A Beginner's Guide to IoT using ESP8266 and MicroPython

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Winter Is Coming

So come down to Sunny Puerto Rico

Agenda

- Presentation
  - IoT
  - MQTT
  - ESP8266
  - MicroPython
- Workshop
  - Hands on with ESP8266 & MicroPython

IoT

IoT - What is it?

- Internet-of-Things (IoT)
- Inter-networking of devices, computers/micro-controllers, sensors, actuators and communications
- Use of sensors to measure/monitor the local environment
- Use of actuators to contor/modify the local environment
- Use of networking to deliver messages between devices and backends
- Use of micro-controllers to coordinate sensors, actuators and networking
- [More info on IoT](https://en.wikipedia.org/wiki/Internet_of_things)

IoT - Types

- Consumer-Residential
- Consumer-Personal
- Business
- Industrial

IoT Devices - Consumer

IoT Devices around the house

NEST Thermostat

NEST Indoor Camera

Samsung Refrigerator

Samsung Refrigerator

IoT Devices - Personal

Fitbit Surge

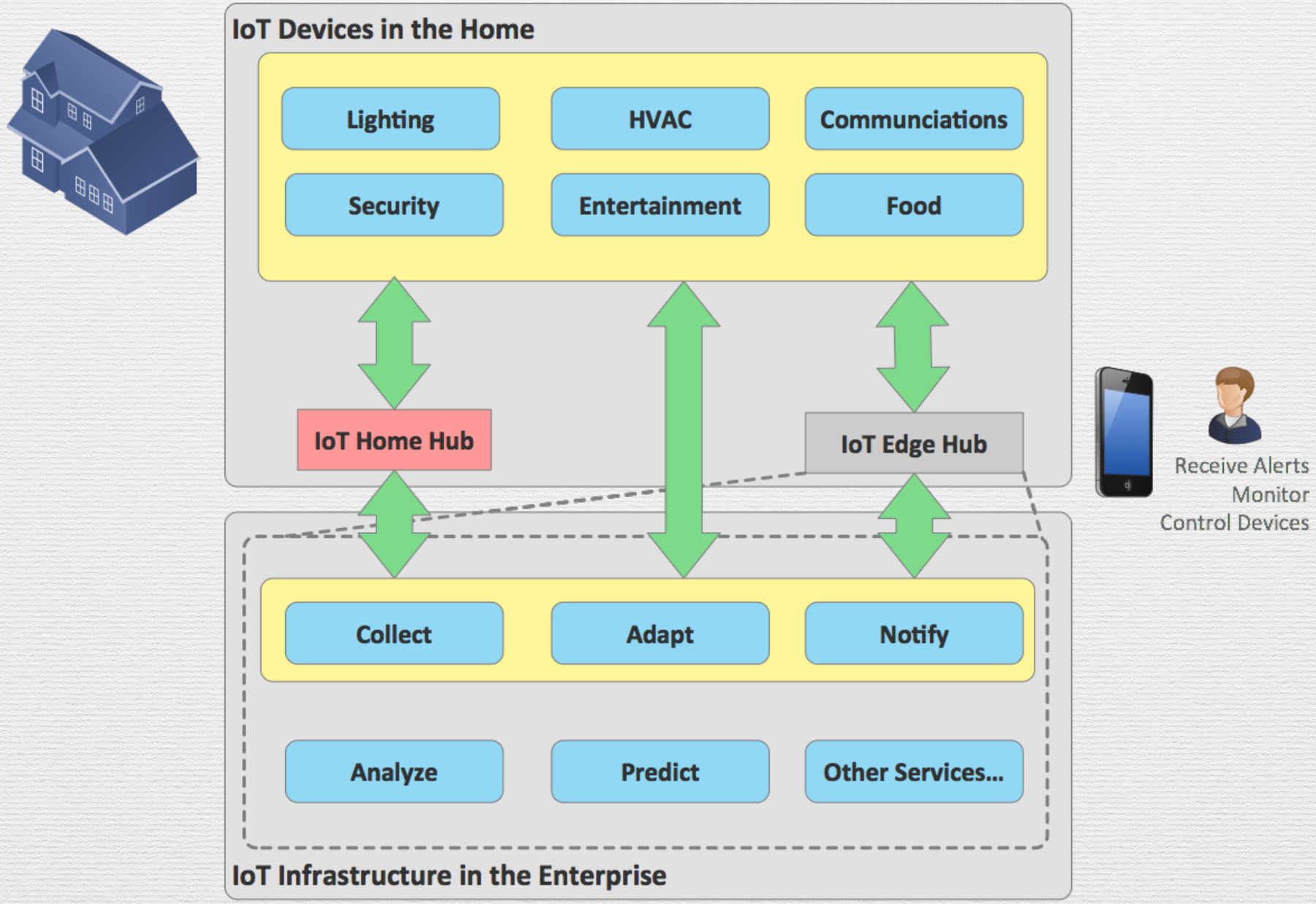
Qardioarm Blood Pressure Monitor

Images © Nest Inc., Samsung Inc., FitBit Inc., Cardio Inc.

IoT - Components

- Client Side Components
  - IoT Sensors
  - IoT Actuators
  - IoT Nodes
  - IoT Hubs
  - IoT Edge Devices
- Server Side Components
  - Gather Data
  - Analyze Data
  - Predict
  - Adapt
  - Machine Learning

The IoT Connected Home



MQTT

MQTT - What is it?

- Message Queue Telemetry Transport
- Publish/Subscribe Model
- Extremely simple and lightweight messaging protocol
- Designed for constrained devices
- Designed for low-bandwidth, high-latency or unreliable networks
