DIY IoT (Internet of Things)

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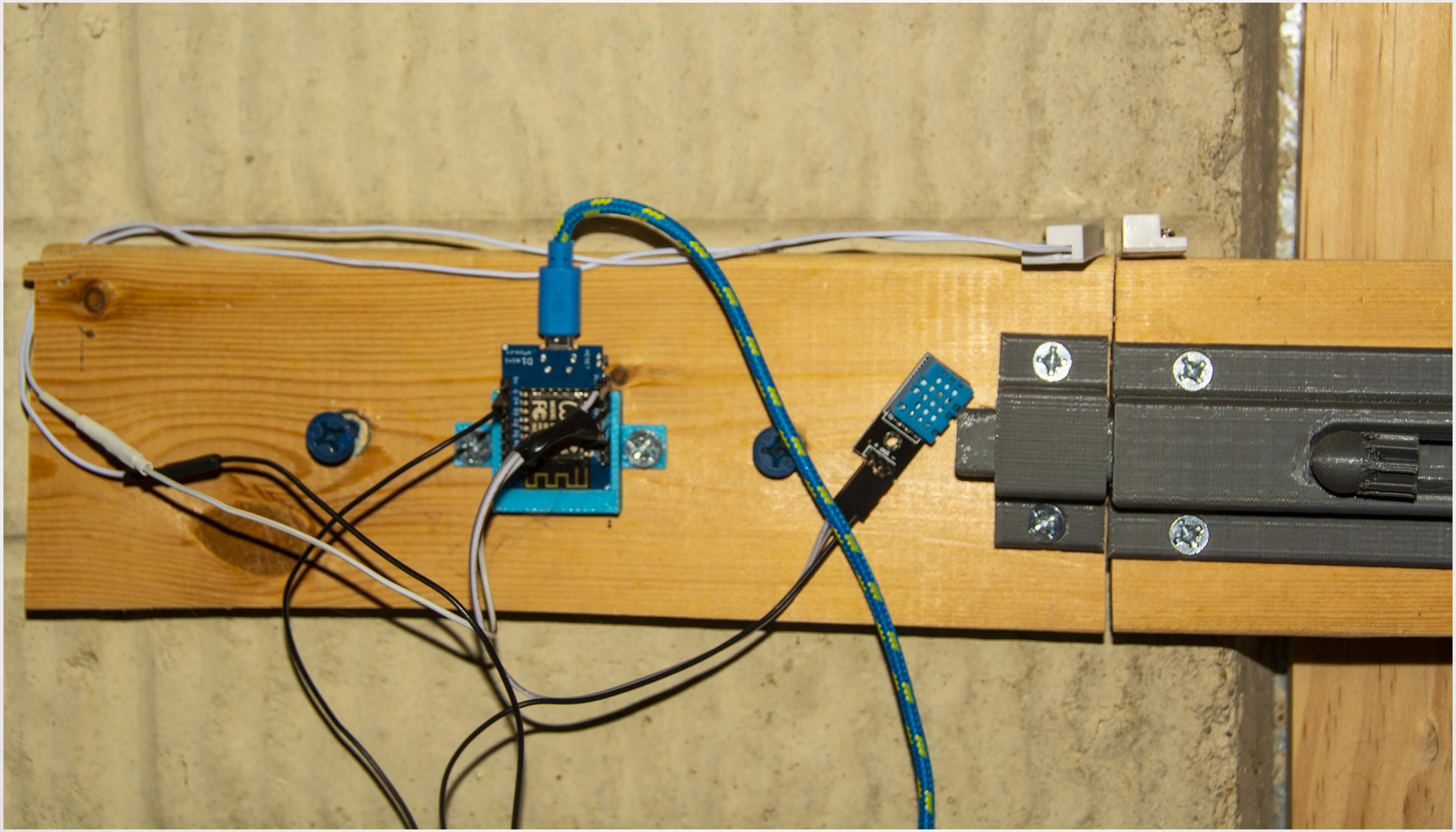
DIY IoT



DIY IoT

Goals of this presentation:

- Give you a good understanding of IoT devices
- Help you on your way to building your own IoT device(s)
- Give you some resources to help you get more info

DIY IoT

Agenda

- Definition of some terms
- Overview of an IoT system
- Overview of hardware components
- Details on software components
- Security Issues
- Example programming of an IoT device
- Available resources
- Hands on lab

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- Definitions
  - IoT (Internet of Things)
    - Physical objects with network connectivity
    - “smart” devices (lights, cars, alarms, etc.)
    - Sensors, actuators
    - Services and servers communicating with devices
    - Estimates of 50 billion devices by 2020

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- Definitions
  - MCU
    - Micro controller Unit
    - Small, generally single-purpose chip
    - Most often does not run an Operating System
  - MPU
    - Microprocessor Unit
    - Usually able to multi-process
    - Typically will run an Operating System

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Why DIY?

