

Home Monitoring using Cellular IoT*



Hands-on Technology – Small Computers

February 22, 2022

Bob Jessup

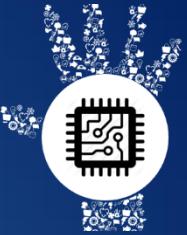
* Internet of Things



The Problem – Remote Monitoring

- Snowbird Concerns
 - Failed furnace or A/C, flooding, doors, lights
- Possible Solutions
 - Honeywell Winter Watchman \$0 / month
 - Wifi router, cameras, thermometers, etc. \$80 / month
 - Security monitored services \$50 / month + \$80 / month
 - Human homewatch service \$50 - \$100/ month
 - IoT cellular sensors < \$2 /month for 1 MByte

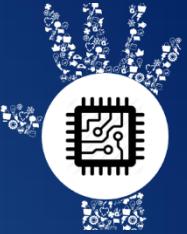
Cellular Solutions – Get on the Google



Hologram offers one free pilot SIM up to 1MB / month

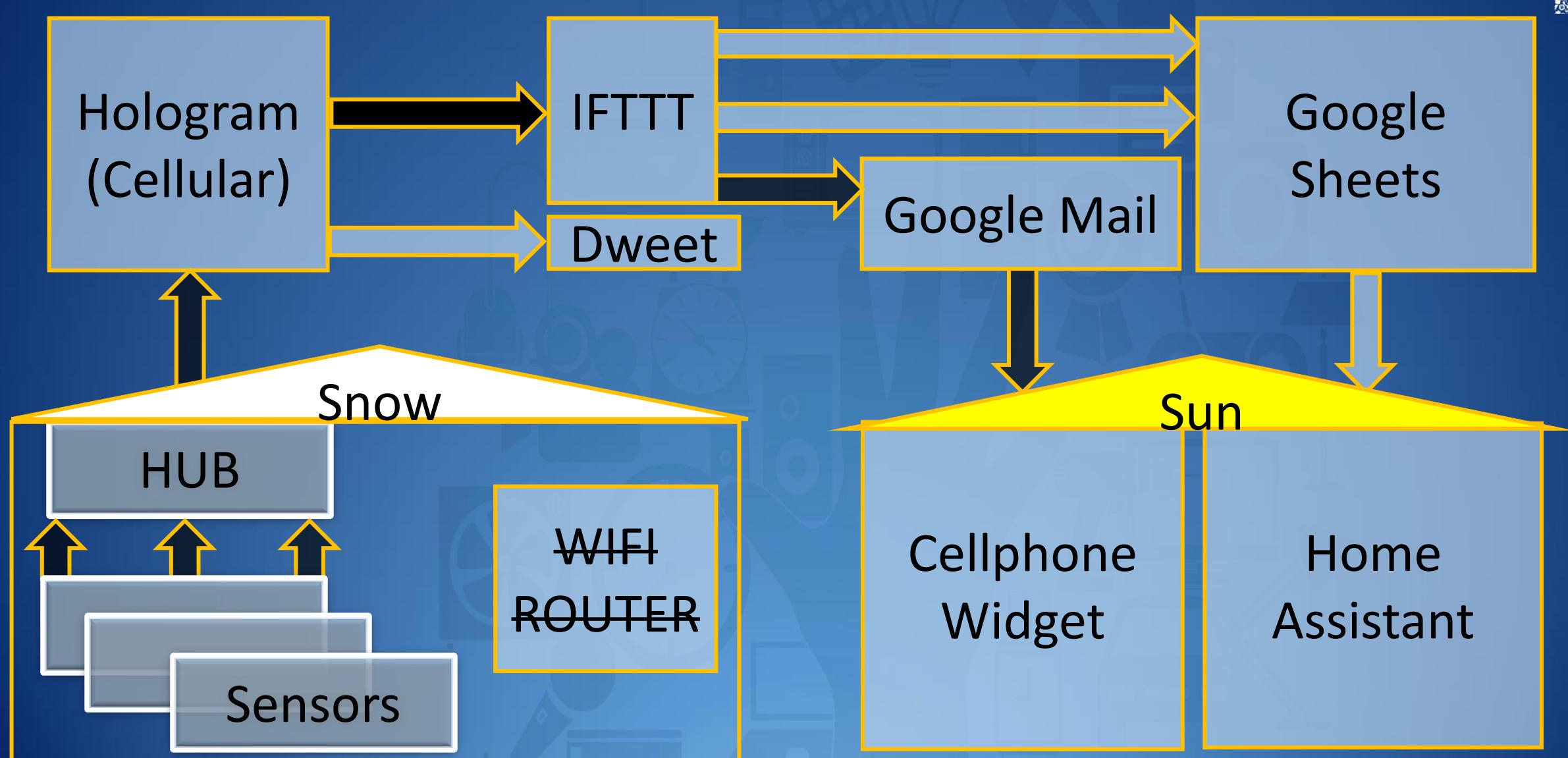
- 3G Sim 800 modems w/ on board processor (obsolescent)
- LillyGo (\$50) includes SIM7000G & ESP32 processor
- Global (\$30) 1.5-inch SIM7000A (iffy sim card holder)
- Botletics (\$65) Arduino shield with SIM7000A modem

Selected Approach: Botletics & ESP32

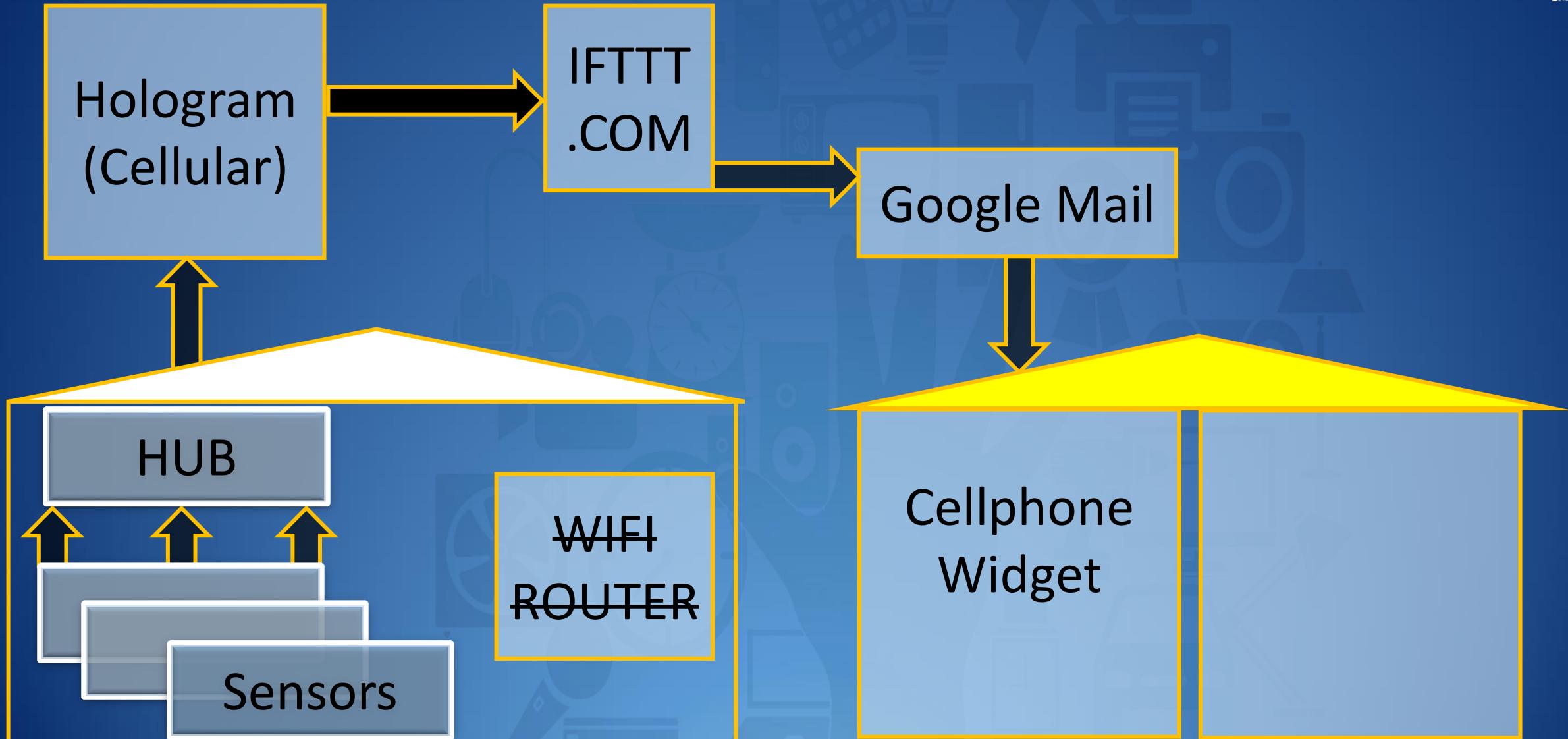
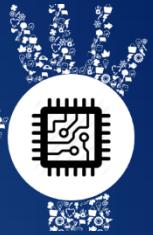


- Botletics Sim7000A Arduino shield (available tomorrow)
 - Hologram SIM card
 - Sensors to monitor 3 floors
 - Apply ESP32 to communicate wirelessly with sensors
 - _____
-
- ..besides, somebody needed a pandemic project..

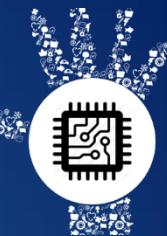
Where We are Going:



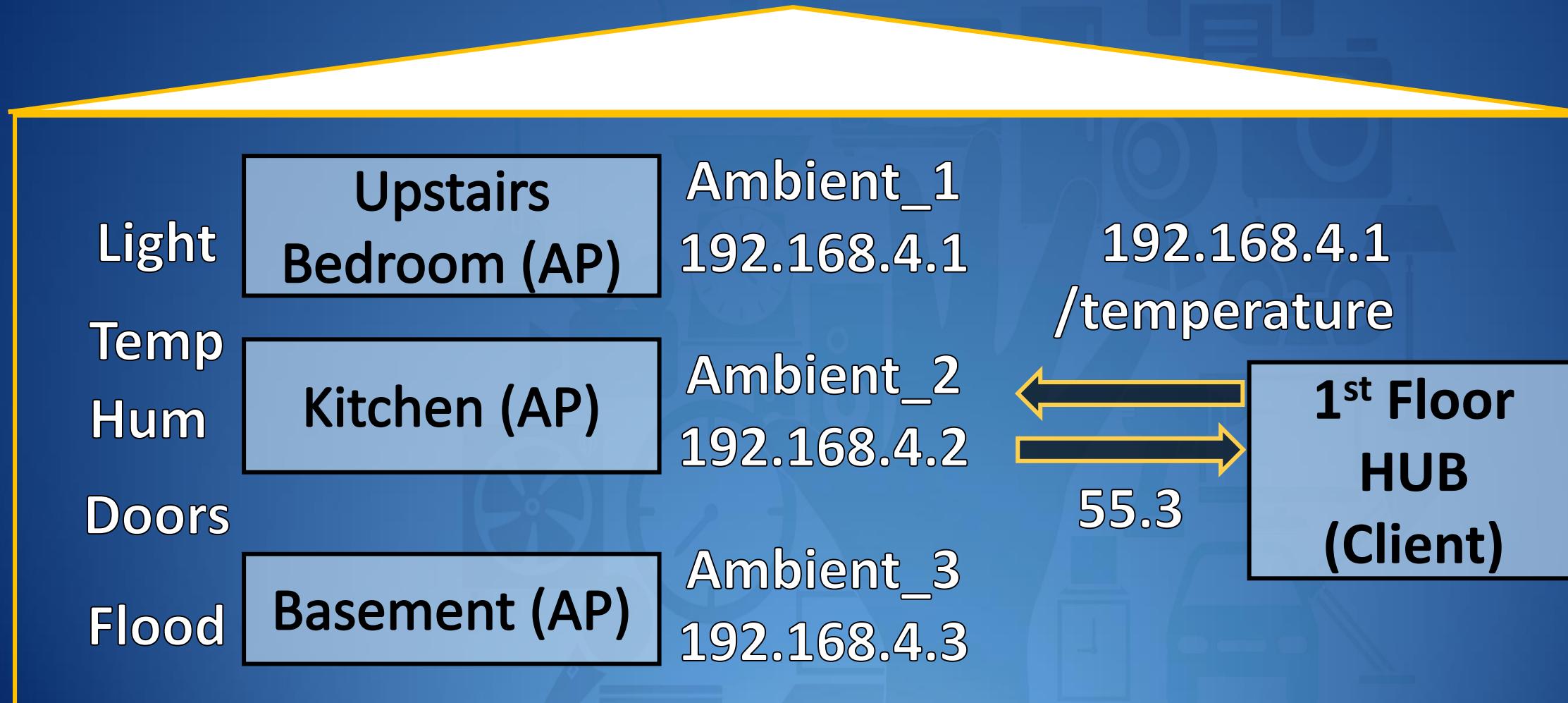
Primary Path: Remote Sensor to Cellphone