- Minimizes network bandwidth and device resource requirements
- Offers various Quality-of-Service assurances
- Ideal for machine-to-machine(M2M)/IoT devices
- [More info on MQTT](http://mqtt.org/faq)

MQTT - Components

- MQTT Publishers
  - Devices can publish messages
- MQTT Subscribers
  - Devices can subscribe/listen to messages
- MQTT Topics
  - Clients publish messages to specific topics
  - Clients subscribe to messages on specific topics
- MQTT Brokers
  - Brokers provide Topic Queues for publishers to publish messages to and subscribers to receive messages on
  - Brokers coordinate receipt of published messages and distribution of subscribed messages

MQTT - Some Implementations

- Eclipse Paho (https://eclipse.org/paho/)
- Apache ActiveMQ/MQTT Adapter (http://activemq.apache.org/mqtt.html)
- RabbitMQ/MQTT Adapter (https://www.rabbitmq.com/mqtt.html)
- Mosquitto (https://mosquitto.org)
- HiveMQ ()

IoT Hardware

The IoT Hardware Options

Sensors

- Temp/Humidity/Pressure
- PIR Motion
- Light
- Accelerometers
- Liquid Level
- pH
- Magnetic

Actuators

- Relays
- DC Motor Controllers
- Servo/Stepper Controllers
- Solenoid/Pumps
- Etc...

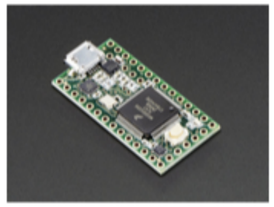
MicroControllers/SBC

Arduino

Raspberry Pi

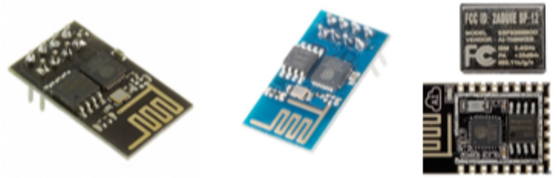
BeagleBone

Teensy



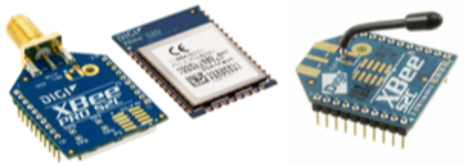
Communications

WiFi



Bluetooth Low Energy (BLE)

ZigBee



Long Range Radio (LoRa)

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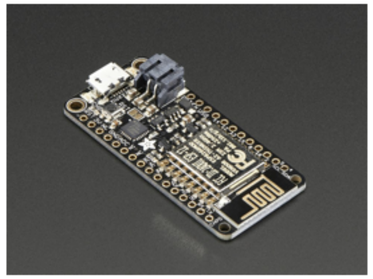
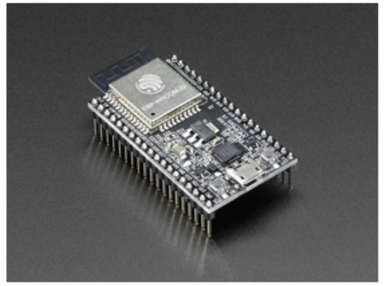
Example of IoT Development Boards