- “Smart” lights, switches, thermostats, etc. are all commercially available
- In the future, even more devices will gain network capabilities
- Control
- Security
- “for the fun of it”

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- Overview of an IoT System
  - End devices
    - Sensors (temperature, movement, light, switches, etc.)
    - Actuators (motors, relays, LEDs, etc.)
    - Displays (optional)
  - Programmable Microprocessor
    - Able to “talk” to devices
    - Has network connectivity
    - Possibly controlled by phone, tablet, etc.
  - Network and servers
    - Data collection and analysis
    - Handling notifications (messaging, emails, etc.)

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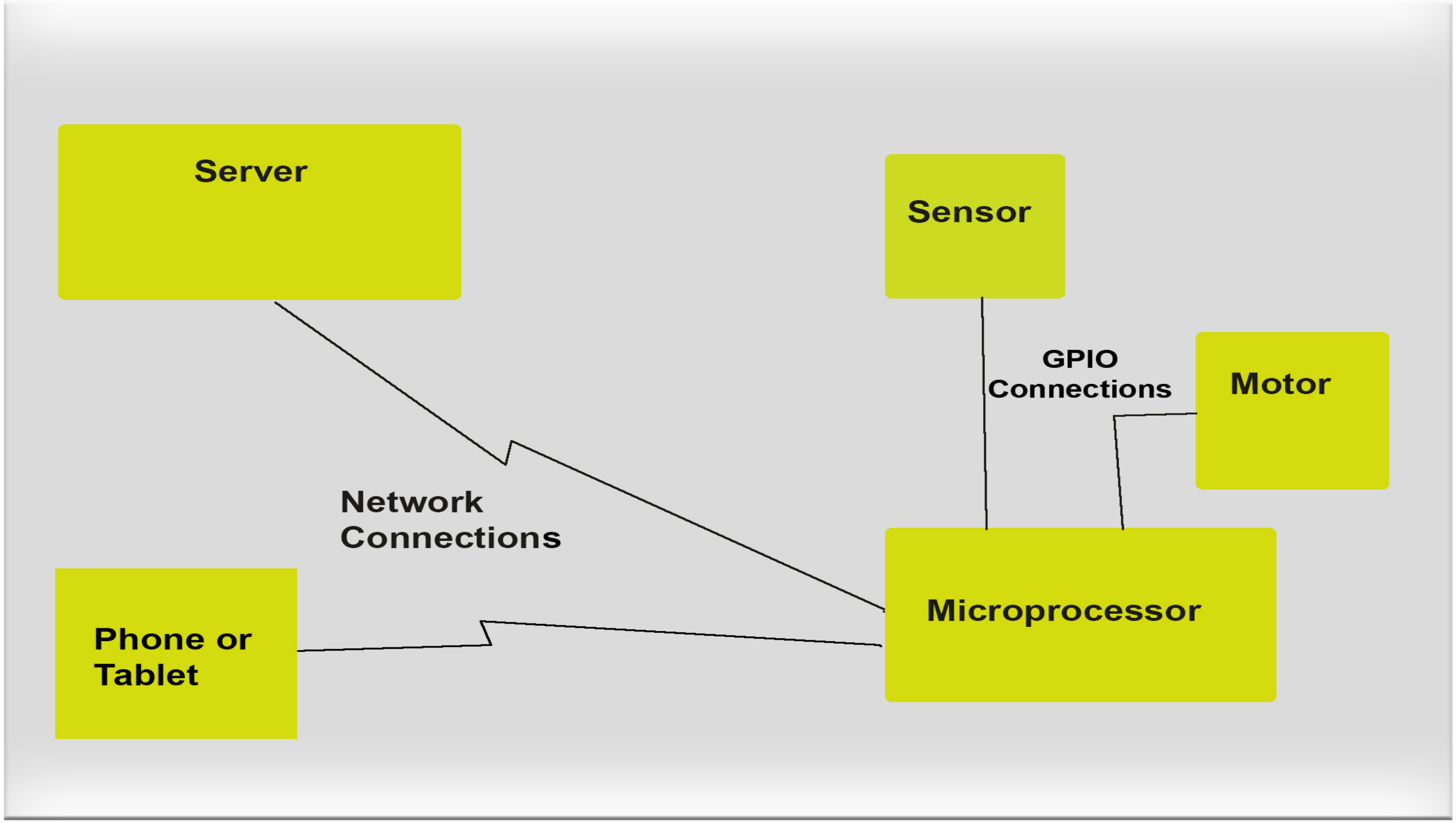
- Graphical Overview of a Typical IoT System