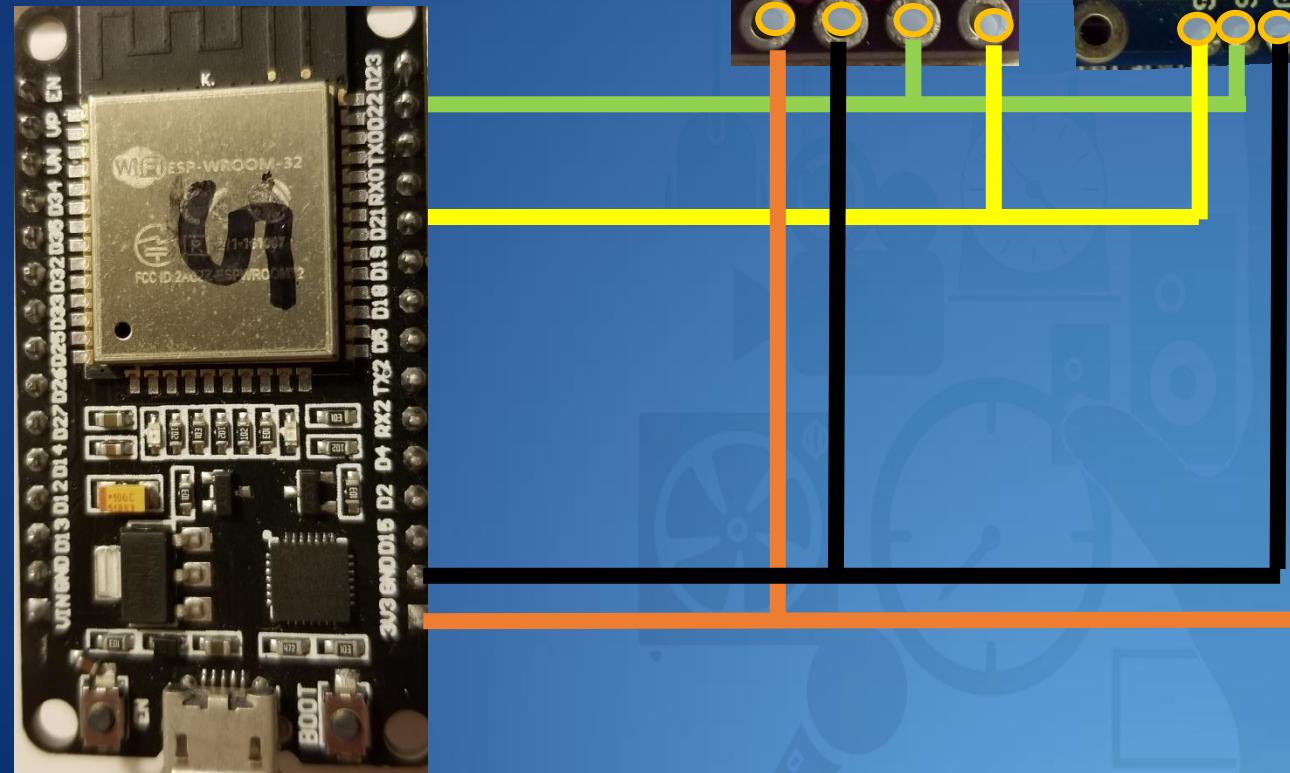
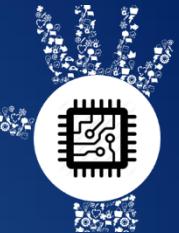
Sensors - Hub Configuration



- Sensors are wireless access point (AP) servers to pass info to HUB w/o a router.



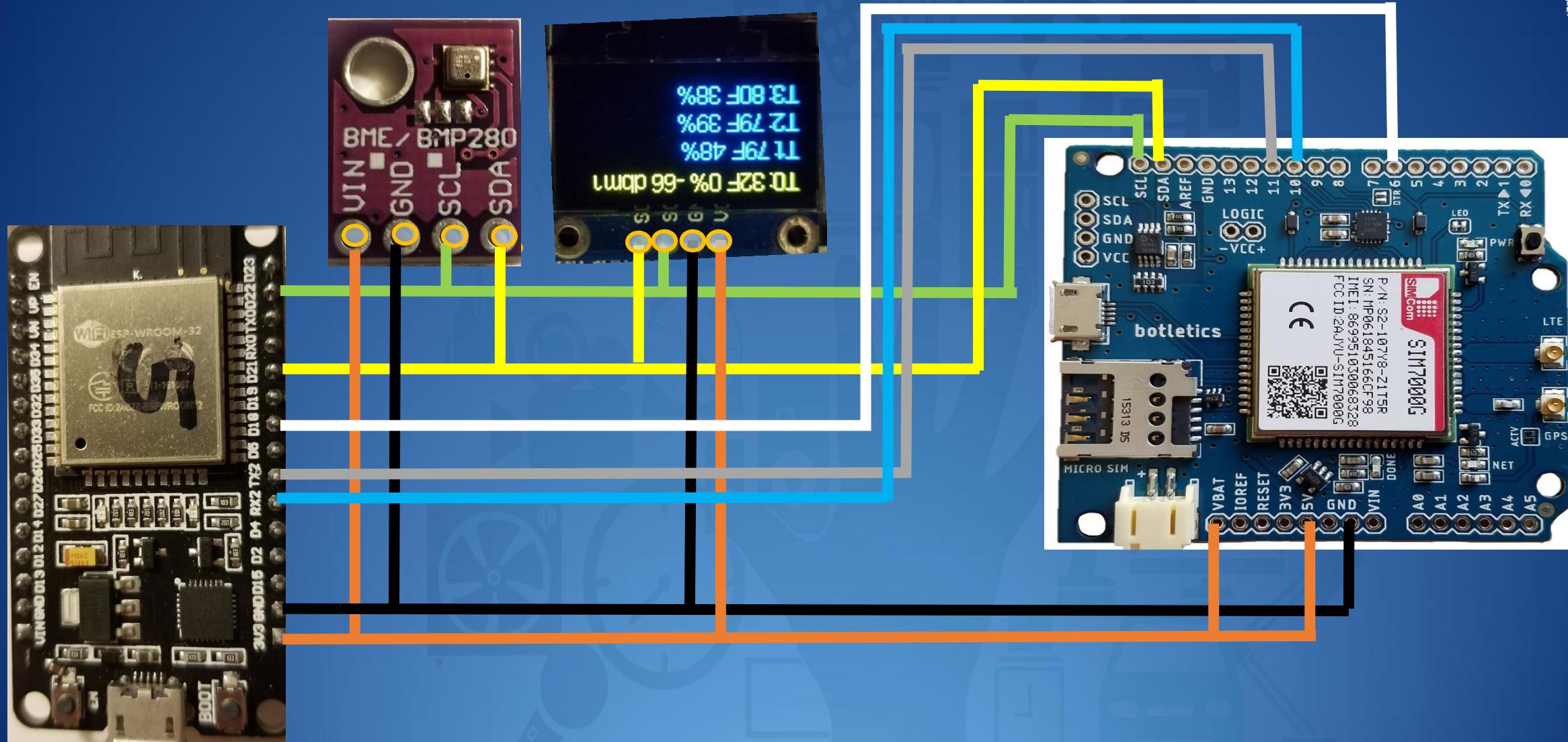
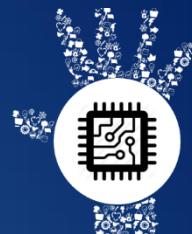
Sensor Wiring ESP32, BME280, SSD1306



Why ESP32?

- Powerful \$9 processor (less \$ if from China)
- Wireless antenna
- Strong wifi Library
- Arduino based
- Easy to program
- Strong on-board 3.3v .8A regulator

HUB Wiring: Sensor + Cellular Modem





Theory of Operation

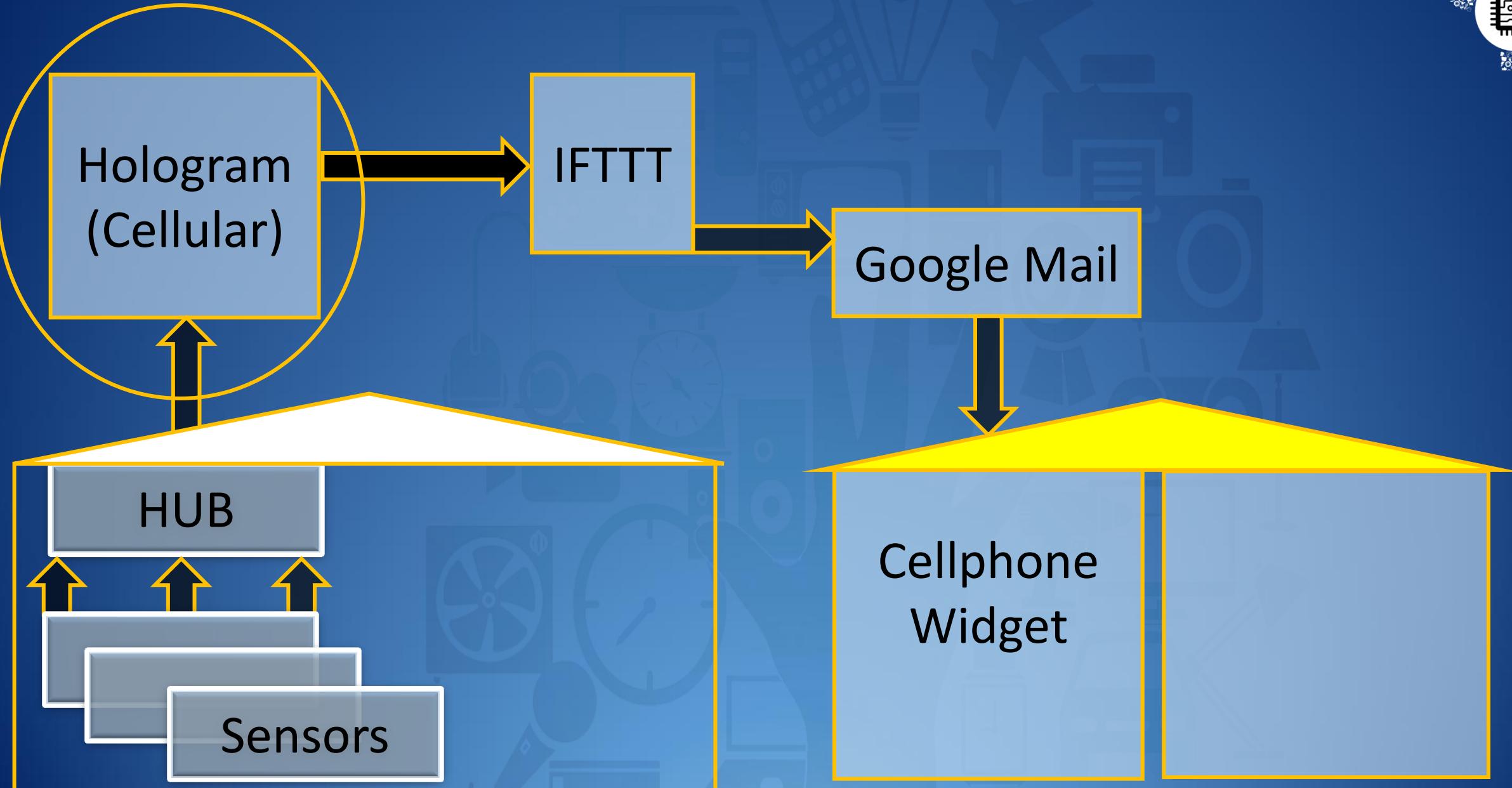
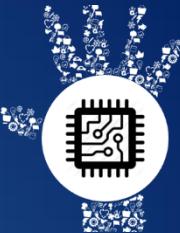
- Sensors are set up as wireless access point AP servers
 - * They return data upon receiving http GET requests
- HUB is base unit (gateway) with cellular modem and processor
 - * It can function alone or collect sensor data using http
- HUB transmits data hourly in JSON format
- Messages require 1.333 kB for data and overhead.
 - * $1.333 \text{ kB} \times 24 \text{ hrs} \times 31 \text{ days} = 992\text{ kB / month}$



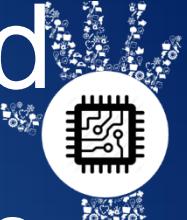
JSON: Human Readable Data

- JSON – JavaScript Object Notation
- Simple format is {label:data,label:data}
 - Example: {"temperature":"57","humidity":"62"}
- IFTTT allows only 3 values, but we need more
 - Workaround: send all our values as one:
`{"Value1":"57,57,56,58,-62,62,64,62,57"}`