Adafruit

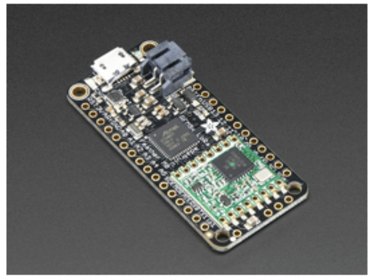
Feather HUZZAH ESP8266



Espressif ESP32 Dev Board



Feather LoRa



SparkFun

SparkFun ESP8266 Thing

SparkFun ESP32 Thing

PyCom

PyCom WiPy

PyCom LoPy

PyCom SiPy

Images © Adafruit Industries, SparkFun Inc., Pycom Inc.

ESP8266

IoT Using ESP8266

Sensors

- Temp/Humidity/Pressure
- PIR Motion
- Light
- Accelerometers
- Liquid Level
- pH
- Magnetic

ESP8266 MicroController
+ WiFi Communications

Actuators

- Relays
- DC Motor Controllers
- Servo/Stepper Controllers
- Solenoid/Pumps
- Etc...

Images © Adafruit Industries, SparkFun Inc., Espressif Inc.

ESP8266 - Functional Specs.

- System-on-Chip (SoC) from Espressif
- Highly integrated SoC with WiFi solution
- Integrated Tensilica L106 32-bit processor with on-chip SRAM
- Can perform as a standalone application or slave to host MCU
- WiFi can act as Access Point or Station mode.
- [More info on Espressif ESP8266 WiFi solution](https://espressif.com/en/products/hardware/esp8266ex/overview)

ESP8266 - Technical Specs.

- 32-bit RISC CPU: Tensilica Xtensa LX106 running at 80MHz
- 64 KB of instruction RAM, 96 KB of data RAM
- External QSPI flash - 512 KB to 4 MB* (up to 16 MB is supported)
- IEEE 802.11 b/g/n Wi-Fi
- WEP or WPA/WPA2 authentication, or open networks
- 16 GPIO pins
- SPI, I^2C,
- UART on dedicated pins, plus a transmit-only UART can be enabled on GPIO2
- 1 10-bit ADC
- [More info on Espressif ESP8266](https://en.wikipedia.org/wiki/ESP8266)