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- Hardware Components
  - Processor
    - More of an SoC “System on a Chip” than just a CPU
    - Programmable
    - Quite a few choices available (more on this later)
  - Sensors and Actuators
    - Sensors report back information about the physical environment
    - Actuators (motors, switches, etc.) do something in the physical environment

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- Hardware Components
  - Network
    - Can be wireless or wired
    - Differentiates IoT from previous sensors/actuators
    - Various sorts of wireless available
      - Internet lists 31 possible IoT networks
      - Wifi
      - Others requiring a gateway to get to the internet
        - Bluetooth/BLE
        - LoRa Radio
        - ZigBee

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- Processor Types (MCU and MPU)
  - Many different vendors and varieties available
    - Wikipedia lists 32 MCU and 65 MPU makers
    - Many vendors offer more than one model
  - Often the biggest single decision when designing an IoT system

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- Some Common MCU Types
  - Arduino
  - ESP8266 (Many form factors including NodeMCU)
  - ESP32
  - ST Microelectronics
- Common characteristics
  - Cheap
  - GPIO pins
  - Fairly slow CPU speed
  - Will have limited memory for program (sketch)

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- Some Common MPU types
  - Raspberry Pi
  - Beagleboard
  - Pine A64
  - Asus Tinkerboard
- Common characteristics
  - On-board compilers
  - Can run more than one program at the same time
  - Online community support
  - Limited numbers of GPIO and other pins
  - Likely more expensive than an MCU

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- Sensors and Actuators
  - Use GPIO (General Purpose Input Output) pins from the CPU
  - Various protocols may be supported
    - I2C – Can handle multiple devices on one set of 2pins
    - UART – Universal Asynch Receive/Transmit
      - Serial port, needs two pins (one XMIT, one RCV)
      - Not all GPIO pins will support this
    - SPI – Serial Peripheral Interface
      - Needs 4 pins, likely defined by hardware
    - PWM – Pulse Width Modulation
      - Needs an analog pin
    - Custom Protocols (such as DHT11)

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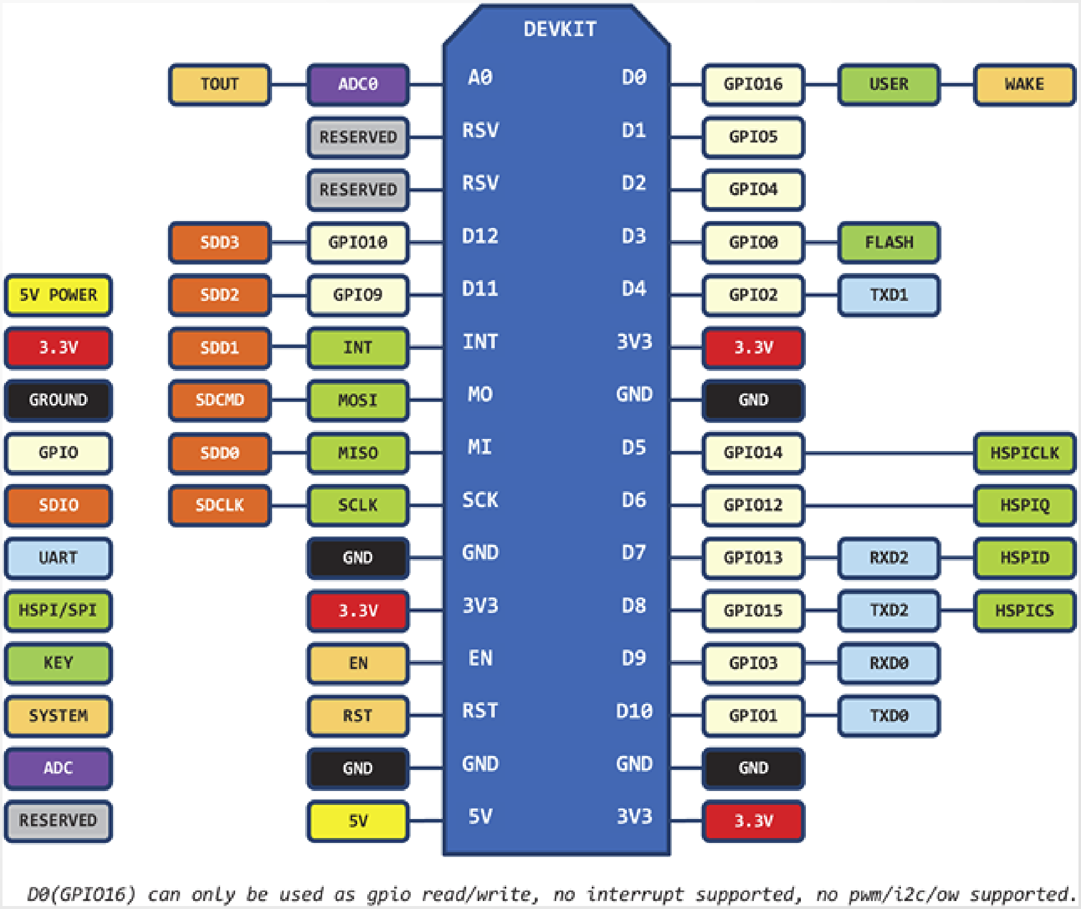
- GPIO Ports matter
  - You will need to check the specs for your exact chip
  - NodeMCU diagram