Hologram Provides Cellular Path to Cloud

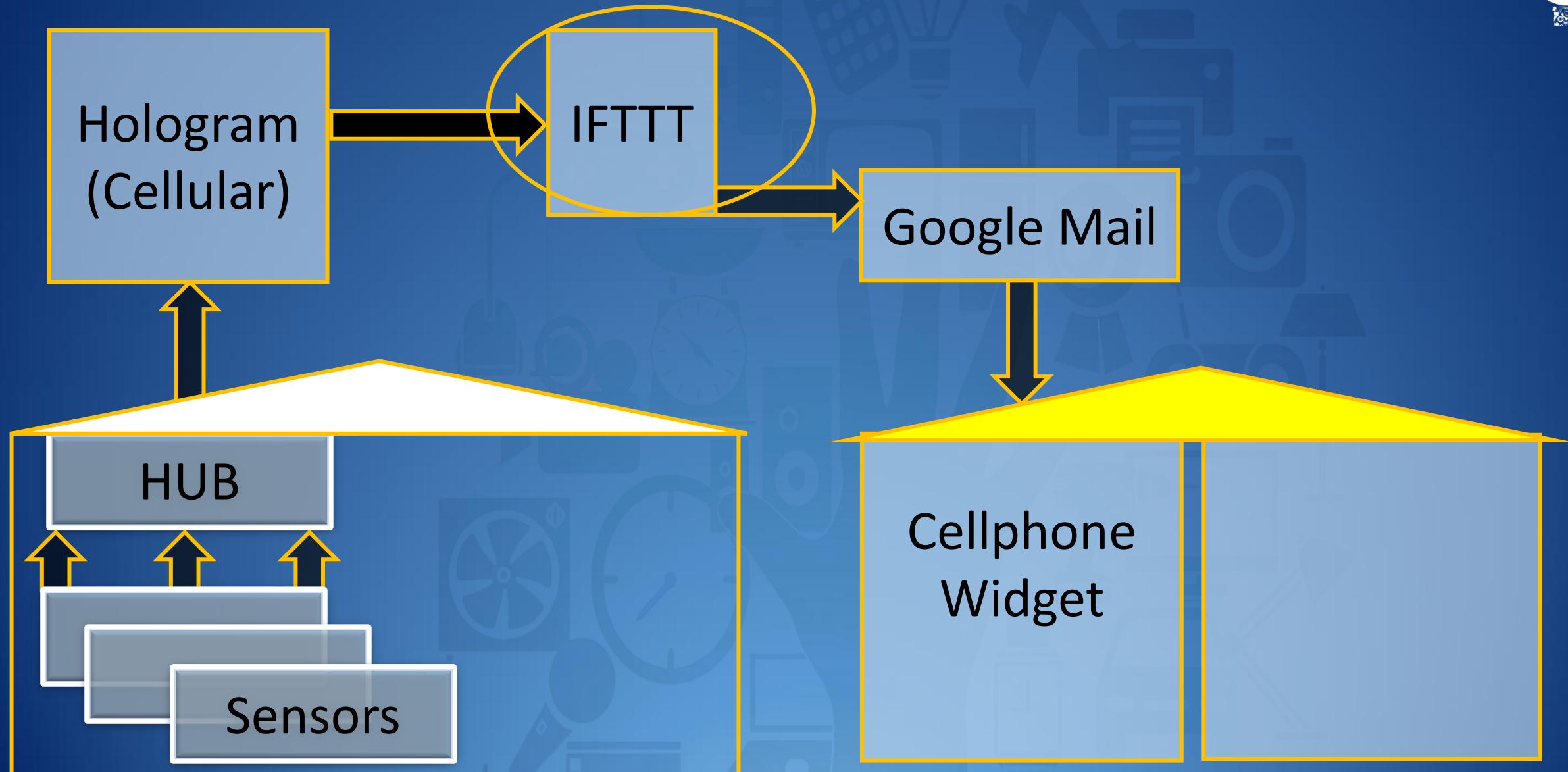


Hologram: Cellular Connectivity to the Cloud

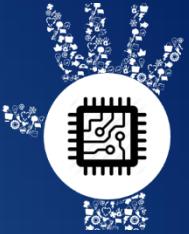


- Hologram enables connection and management of devices worldwide
- Claim 470+ global cellular networks
- Hologram offers free pilot IoT SIM card which includes 1MB/mo
 - Additional cards cost \$1.50/month plus \$.40 per MB
 - Each card includes mini (2FF), micro (3FF), Nano (4FF) size

IFTTT Links (Disparate) Services

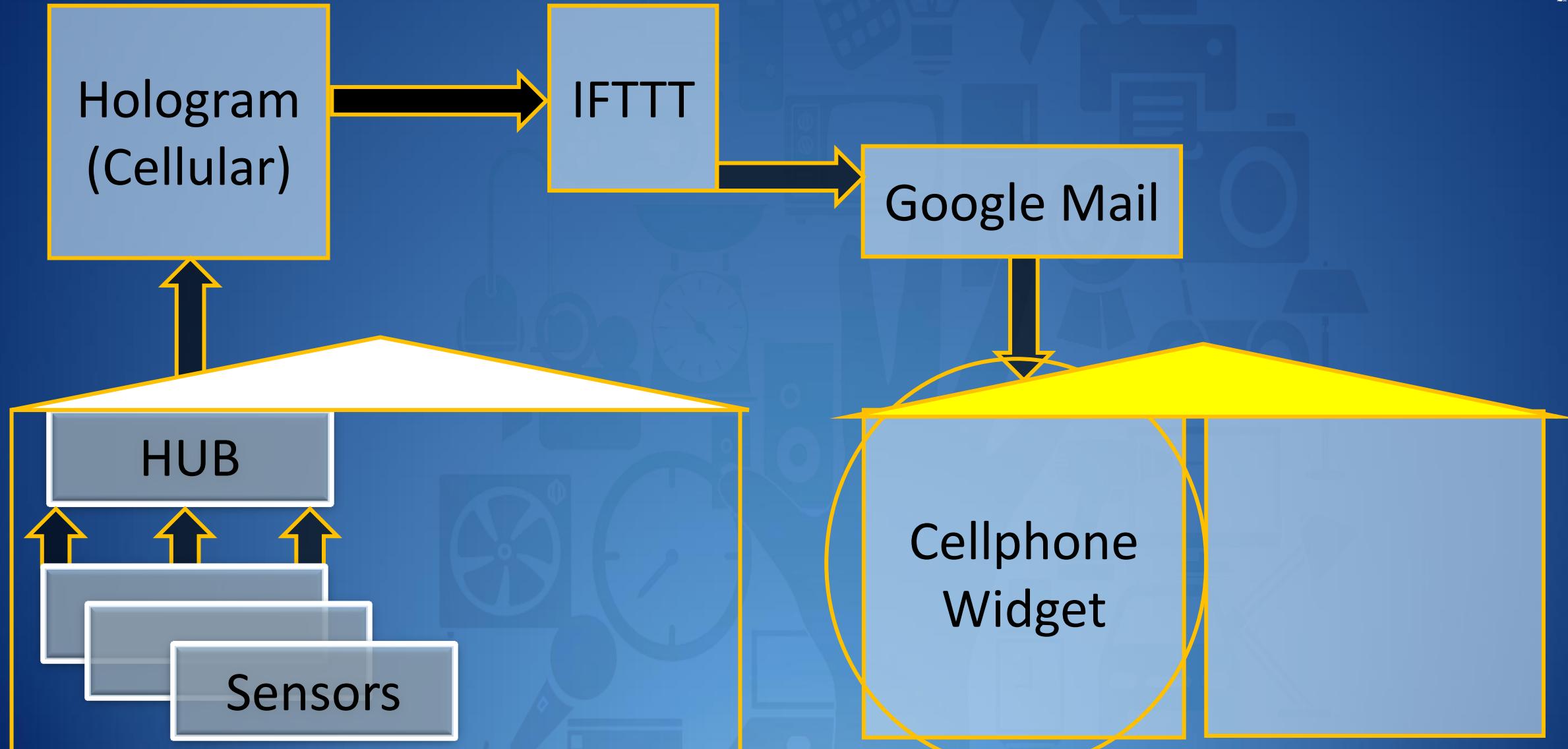


IFTTT – IF THIS Then THAT

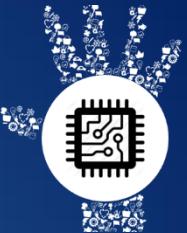


- IFTTT Links Services
- IFTTT webhook event (HB) emails data and adds to Google Sheets. (IF HB THEN email data and add to Google Sheets)
- IFTTT is also set up to pass weather info every 3 hours.
- Use a dedicated gmail account to set up your IFTTT account.

Data Appears on Phone Home Screen

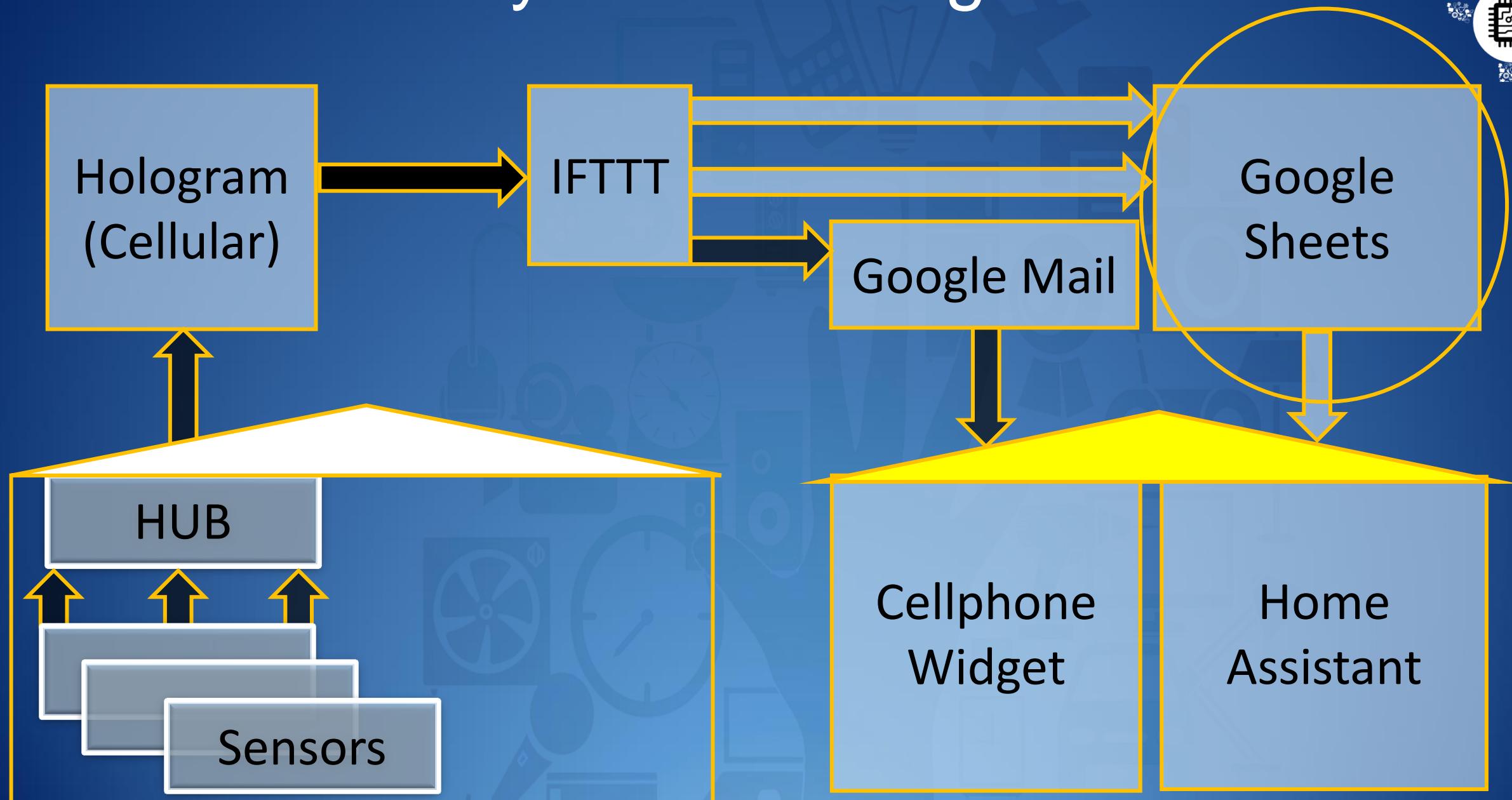


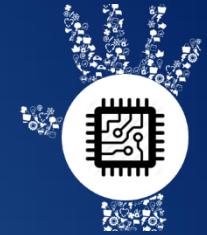
Reports Appear on Phone Home Screen



- The IFTTT webhook (HB) forwards data to the subject line
- Set up a 2"x2" gmail widget on the home screen of your phone
 - Shows 2 hrs sensor data, latest weather rpt
- Time, Event, 5 temps, 2 doors, 5 lights, 2 moisture, 1 SS, 4 humidity:
- 14:47 HB 54,55,56,58,50,0,0,00,05,03,93,00,00,-62,25,29,30,32
- 12:47 HB 53,54,56,56,50,0,0,00,05,03,96,00,00,-60,24,28,32,31
- 12:02 temp 28 AM Clouds/PM Sun today! High 32, Low 22.