Adafruit Feather HUZZAH ESP8266

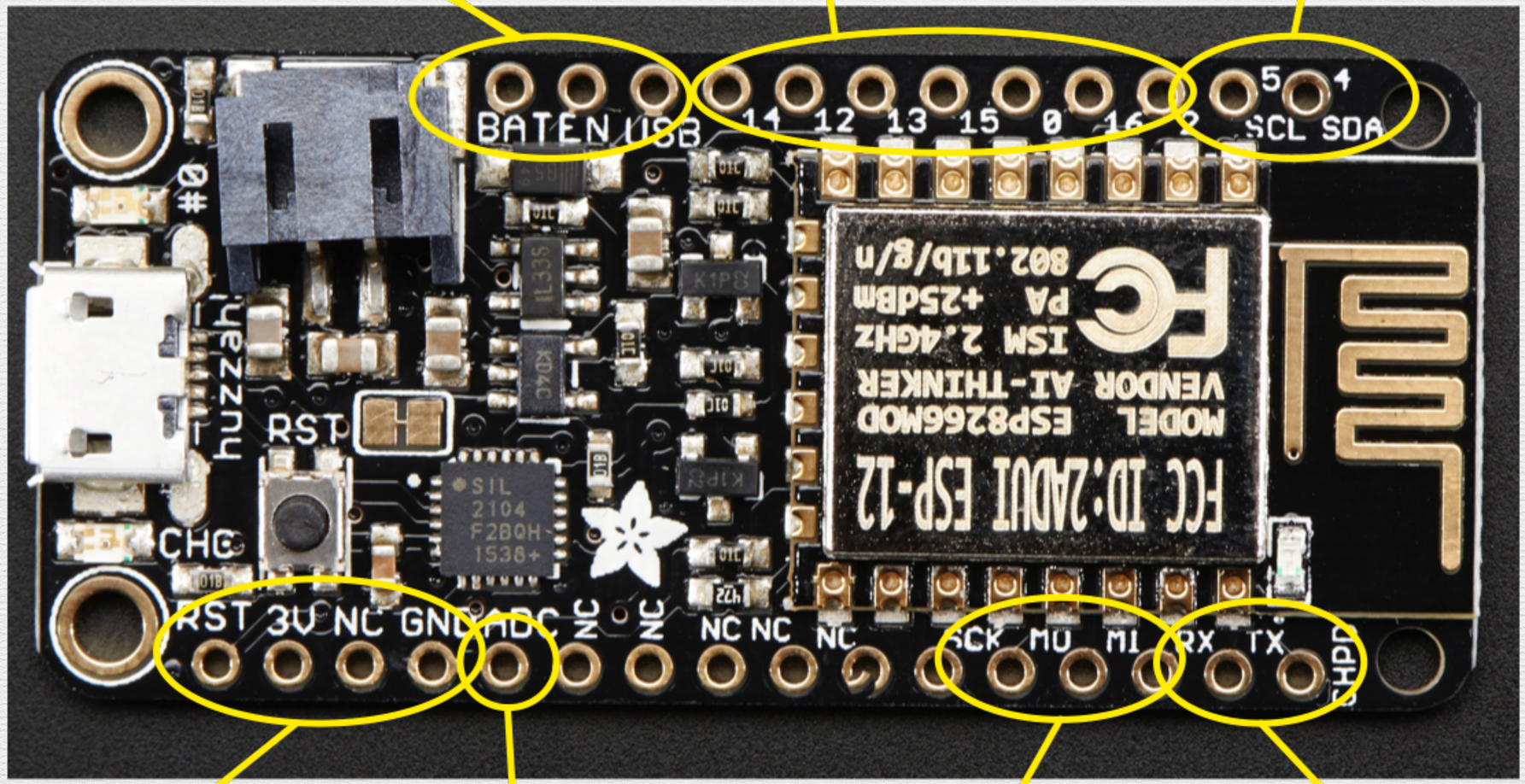
- A development board from Adafruit incorporating the ESP8266 WiFi module
- Incorporates the ESP8266 @ 80 MHz or 160 MHz
- 4MB of Flash
- 3.3V regulator with 500mA peak current output
- CP2104 USB-Serial convertor board with 921600 max baudrate
- 9 GPIO pins - can be used as I2C and SPI
- 1 analog input 1.0V Max
- 2 Pins connected to LEDs
- Power/Enable pin
- Reset button
- [More info on Adafruit Feather HUZZAH ESP8266](https://learn.adafruit.com/adafruit-feather-huzzah-esp8266/overview)

Adafruit Feather HUZZAH ESP8266

Power/Control Pins
BAT: Postitive Voltage from LiPoly Battery
USB: Positve Voltage for USB Micro
EN: 3.3V Regulator Enable

GPIO Pins (3.3V I/O)
Pins 0, 2, 4, 5, 12, 13, 14, 15, 16

I2C Pins
SCL: Serial Clock
SDA: Serial Data



Power/Control Pins
3V: 3.3V Regulator Output
GND: Ground
RST: Reset

A/D Pins
ADC: Analog-to-Digital Input

SPI Pins
SCK: Serial Clock
MOSI: Master Output Slave Input
MISO: Master Input Slave Output

Serial Pins
RX: Receive
TX: Transmit

Images © Adafruit Industries

IoT Device Firmware/Operating Systems

- RTOS (FreeRTOS) (http://www.freertos.org)
- Arduino (https://www.arduino.cc)
- NodeMCU Lua (http://www.nodemcu.com/index_en.html)
- MicroPython (https://micropython.org)

MicroPython

MicroPython - What is it?

