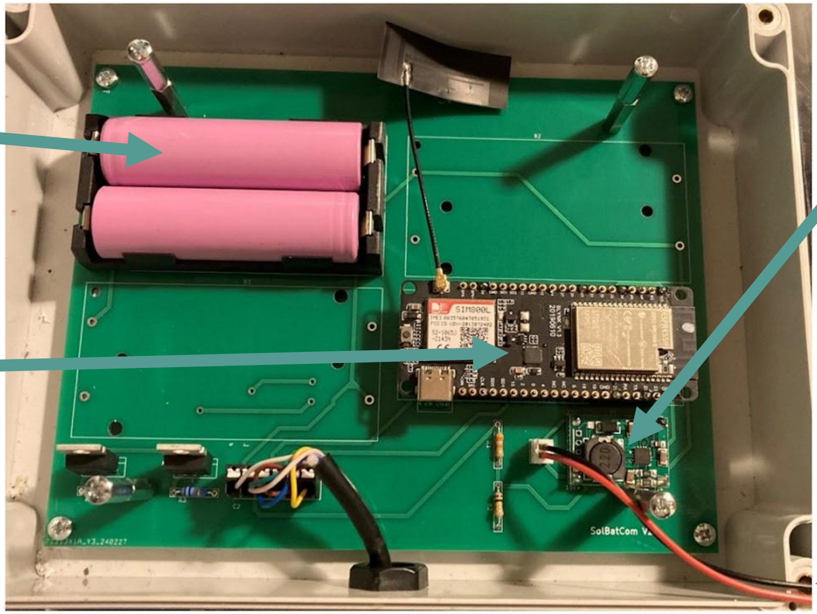


5.a Battery and solar

→ Almost always Lithium-ion battery and solar panel, could be mains connected if not remote

3. Batteries,
2.5-4.2 V

4. Microcontroller, with
onboard voltage regulator
in: 2.5–4.2 V, regulated: 3.3 V



2. Battery charger circuit,
in: 5.5 V, out: 2.5–4.2 V

1. Solar, in: 5.5 V

→ Quantity of data seems to normally be limited by power constraints

- Biosphere water sensors changing data collection frequency summer / winter

Conclusion

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