	TOUT	ADC0	A0	D0	GPIO16	USER	WAKE
		RESERVED	RSV	D1	GPIO5		
		RESERVED	RSV	D2	GPIO4		
	SDD3	GPIO10	D12	D3	GPIO0	FLASH	
5V POWER	SDD2	GPIO9	D11	D4	GPIO2	TXD1	
3.3V	SDD1	INT	INT	3V3	3.3V		
GROUND	SDCMD	MOSI	MO	GND	GND		
GPIO	SDD0	MISO	MI	D5	GPIO14		HSPICLK
SDIO	SDCLK	SCLK	SCK	D6	GPIO12		HSPIQ
UART		GND	GND	D7	GPIO13	RXD2	HSPID
HSPI/SPI		3.3V	3V3	D8	GPIO15	TXD2	HSPICS
KEY		EN	EN	D9	GPIO3	RXD0	
SYSTEM		RST	RST	D10	GPIO1	TXD0	
ADC		GND	GND	GND	GND		
RESERVED		5V	5V	3V3	3.3V		

D0(GPIO16) can only be used as gpio read/write, no interrupt supported, no pwm/i2c/ow supported.

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- Issues when selecting external devices
  - Power requirements
    - May be 3.3 or 5 volts, may not match your CPU
    - May require more current than your board can provide (i.e. could need an external power supply)
  - Connectivity
    - May require special cables
    - May need more GPIO pins than you have available
  - Openness
    - May have proprietary issues, making it hard to modify to do what you want

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- Software Components
  - Several languages available
    - Arduino IDE uses C/C++
    - Micro Python available on more capable processors
    - Lua script for ESP boards
    - Arduino has some visual block editors available (ArduBlock, Snap4Adruino)
    - Processors running their own OS have an even wider choice, both scripting and compiled languages.

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- Software Components
  - Software is usually needed external to your IoT device
    - Somewhere to send monitor readings
      - MQTT broker
      - IFTTT (if this then that)
      - Flow controller (such as Node-Red)
      - Browser client
    - Someone to send info that triggers an action to take
      - MQTT broker
      - Flow controller
      - Browser

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- Definitions
  - Message Broker (MQTT)
    - Program that handles the queuing up of input messages (publishing) and sending out to interested clients (subscribing)
    - Messages are organized by topics, with formats like directory paths (i.e. /myhouse/basement/window/1)
    - Several are available, we will be using an Open Source one named mosquitto
    - Fairly low overhead, can be run on small systems (such as a Raspberry Pi)

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- Software Components
  - Protocols
    - TCP/IP underlies almost everything you will do
      - Have to create or obtain an IP address
      - TCP/IP routing matters
    - Extensible Messaging and Presence Protocol (XMPP)
    - Message Queuing Telemetry Transport (MQTT)
    - HTTP
    - Advanced Message Queuing Protocol (AMQP)
    - Constrained Application Protocol (CoAP)