Secondary Path – Google Sheets

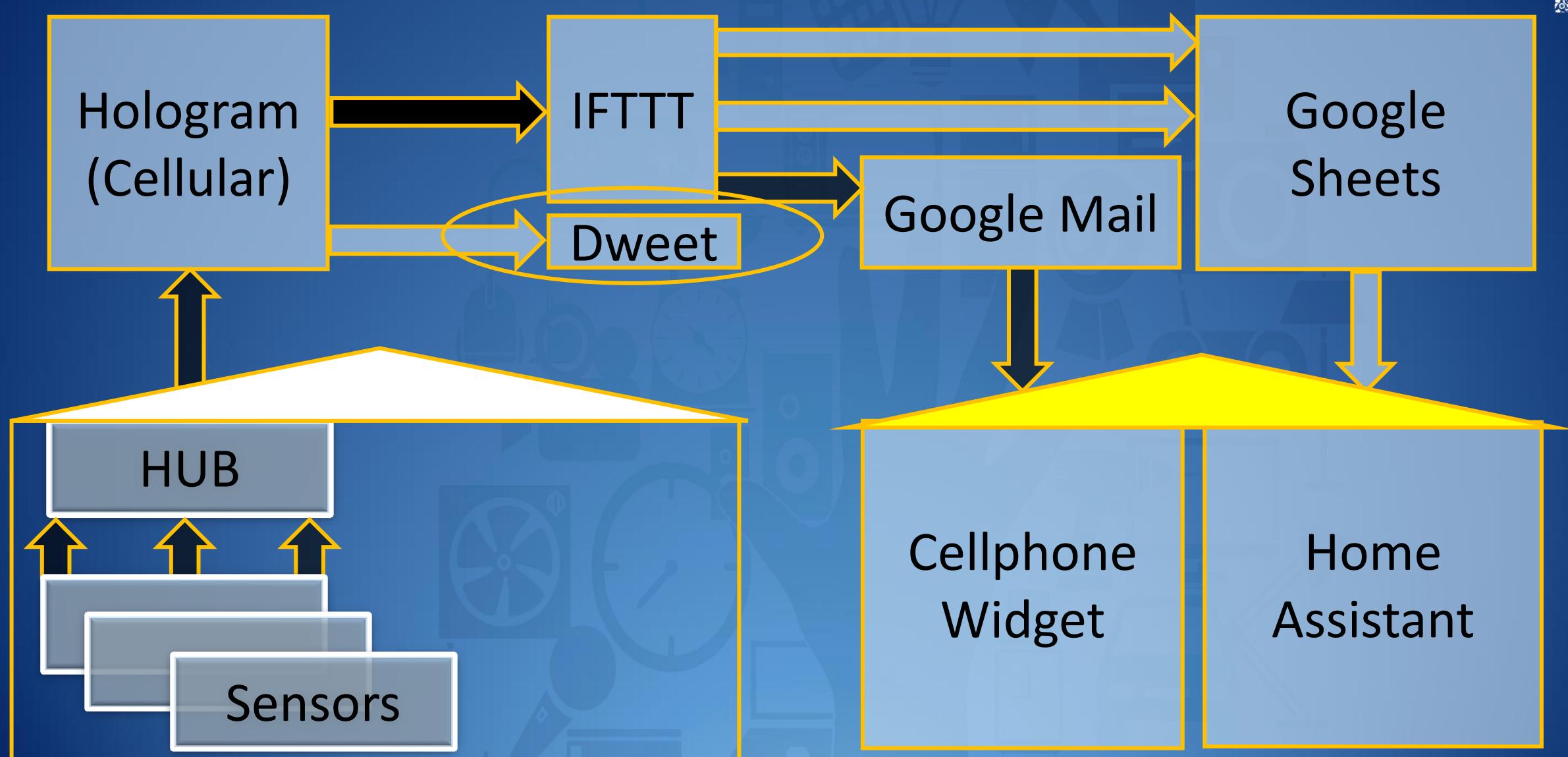
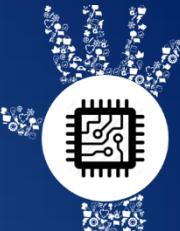




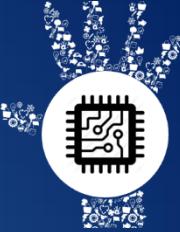
Secondary Path – Google Sheets

- IFTTT populates the spreadsheet for system performance
- DateTime, Event (HB, Weather) data are appended
- IFTTT also updates the 2nd row with HB events
- Home Assistant can open a card to monitor this row
- Eliminates the need to track the latest inserted row

IF IFTTT Fails Then Dweet!

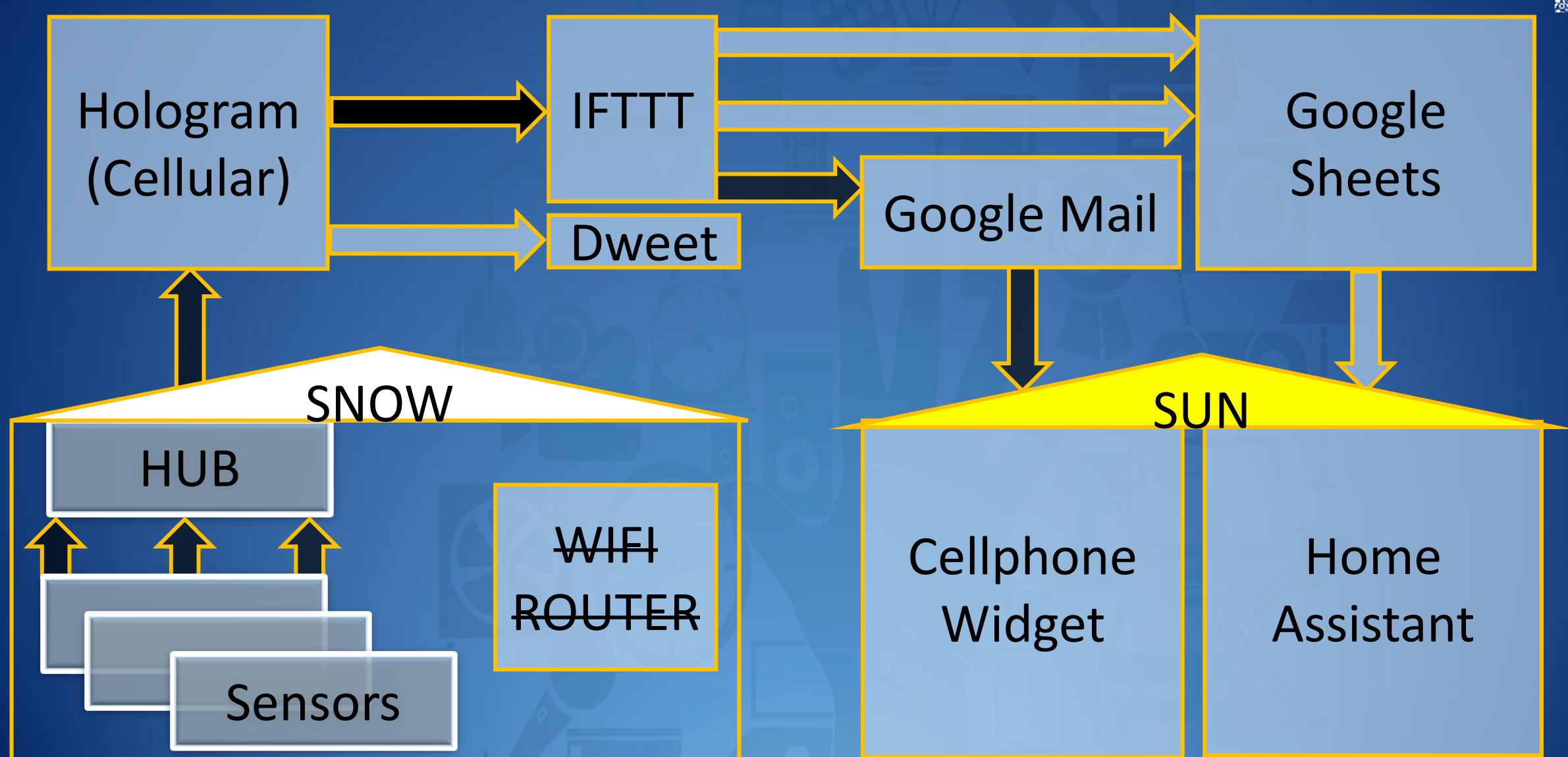


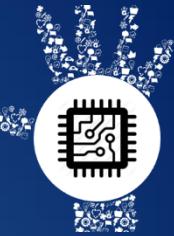
Dweet.io Provides a Free Service



- Displays the last 5 messages within past 24 hours
- Use to view information if (when) IFTTT path fails
- No credentials, passwords, etc.; simply make up an identifier
- I use the 15 digit SIMCOM modem imei as my identifier
- Retrieve at [dweet.io/get/dweets/for/\(your identifier\)](https://dweet.io/get/dweets/for/(your identifier))

Cellular IoT Home Monitor





Troubleshooting Tips - Remote

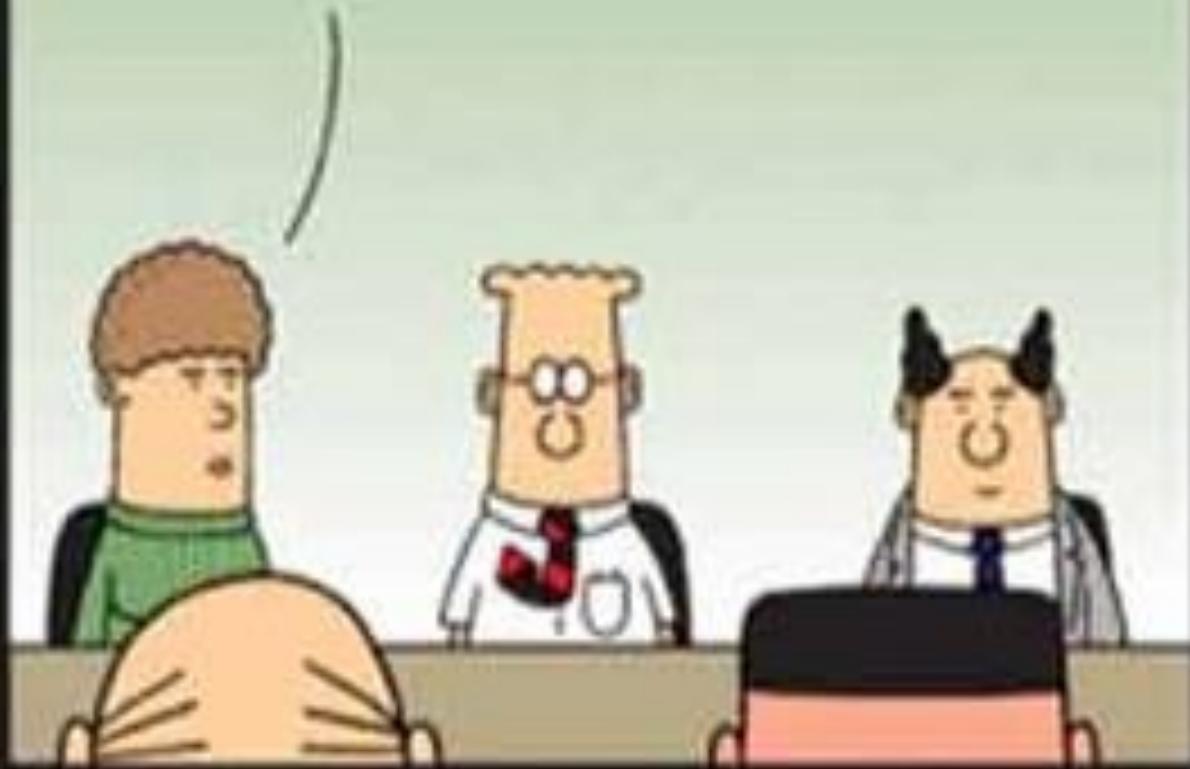
- Hologram, IFTTT dashboards
- Dweet provides alternate report if failure occurs downstream
- External timer to reboot system periodically
- Run duplicate system using same software
- Neighbors can read sensors directly on cellphone
- Catastrophic failure – exchange units

To Do List – Florida



- Verify Florida vendors via cellular IoT
 - Lawncare, bush trimming, weed & pest control
 - Manage sprinklers remotely
 - Camera to send still photos

WHAT'S YOUR
TAKE ON THIS,
DILBERT?