- Based on Python 3.x
- Implements a small subset of the Python standard library
- Optimized to run on microcontrollers in constrained environments
- Fits and runs within 256K of code space and 16K of RAM
- Developed by Dr. Damien P. George (Cambridge University)
- [More info on MicroPython](https://micropython.org)
- [More info on MicroPython for ESP8266](http://docs.micropython.org/en/latest/esp8266/)

MicroPython Standard/Micro Libraries

- Builtin Functions
- array, gc, math, sys
- ubinascii, ucollections, uhashlib, uheapq
- uio, ujson, uos, ure
- usocket, ussl
- ustruct, utime, uzlib
- [More info on MicroPython Standard Libraries](http://docs.micropython.org/en/latest/esp8266/library/index.html)

MicroPython Specific Libraries

- machine
- micropython
- network
- uctypes
- [More info on MicroPython Specific Libraries](http://docs.micropython.org/en/latest/esp8266/library/index.html)

MicroPython ESP8266 Port Libraries

- esp
- [More info on MicroPython ESP8266 Port Libraries](http://docs.micropython.org/en/latest/esp8266/library/esp.html)

MicroPython External Libraries

- micropython-lib GitHub project
- umqtt
- [More info on MicroPython-Lib Project](https://github.com/micropython/micropython-lib)

MicroPython - Firmware - Pre-Compiled Binaries

- Precompiled Binaries are available for various boards
- Available for download from the MicroPython Downloads page
- Easiest way to get started with MicroPython

MicroPython - Firmware - Compile From Source

- Source code repository is available for each supported board
- Platform specific compiler tool chain needs to be downloaded
- Uses the Tensilica compiler tool chain from Espressif for ESP8266
- Uses a VM launched via Vagrant for compiling
- Allows selective inclusion of necessary modules
- Allows inclusion of external libraries
- User modules can be 'frozen' into the binary
- Frozen modules store the Python source with the firmware
- Frozen bytecode stores the compiled bytecode with the firmware
- Modules need to be placed in a specific directory
- Compilation process is long but binaries are more space efficient
- Flash the resulting binary to the device

MicroPython - Firmware - Boot Sequence

- Two files are used to boot up the device
- boot.py is the first file that is loaded and executed
- main.py if available is then loaded
- main.py is optional and contains the user application program
- main.py can either the full code or can call applicaton code in other application modules
- main.py is usually edited on the host machine and then pushed to the device
- If there is no main.py then REPL automatically launches

MicroPython - Firmware Installation

- Download the latest pre-compiled firmware from the MicroPython Downloads page (http://micropython.org/download#esp8266)
- Download and install the firmware deployment tool, esptool.py, from the following page (https://github.com/espressif/esptool)
- Connect the device (Adafruit Feather HUZZAH ESP8266) to the computer using the USB Micro cable
- Identify the serial port that is connected to the device
- Install the firmware onto the device using the esptool.py deployment tool
- Reset the device so that it boots into the MicroPython REPL

MicroPython - Firmware Deployment Tool (esptool.py)

esptool.py -h

```
$ esptool.py
usage: esptool [-h] [--port PORT] [--baud BAUD]

{load_ram,dump_mem,read_mem,write_mem,write_flash,run,image
_info,make_image,elf2image,read_mac,chip_id,flash_id,read_f
lash,verify_flash,erase_flash,version}
    ...
esptool: error: too few arguments
```

MicroPython - Firmware Deployment Tool (esptool.py)

```
$ esptool.py --port /dev/tty.SLAB_USBtoUART erase_flash

$ esptool.py --port /dev/tty.SLAB_USBtoUART --baud 460800
write_flash --flash_size=detect 0 esp8266-20170108-
v1.8.7.bin
```

MicroPython - Making the Connection

- Through the serial port REPL
- Through the WiFi WebREPL

Making the Connection - SerialREPL

- Connect the device using the USB cable

```
$ screen /dev/tty.SLAB_USBtoUART 115200


>>>
```

Making the Connection - WebREPL

```
$ screen /dev/tty.SLAB_USBtoUART 115200
>>> import webrepl_setup
WebREPL daemon auto-start status: disabled
Would you like to (E)nable or (D)isable it running on boot?
(Empty line to quit)
> E
To enable WebREPL, you must set password for it
New password: password
Confirm password: password
Changes will be activated after reboot
Would you like to reboot now? (y/n) y
>>>
...
 WebREPL daemon started on ws://192.168.4.1:8266
 Started webrepl in normal mode
 could not open file 'main.py' for reading
 MicroPython v1.8.7-7-gb5a1a20a3 on 2017-01-09; ESP module with ESP8266
 Type "help()" for more information.
 >>>
```

MicroPython - machine Module

- The machine module contains functions and classes that control the hardware on the board
- Some of the functions available:
  - reset(), freq(), idle(), sleep(), deepsleep()
- Some of the classes available:
  - Pin - controls the I/O pins on the board
  - I2C - a two-wire serial protocol for communications with devices
  - SPI - a synchronous serial protocol driven by a master
  - Timer - hardware timers
  - UART - implements the standard UART/USART duplex serial protocol
  - WDT - watchdog timer used to restart the system when the application crashes.