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- Software Components
  - Programming IDE (Integrated Development Environment)
    - Most common is the Arduino IDE – even for other MCUs
  - Frameworks
    - May help you get running without doing much (or any) coding
    - Several available
      - ESPEasy - https://github.com/letscontrolit/ESPEasy
      - ESPurna - https://bitbucket.org/xoseperez/espurna
      - Espidf - http://docs.platformio.org/en/latest/frameworks/espidf.html
      - Tasmota - https://github.com/arendst/Sonoff-Tasmota

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- Software Components
  - Some Additional Elements
    - NodeRED
      - drag and drop visual flow control, runs on a server (Linux,Windows, Mac)
    - IFTTT (If this then that) - https://ifttt.com/
      - Create applets to tie services together
    - MQTT Brokers
      - Mosquitto – easy to set up, runs on a server (Linux, Windows, Mac)
      - io.adafruit.com – run by Adafruit, provides a dashboard

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- Software Components
  - Some Additional Elements
    - Cloud Provider – many available
      - Amazon AWS
      - Microsoft Azure
      - IBM Watson
      - Adafruit IO

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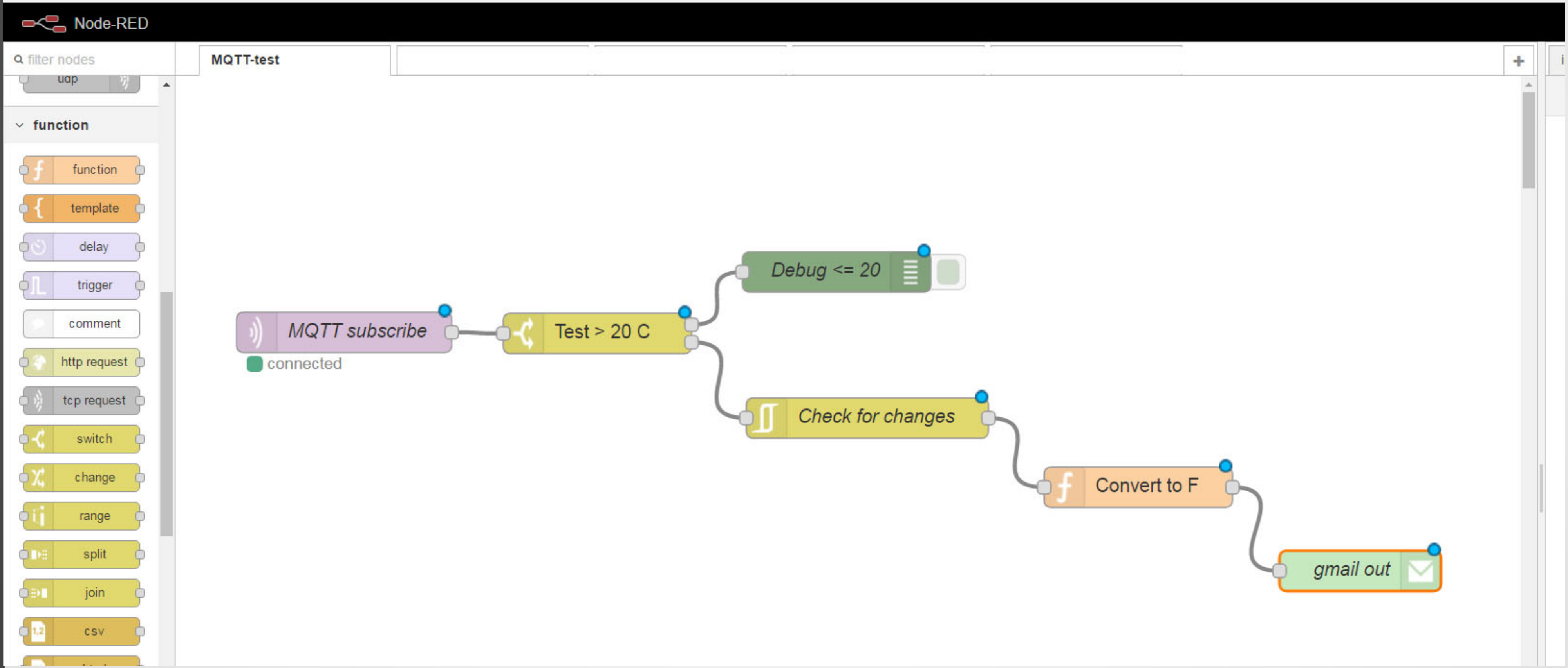
Example of a Node-RED flow