Dilbert.com DilbertCartoonist@gmail.com

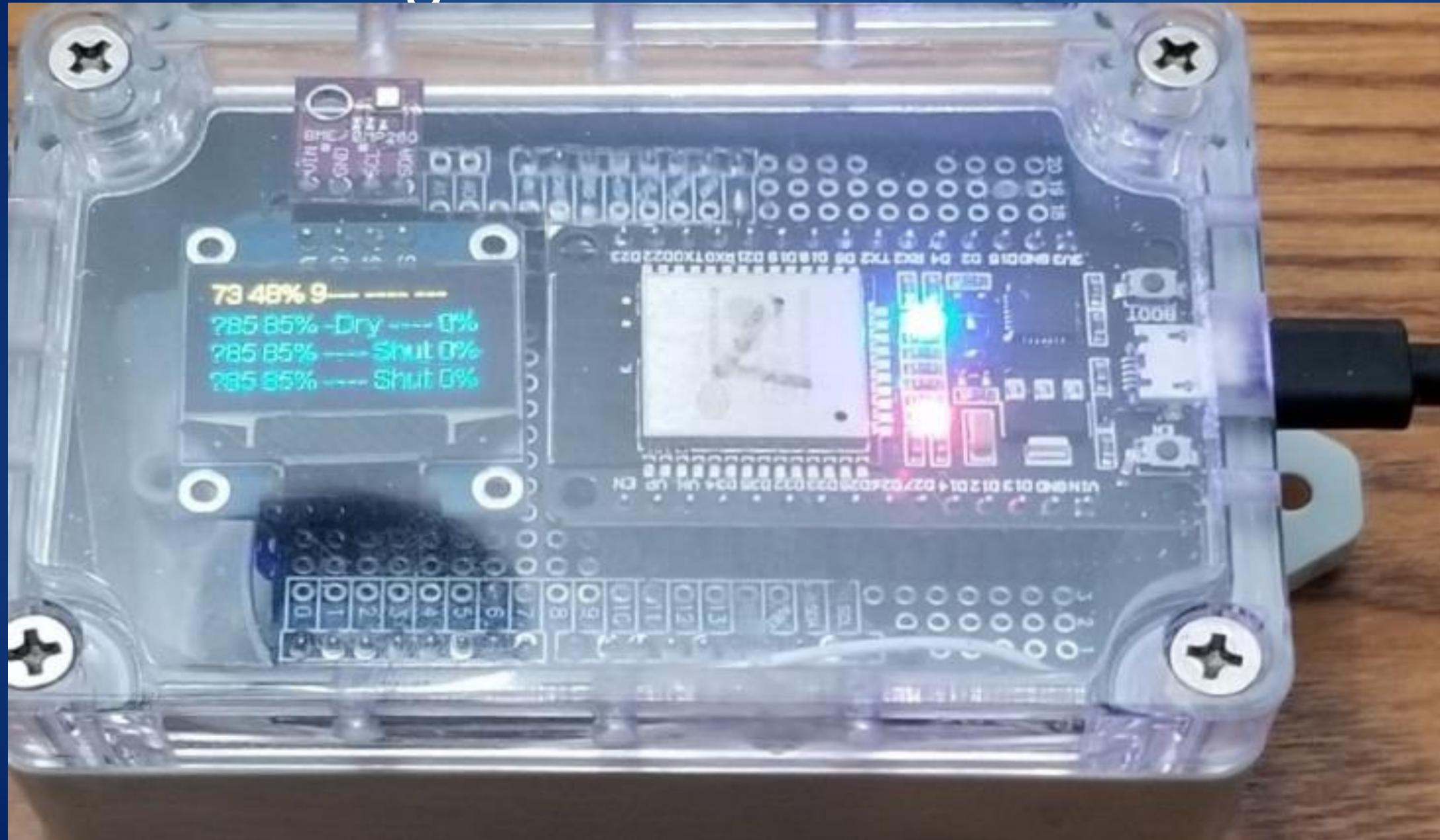
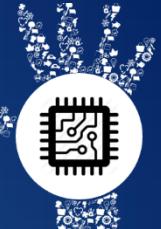
WHAT? SORRY. I
WAS USING THIS
TIME TO THINK
ABOUT SOMETHING
USEFUL.

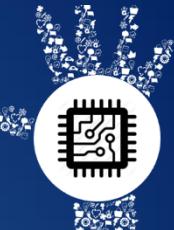




Hardware – A collection of all the parts you can physically Touch

Hub Progression – Oct 2021 Maine

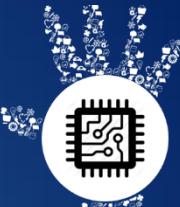




Hub Parts List

Description	Amazon	AliExpress	Notes
MELife 2 Pack for ESP32 ESP-32S Development Board (not Mini!)	\$16.99/pair	\$1-\$3	Onboard AMD1117 regulator adequate for modem
Botletics SIM7000A LTE CAT-M1 NB-IoT Cellular + GPS + Antenna	\$65		
Ultronics .96 Inch OLED Module 128x64 SSD 1306 .96" Display	\$3 - \$10		I2C bus; optional, but convenient during development/debug
BME280 temp/hum sensor	\$15 was \$5	\$1.80	I2C bus;
ELEGOO 3pcs Breadboard 830 Point Solderless Prototype	\$9.99/3		OR: Prototype PCB for Arduino R3 Shield Board DIY \$8.00/4

Hub Parts List 2 – PCB & Enclosure Options

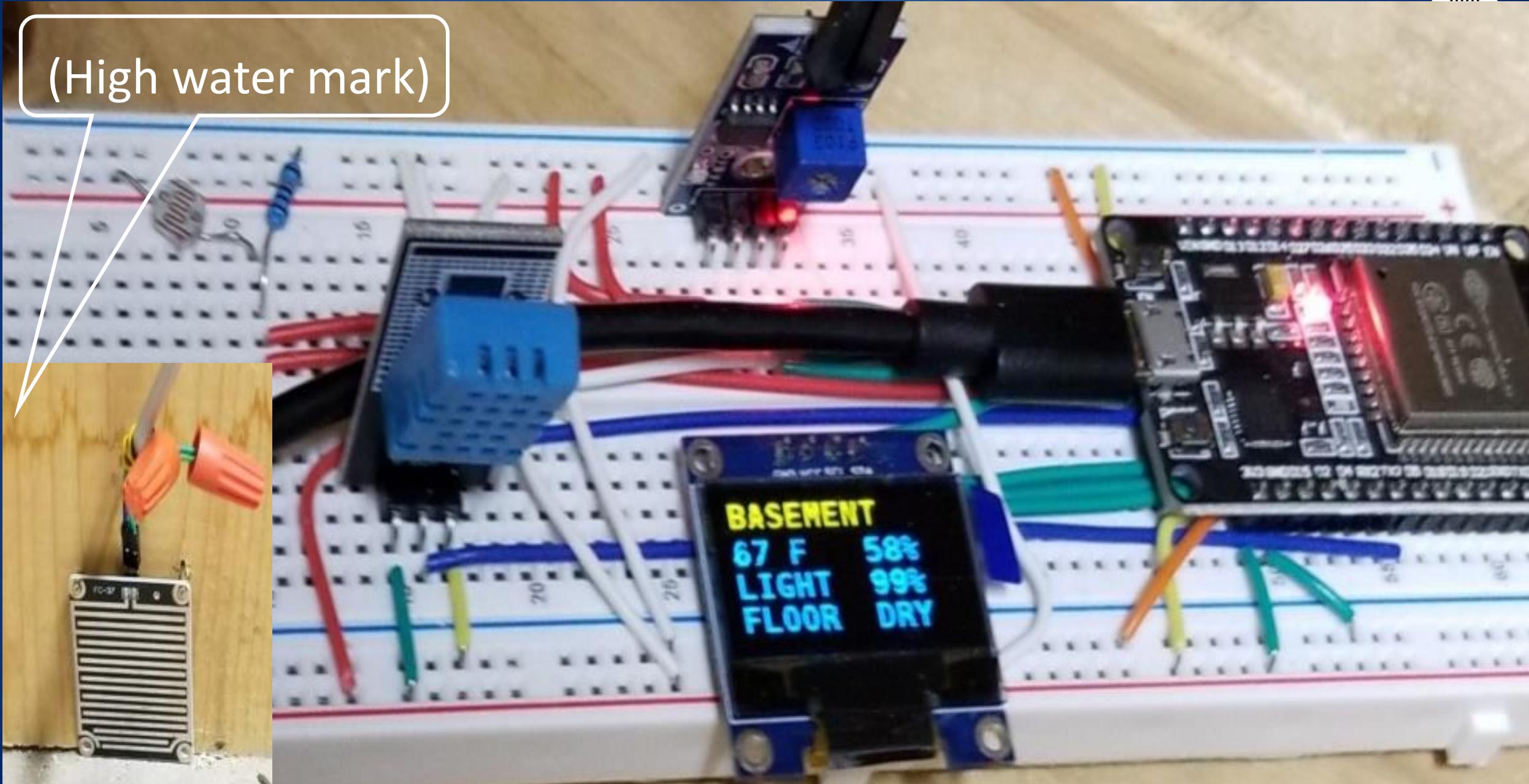


Description	Amazon	Notes
ElectroCookie Solderable Breadboard PCB Double Column	\$12.99/3	PCB having same hole pattern and connections as breadboard!
AwClub Waterproof Dustproof ABS Plastic Junction Box Model 115*90*55	\$6.99	Use with prototype Arduino shield; transparent cover to view OLED display
OR:		
Prototype for Arduino UNO R3 Shield DIY	\$8.90/4	Hole pattern matches Botletics/Arduno
AwClub Waterproof Dustproof ABS Plastic Junction Box Model 100*68*10	\$6.99	Use with prototype arduino shield; transparent cover to view OLED display
40 pin female header sockets		Allows plugging in your compnents instead of soldering
40 pin male breakaway header		Plug proto board onto Botletics

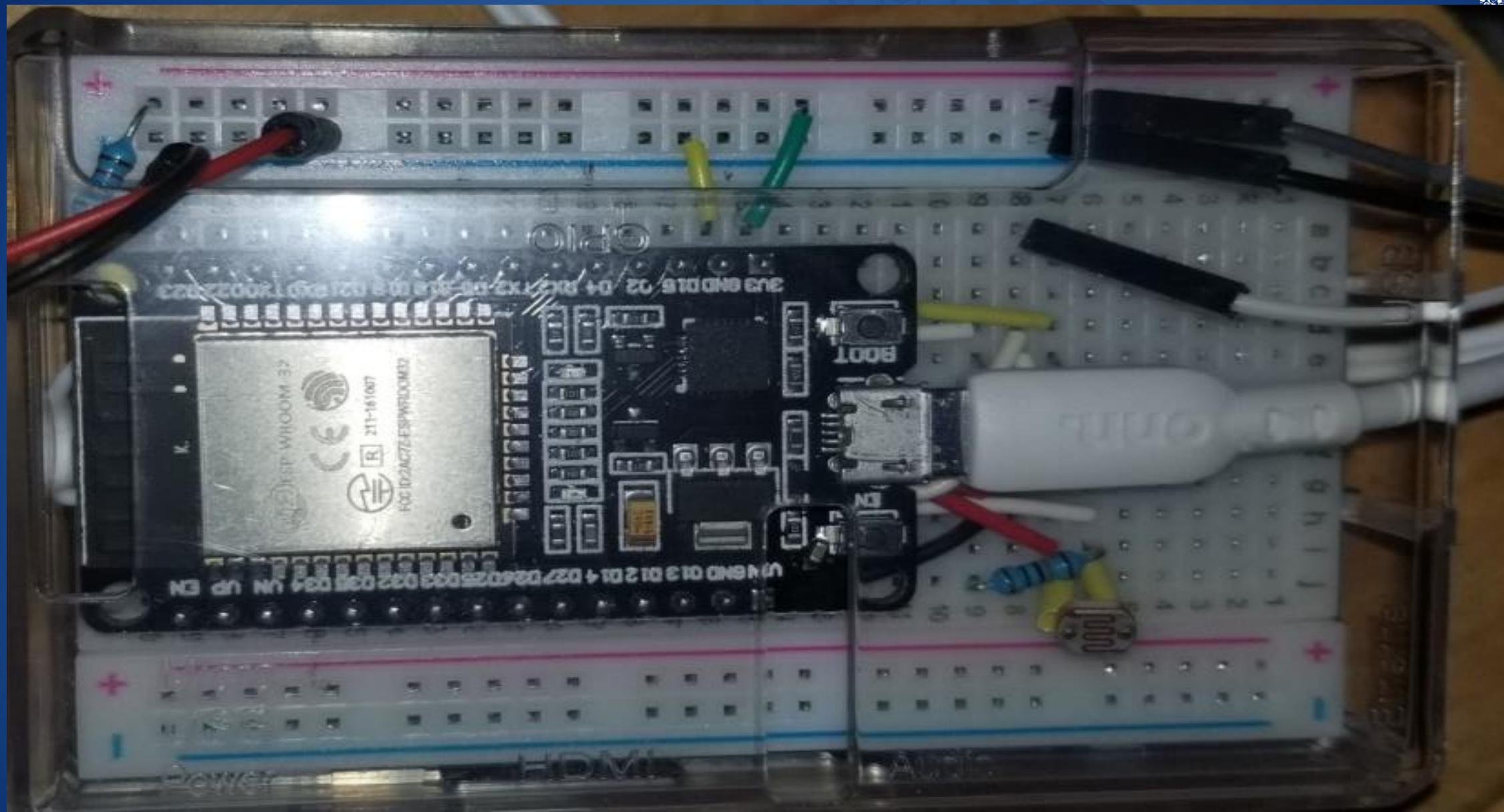
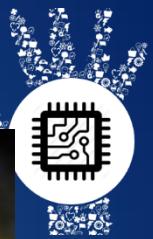
Maine Basement Sensor