MicroPython - network Module

- The network module provides network drivers and configurations
- Contains the WLAN class which contains the following methods:
  - wlan.active(), wlan.connect(), wlan.disconnect(), wlan.scan(), wlan.status(), wlan.isconnected(), …

MicroPython - esp Module

- The esp module contains functions related to the ESP8266 module
- Examples of methods are:
  - esp.deepsleep()
  - esp.flash_id()
  - esp.flash_write()
  - esp.flash_read()
  - esp.flash_erase()

MicroPython-Lib - umqtt.simple Module

- The umqtt.simple module contains functions related to connecting to an MQTT Broker
- Examples of methods are:
  - connect(), disconnect()
  - publish(), subscribe()
  - set_callback()
  - set_last_will()
  - wait_msg()
  - check_msg()

Questions???

Workshop

Downloads Need

- micropython (http://micropython.org/download#esp8266)
- USB SLAB Driver for OS X (https://www.silabs.com/products/development-tools/software/usb-to-uart-bridge-vcp-drivers)
- esptool.py (https://github.com/espressif/esptool)
- mpfshell (https://github.com/wendlers/mpfshell)
- mosquito (https://mosquitto.org/download/)
- sample code at github (https://github.com/spicecoaster/pycaribbean2017)
  - Workshop subdirectory

Topics

- Flash the ESP8266 with MicroPython
- Connect to REPL on ESP8266
- Enable WebREPL and connect to ESP8266
- Hello World of MicroPython - Blinky.py
- Connecting the ESP8266 to WiFi as a Station
- Sample MQTT publish from ESP8266
- Sample MQTT subscribe from ESP8266

Important Commands

- esptool
- mpfshell
  - mpfshell -c ‘open tty.SLAB_USBtoUART’
  - mpfshell/ > put main.py
- screen
  - screen /dev/tty.SLAB_USBtoUART 115200
  - Press Enter if the screen is blank
  - You should see ‘>>> ‘ prompt

WiFi Details

- For WebREPL
  - Find the WiFi AccessPoint that has the form ‘MicroPython-aaaaa’ where ‘aaaaa’ is based on your boards MAC Address. Look behind the board for your boards Access Point
  - Password: micropythoN
- For other labs:
  - SSID: PYCARIB_IOT_WORKSHOP
  - Password: WELCOMETOIOT

Connecting to REPL

```
$ screen /dev/tty.SLAB_USBtoUART 115200

$
```

Connecting to WebREPL

- Connect to the Micropython-aaaaa AP with password: micropythoN
- Open a browser tab and go to ‘http://micropython.org/webrepl'
  - This should open a web page with a text box at the to right that will say
    - ws://192.168.4.1:8266
    - and a button that says ‘Connect’.
  - Press ‘Connect’ and the screen below should show the MicroPython REPL prompt ‘>>> ‘
  - type help() to see options to paste code in…

Blinky - Hello World

- Download the sample_blinky_red.py from the github page
- Copy sample code to main.py
- use mpfshell to place the main.py onto the board
- Reset the board

Extra Credit: Try the blue blinky also

Access WiFi code

- Download the sample_wifi_station.py from the github page
- Copy sample code to main.py
- use mpfshell to place the main.py onto the board
- Reset the board

MQTT Publish

- Download the sample_mqtt_pub.py from the github page
- Copy sample code to main.py
- use mpfshell to place the main.py onto the board
- Reset the board
- Launch ‘mosquitto’
- Launch ‘mosquitto_sub’
- Watch for messages

MQTT Subscribe

- Download the sample_mqtt_sub.py from the github page
- Copy sample code to main.py
- use mpfshell to place the main.py onto the board
- Reset the board
- Launch ‘mosquitto’
- Launch ‘mosquitto_pub’
- Watch for RED led to turn on or off