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- Security Issues
  - Unencrypted wireless network traffic can be seen by anyone close by
    - Do you really want a stranger to be able to open your garage door?
  - Default router passwords are known to all the 'bad guys'
  - Vendors of commercial IoT devices have been known to be lax when it comes to security
    - Google for “IoT light bulb security” - scary
  - Bottom line – don't trust anyone else to make your devices secure

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- Security Issues
  - OTA (Over the air updates)
  - Using a DIY IoT system for home security
    - Need to consider the monitoring issue
      - Commercial vendors are 24x7; you will need to sleep
    - You control who sees what
    - Several good open source packages available
      - ZoneMinder - https://zoneminder.com/
      - openhab - https://www.openhab.org/
      - Home Assistant - https://home-assistant.io/

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- Example Programming
  - Simple ESP8266 program

```
/*
 ESP8266 Blink by Simon Peter
*/
void setup() {
  pinMode(LED_BUILTIN, OUTPUT);     // Initialize the LED_BUILTIN pin as an output
}
// the loop function runs over and over again forever
void loop() {
  digitalWrite(LED_BUILTIN, LOW);   // Turn the LED on by making the voltage LOW
  delay(1000);                      // Wait for a second
  digitalWrite(LED_BUILTIN, HIGH);  // Turn the LED off by making the voltage HIGH
  delay(2000);                      // Wait for two seconds (to demonstrate the active low LED)
}
```

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- Example Programming
  - Simple ESP8266 program with networking

```
#include <ESP8266WiFi.h>
#include <WiFiClient.h>
#include <ESP8266WebServer.h>

const char* ssid = "........";
const char* password = "........";

ESP8266WebServer server(80);
const int led = 13;
```

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- Example Programming
  - Simple ESP8266 program with networking

```
void handleRoot() {
  digitalWrite(led, 1);
  server.send(200, "text/plain", "hello from esp8266!");
  digitalWrite(led, 0);
}
```

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- Example Programming
  - Simple ESP8266 program with networking

```
  void handleNotFound(){
  digitalWrite(led, 1);
  String message = "File Not Found\n\n";
  message += "URI: ";
  message += server.uri();
  message += "\n";
  for (uint8_t i=0; i<server.args(); i++){
    message += " " + server.argName(i) + ": " + server.arg(i) + "\n";
  }
  server.send(404, "text/plain", message);
  digitalWrite(led, 0);
}
```

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- Example Programming
  - Simple ESP8266 program with networking

```
void setup(void){
  pinMode(led, OUTPUT);
  digitalWrite(led, 0);
  Serial.begin(115200);
  WiFi.begin(ssid, password);

  // Wait for connection
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
```

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- Example Programming
  - Simple ESP8266 program with networking

```
Serial.print("Connected to ");
  Serial.println(ssid);
  Serial.print("IP address: ");
  Serial.println(WiFi.localIP());

  server.on("/", handleRoot);
  server.on("/inline", [ ](){
    server.send(200, "text/plain", "this works as well");
  });
  server.onNotFound(handleNotFound);

  server.begin();
  Serial.println("HTTP server started");
}
```

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- Example Programming
  - Simple ESP8266 program with networking

```
void loop(void){
  server.handleClient();
}
```

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- Other Resources
  - Arduino IDE - https://www.arduino.cc/en/main/software
  - ESP8266 Arduino reference docs
    - https://github.com/esp8266/Arduino/tree/master/doc
  - Mosquitto MQTT broker - https://mosquitto.org/download/
  - Node-RED flow manager - https://nodered.org
  - General Esp8266 tutorials – https://hackster.io
  - Google AIY Kit - http://www.microcenter.com/product/483414/AIY_Voice_Kit

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- Other Resources
  - YouTube videos
  - Node-Red MQTT on Raspberry Pi https://youtu.be/WxUTYzxIDns
  - Installing mosquitto https://youtu.be/Y-H6grpWdec
  - Videos showing combined data flows:
    - https://www.youtube.com/watch?v=QU24kMqpFdY
    - https://www.youtube.com/watch?v=YahFRqf-rFAO

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- Other Resources
  - Some of the books available
    - ESP8266: Programming NodeMCU Using Arduino IDE - Get Started With ESP8266 by UpSkill Learning
    - Building an IoT Node for less than 15 $: NodeMCU & ESP8266 by Claus Kühnel
    - Learning ESP8266 — Build the Internet of Things with the Arduino IDE and Raspberry Pi
      - Not yet released
    - Neil Kolban ebook
      - http://neilkolban.com/tech/esp8266/