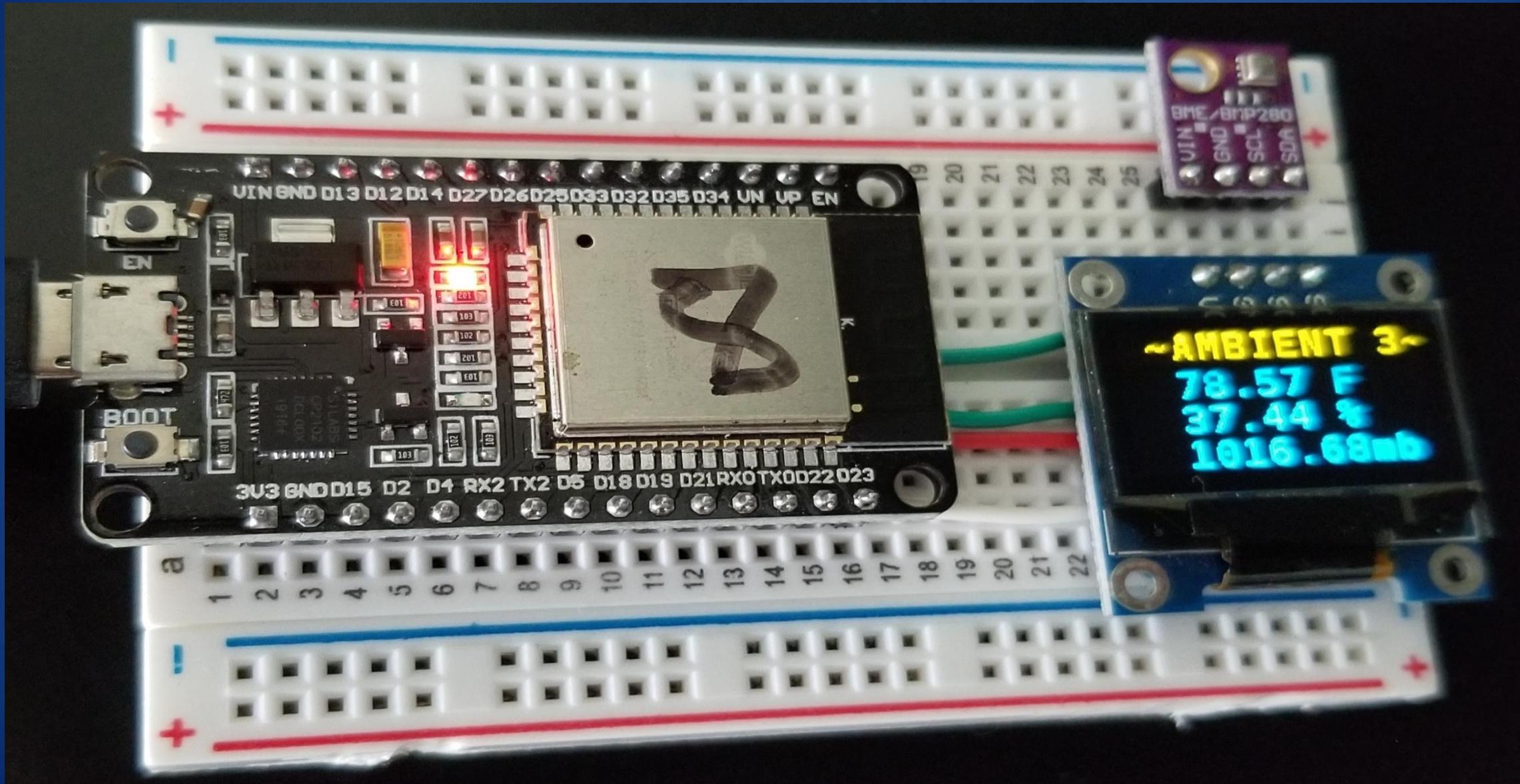
(High water mark)



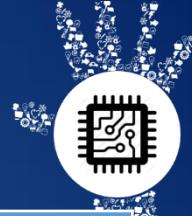
Maine Kitchen Sensor in Rpi case (light, front door, temp)



Florida Sensor



Florida Sensor Parts List

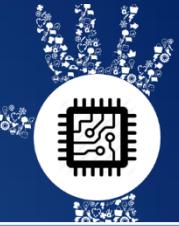


Description	Amazon Price	AliExpress + Shipping	Notes
MELife 2 Pack for ESP32 ESP-32S Development Board	16.99/pair	Less \$	Option: Wemos D1 Mini 8266 (1 only) \$3 - \$8
Ultronics .96 Inch OLED Module 128x64 SSD 1306 .96" Display	\$3 - \$10	Less \$	I2C bus; optional, convenient
BME280 temp/hum sensor	\$15	\$1.80	I2C bus
ELEGOO Breadboard 415 Point Solderless Prototype			
Option: ATPWONZ Plastic Boxes	\$14.99/10		Enclosure encompasses breadboard. Drill ventilation holes.



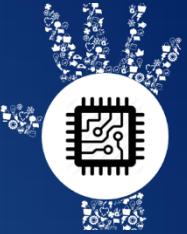
Software – Instructions that tell a computer what to do

Software & Services



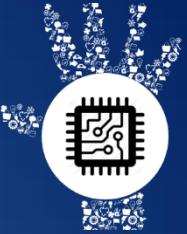
Description	Base Cost	Source	Why is Necessary
Hologram.io Service	\$0	Google it	Cellular access, IoT SIM card
IFTTT.com Service	\$0 for up to 5 applets	Google it	Pass data to gmail, populate google sheets
Dweet.io Service	\$0	Google it	IFTTT backup
Arduino IDE Software	\$0	Google it	Edit & Load ESPxx sketch
AmbientHUB Software	\$0	H.O.T 2/22/2022	Hub Software
AmbientAP Software	\$0	H.O.T 2/22/2022	Optional Sensor Software
Arduino Libraries (listed as #include in Ambient software)	\$0	Import using IDE	Building blocks for Ambient software
Google Drive, Sheets, Gmail	\$0	Google	Dedicated email, analysis

Options – Alert Mode or Snooze Mode



- Alert Mode responds immediately
- HUB stays awake, polling sensors
- Sensors can stay awake or sleep until interrupt event
- HUB uploads hourly heartbeat data as well
- Requires temperature sensors outside case

Options – Alert Mode or Snooze Mode



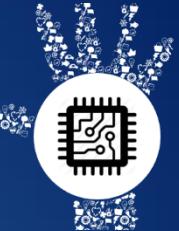
- Snooze Mode simply sends data Hourly
- HUB sleeps 48 minutes, wakes 12 minutes
- Sensors sleep 8 minutes, wake 2 minutes
- HUB can read all 3 sensors while awake
- Enables internal temperature sensors to stay cool

Ambient_AP Sensor Software



- Compile-time options are explained in the top section
- Setup()
 - reads sensors & starts AP to respond to http requests
- Loop() execution
 - If snooze mode, do nothing until its time to go to sleep
 - Else
 - Read sensors at timed intervals
 - Repeat Loop()

Ambient_HUB Software



- Compile-time options are explained in the top section
- Setup()
 - initialize hardware
- Loop() execution
 - Reads sensors when & sends an event to IFTTT immediately if alarmMode = 1
 - Heartbeat data is sent to IFTTT or Dweet.io each hour
 - If Snooze Mode, Sleeps 48 minutes after which time setup is run again before repeating Loop() for 12 minutes

Troubleshooting Tips - Local

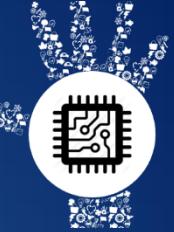


- Interpret OLED displays and LED blink rates
- Embedded Print Statements to status monitor in test mode
- EN button on ESP's reboot system tests entire loop on startup
- Misc software flags can be adjusted to diagnose issues



To Do List - Software

- AT commands to eliminate the fona library, reduce 1.3k / msg
- Evaluate the 1.5-in Global.com unit to reduce the size and cost
 - Ordered one Jan 9, 2022; it arrived Jan 24 from AliExpress
- MQTT using online broker?
- Evaluate ESP Now for sensor-hub communication



The Devil is in the Details



Where's the beef?!

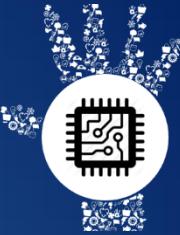
Moving on . . .

What Exactly IS this Project?



- Sensors monitor ambient conditions in empty home x 2
- Sensors are hard wired – no batteries
- It is NOT a security system
- It is NOT FCC approved for resale (FCC 47 cfr 2.803)

Alphabet Soup – Cellular Terms



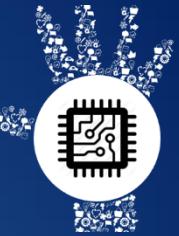
Cellphones sell access by the GigaByte (\$2/GB)

- 3G GSM – Global System for Mobiles (AT&T, T-Mobile)
- 3G CDMA – Code Division Multiple Access (Verizon, Sprint)
- 4G HSPA – High Speed Packet Access = faster version of 3G GSM
- “4G” LTE – Long Term Evolution – Verizon, fast data performance technology designed with an eye on 5G; 4G LTE speed = 3G x 10
- 5G – 4G LTE x 100 (download a 2-hr movie in < 10 seconds)

Alphabet Soup – Cellular Terms

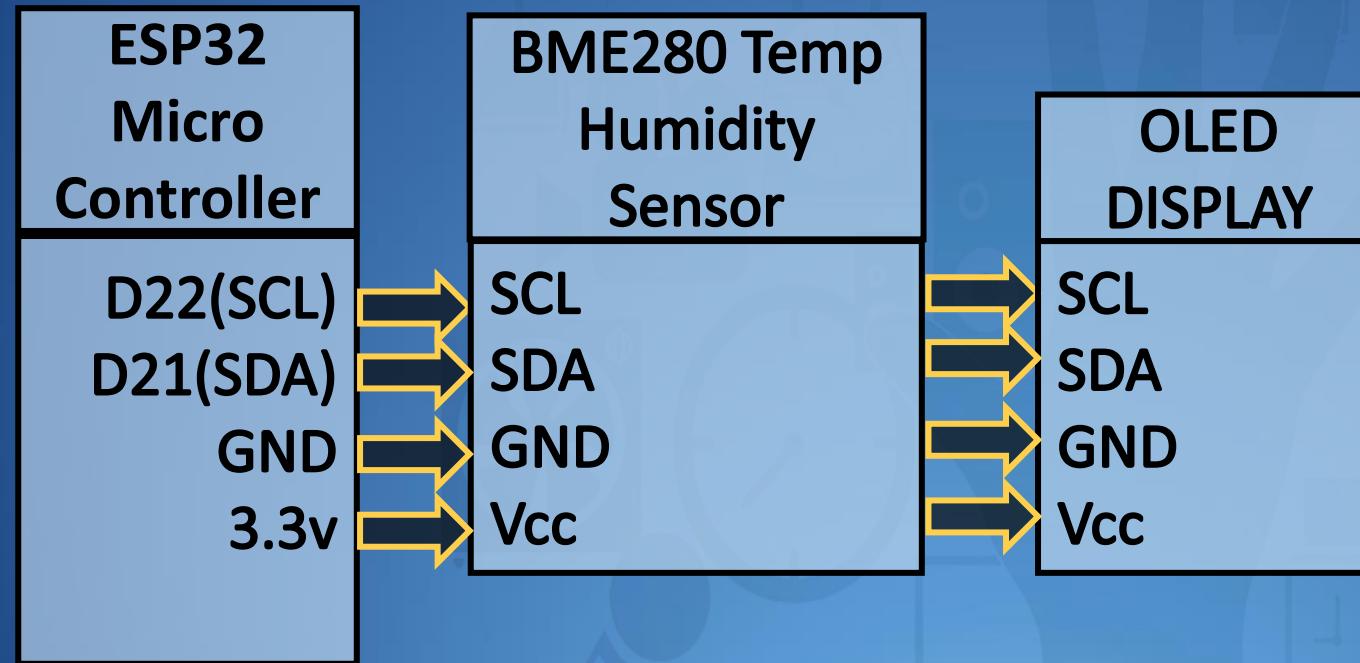


- IoT sells access by the Mbyte (1\$/MB) x 1000 = \$1000/GB
 - NB-IoT – 200 kHz BW 30/60 DnLd/UpLd kbps, 35km range
 - LTE-M – 1.4 MHz BW 300/375 DnLd/UpLd, 15-20 km range
- Simcom LTE-M/NB-IoT Modems – SIM7000A,C,E,G
 - America, China, Europe, Global

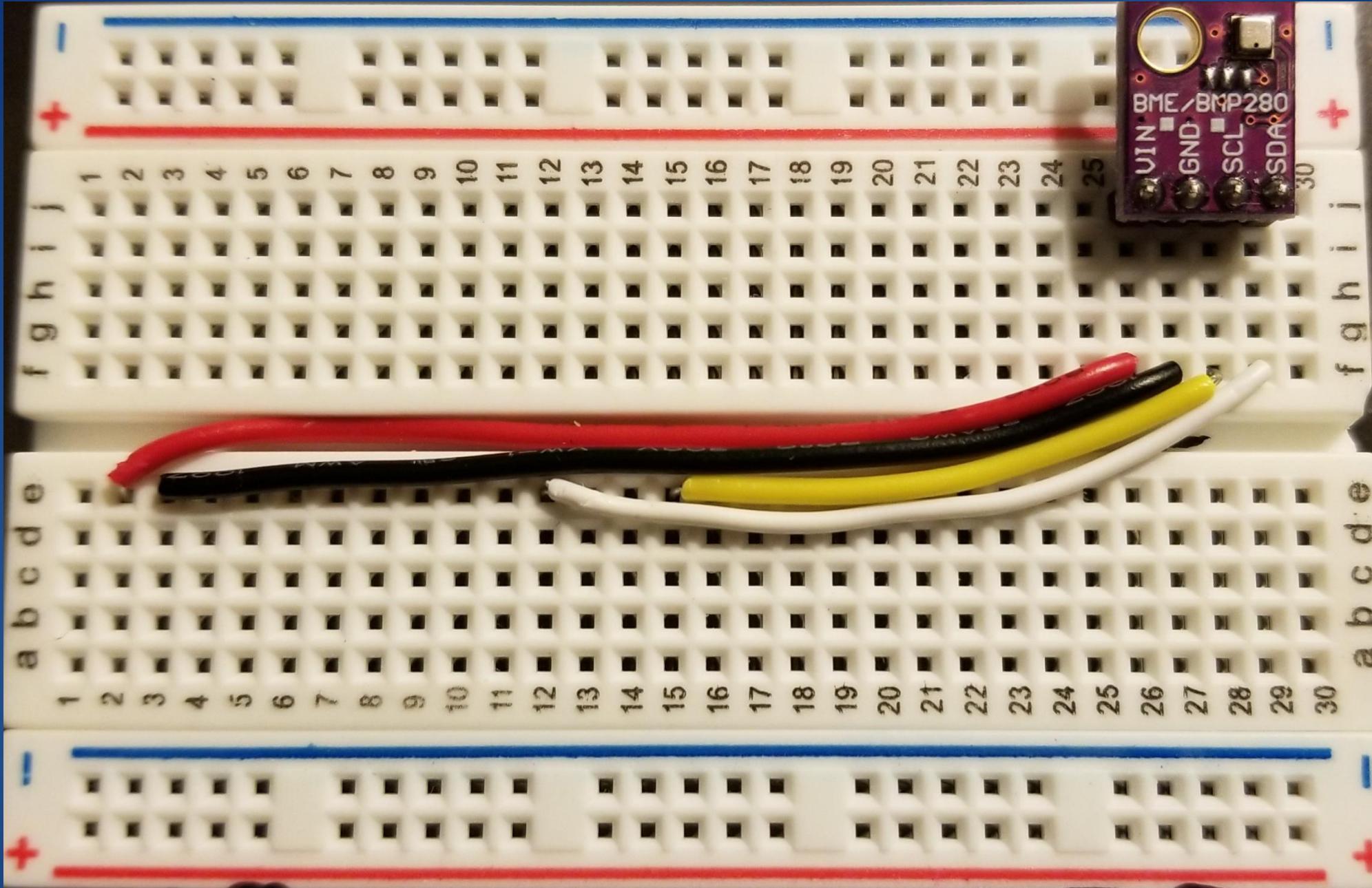
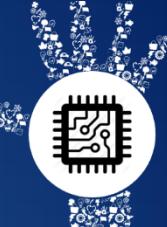


Sensor Wiring (ESP32)

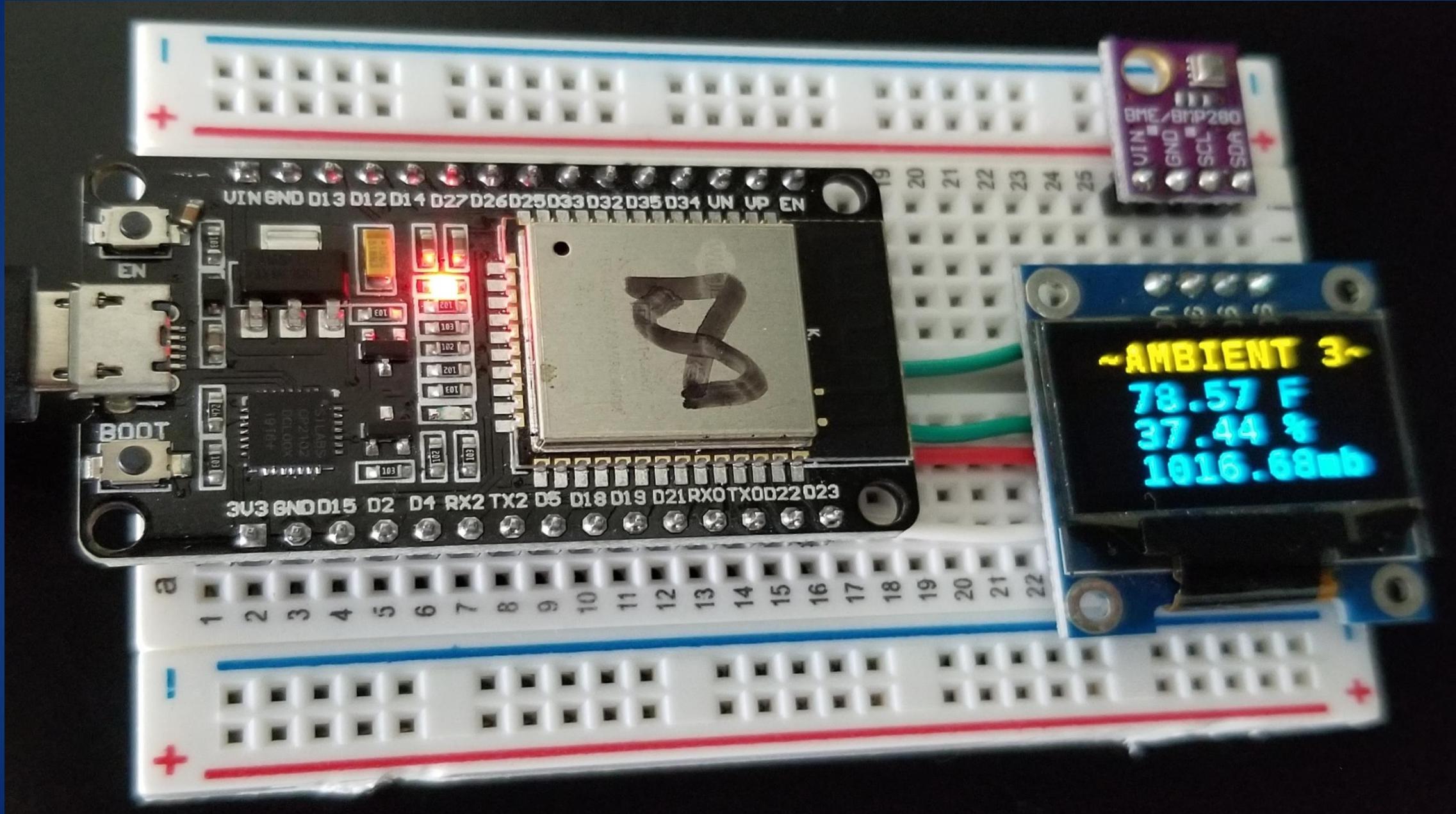
- All labels are as printed on ckt board, not schematic pins!
- Function is in ()
- External power is supplied to the ESP32 via USB cable
- ESP32 3.3 volt pin supplies power to all components

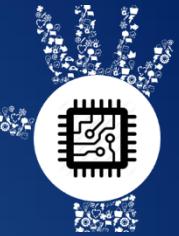


ESP32 Temp Sensor / OLED Wiring



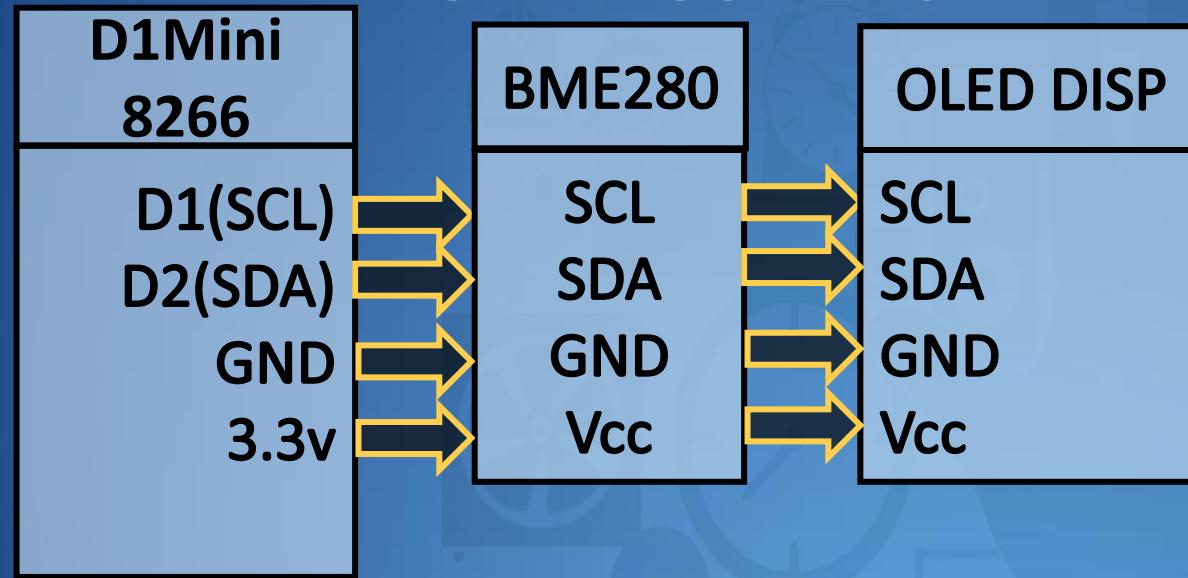
ESP32 / Temp Sensor / OLED Placement



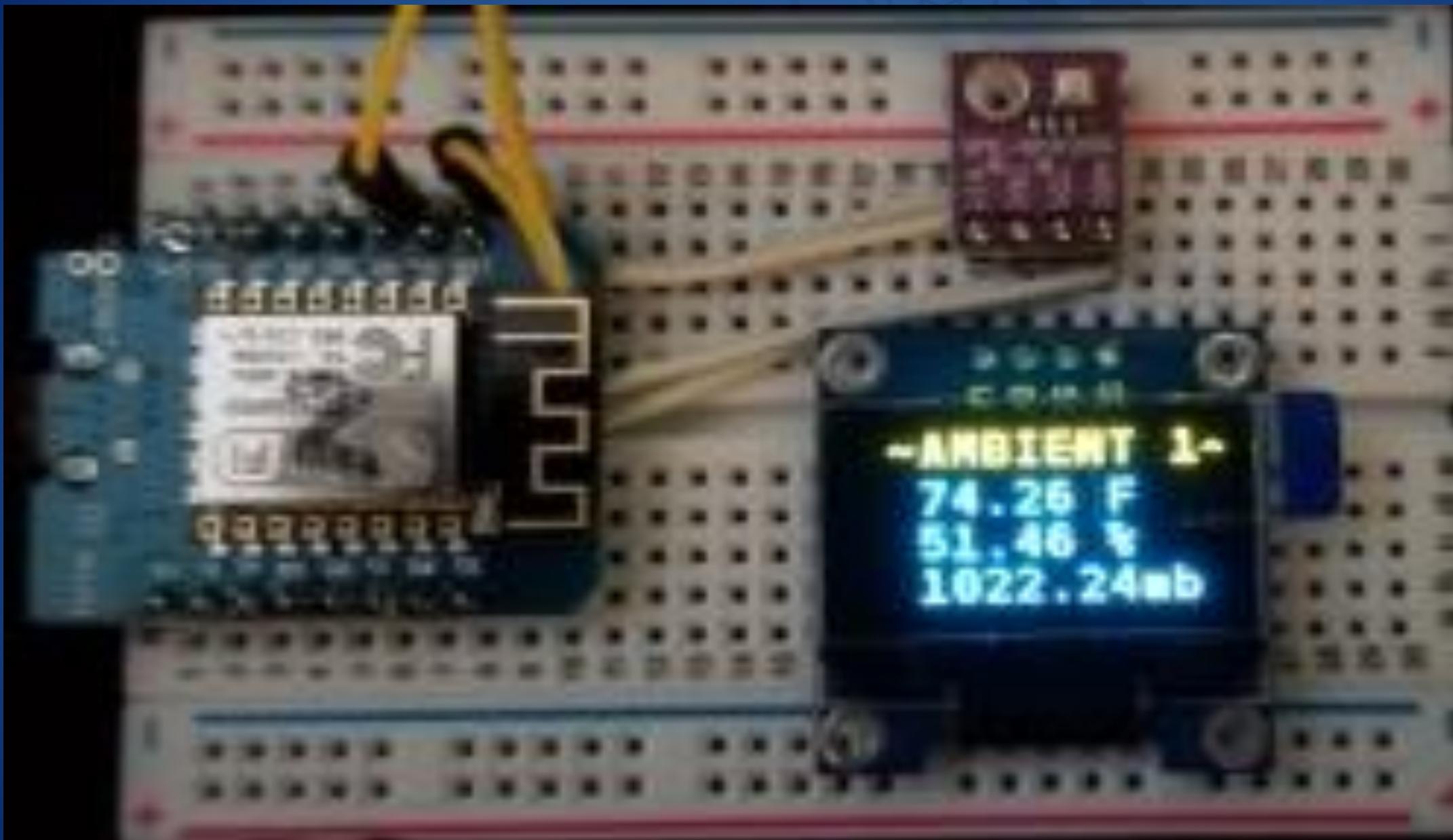
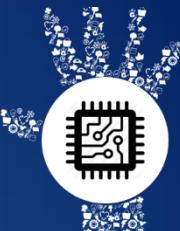


Sensor Wiring (Wemos D1 Mini)