DIY IoT

- Summary
  - The price of MCU hardware with WIFI / Bluetooth makes this cost effective now
    - Esp8266
    - Esp32
  - The price of MPU (SBC) hardware makes it possible to keep your data contained with only going outside with specific data
    - Raspberry Pi
    - Beaglebone
  - Advances in software frameworks allows for limited programming experience needed
    - ESPeasy
    - Node-Red
  -

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- Summary
  - Advances in Home Automation Open Source Frameworks allow for complete home automation systems
    - Home Assistant
    - OpenHAB
  - Existing protocols are leveraged for their simplicity
    - MQTT
    - HTTP
- Our contact info
  - siehputz@gmail.com
  - https://github.com/siehputz/penguicon2018

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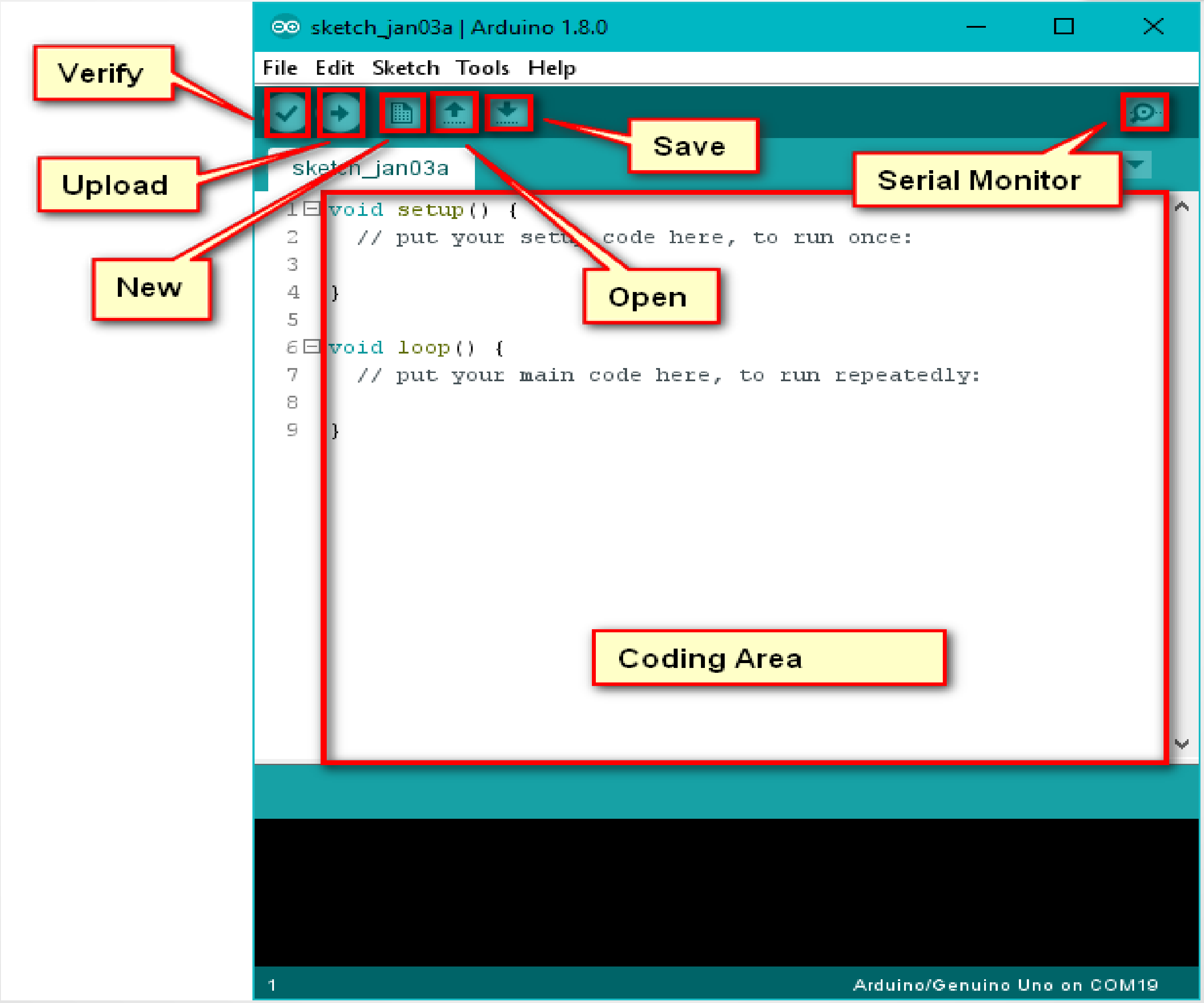
sketch_jan03a | Arduino 1.8.0
File Edit Sketch Tools Help
Verify
Upload
New
Open
Save
Serial Monitor
sketch_jan03a
Coding Area
1
Arduino/Genuino Uno on COM19

```
void setup() {
  // put your setup code here, to run once:

}

void loop() {
  // put your main code here, to run repeatedly:

}
```

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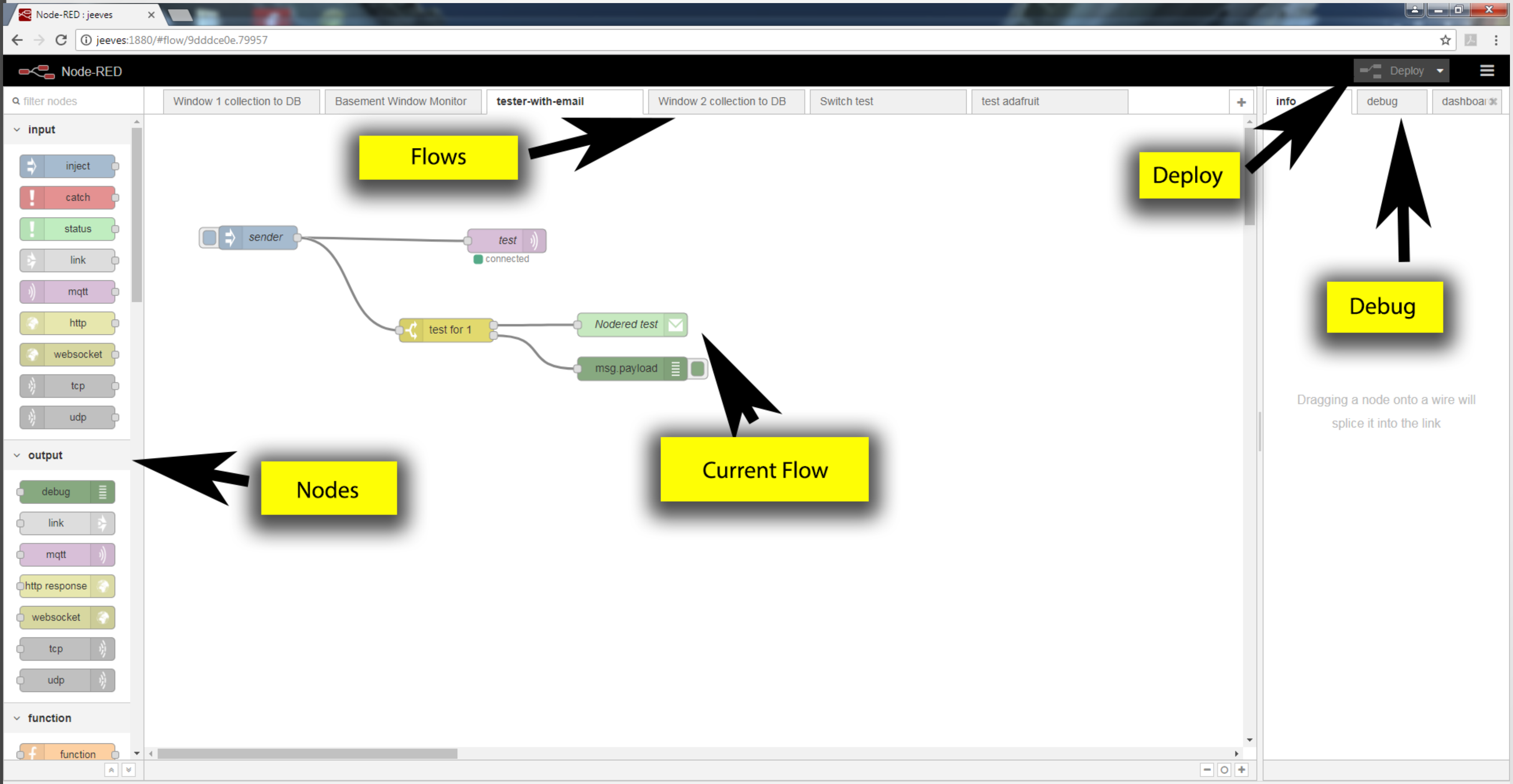

jeeves:1880/#flow/9dddce0e.79957

Dragging a node onto a wire will splice it into the link