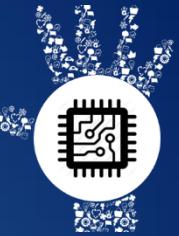
- All labels are as printed on ckt board, not schematic pins!
- Function is in ()
- External power is supplied to the D1 Mini via USB cable
- ESP32 3.3 volt pin supplies power to all components



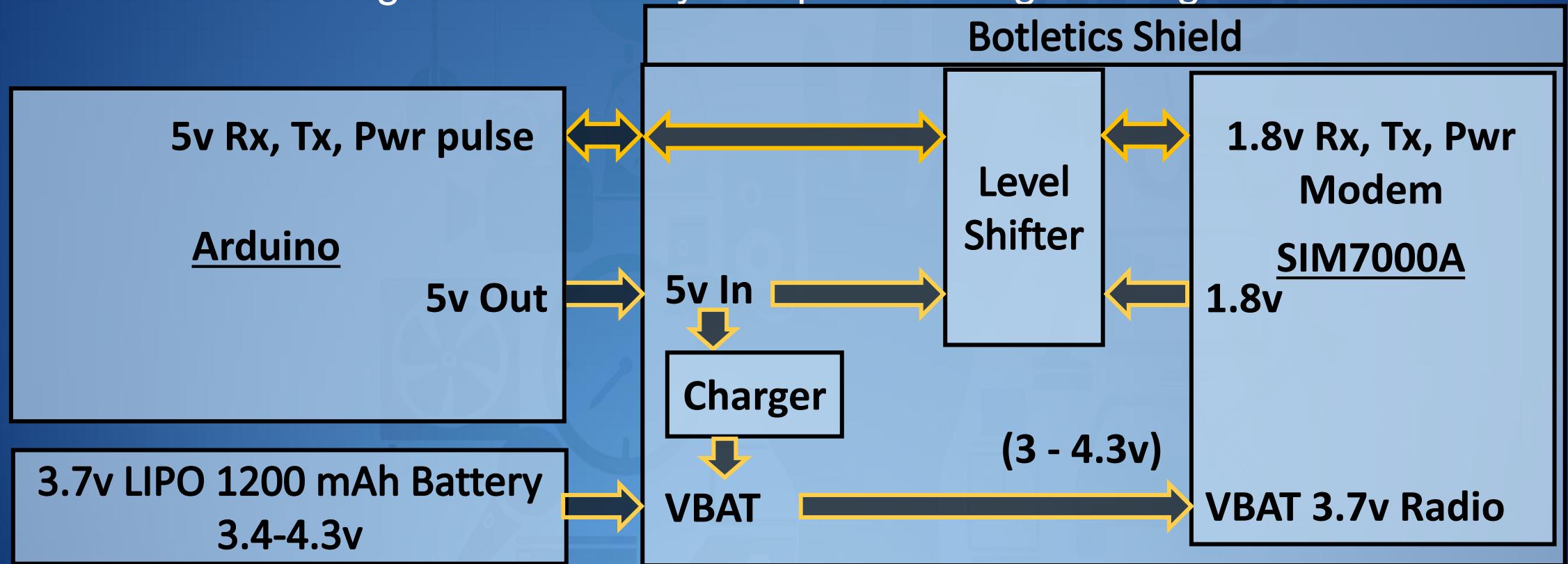
D1 Mini Example – Jumper cable to wake up



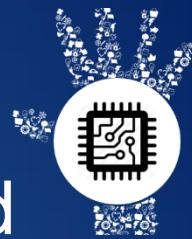
Botletics Shield Properties - Arduino



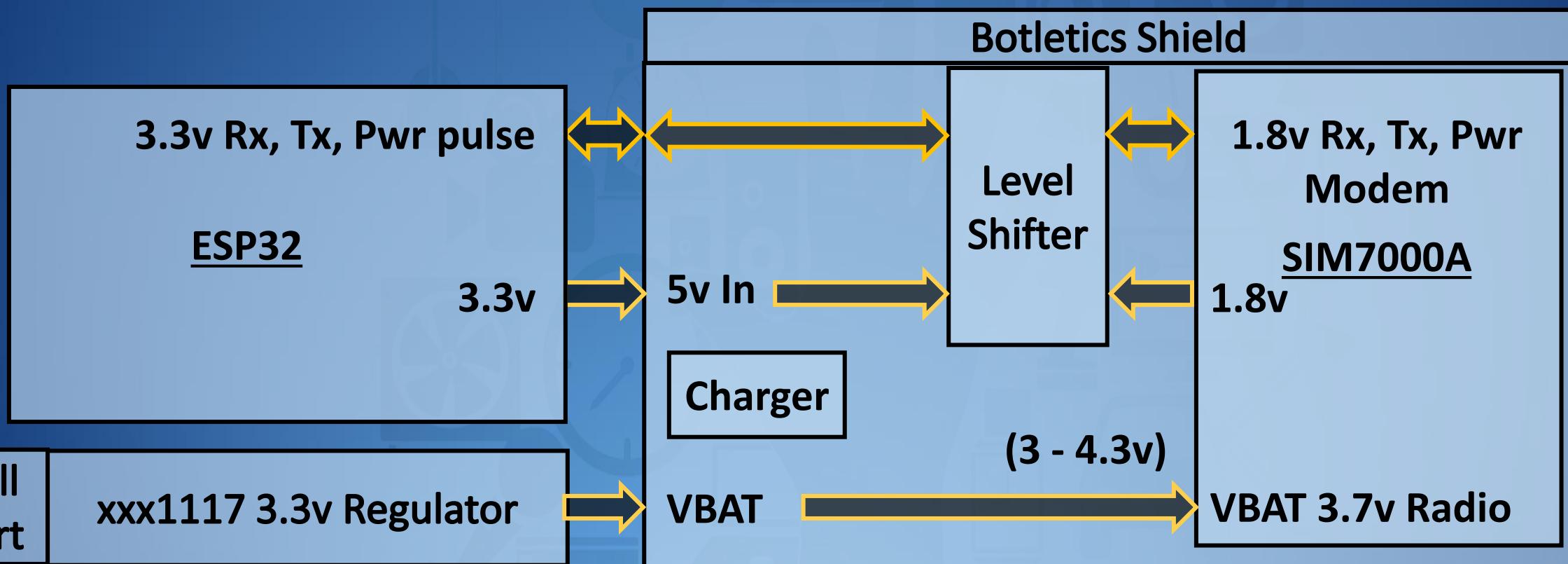
- Botletics Shield has 2 voltage inputs
 - LiPo Battery to meet surge current requirements for SIM7000A Radio
 - Surge current can be up to .6A LTE-M or up to 2A NB-IoT
 - 5 volt line charges LiPo battery and provides logic voltage



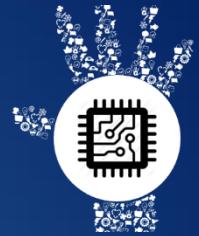
Botletics – Workaround 1



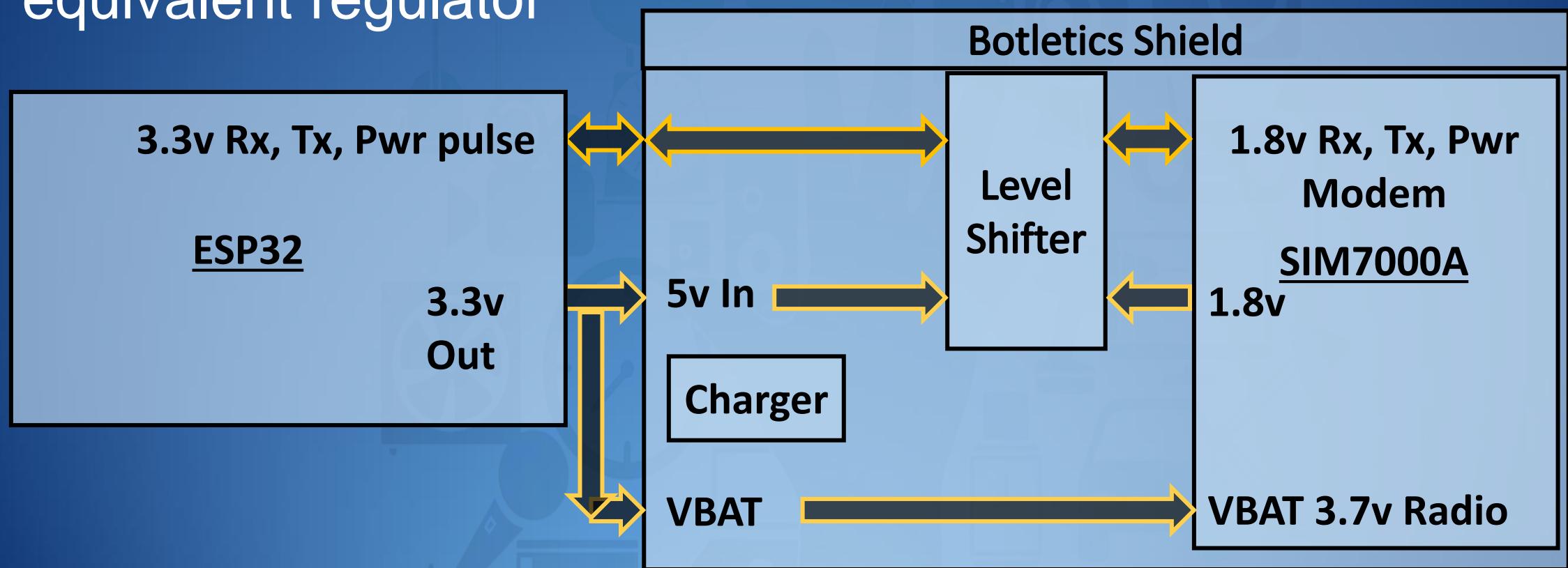
- Replace the Arduino, dump the battery, and use the LTE-M band
- A dedicated 3.3v .8A regulator handles SIM7000A radio
- ESP32 3.3v feeds into shield 5v In to the level shifter



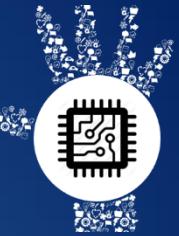
Botletics – Workaround 2



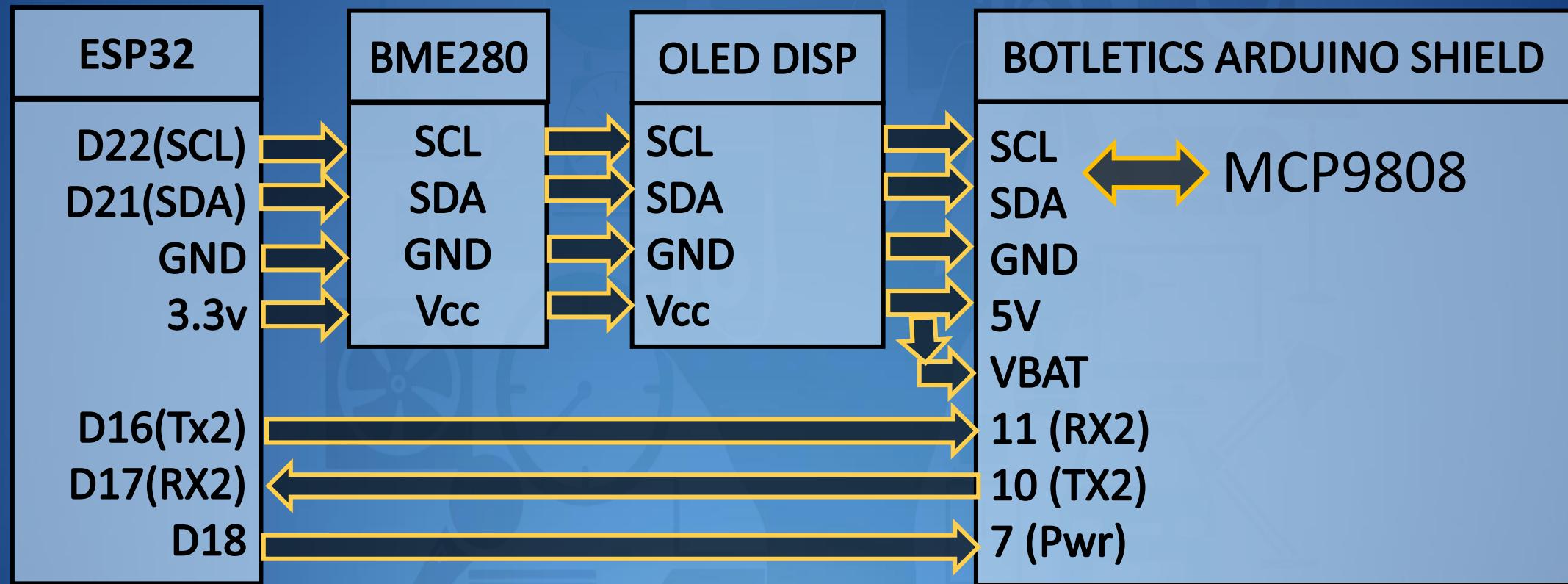
- Route The ESP32 3.3v to the battery input
- Verify your ESP32 uses a LM1117 or AMS1117 or equivalent regulator



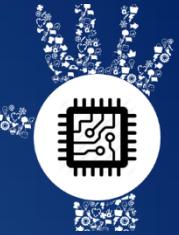
Hub Wiring (ESP32)



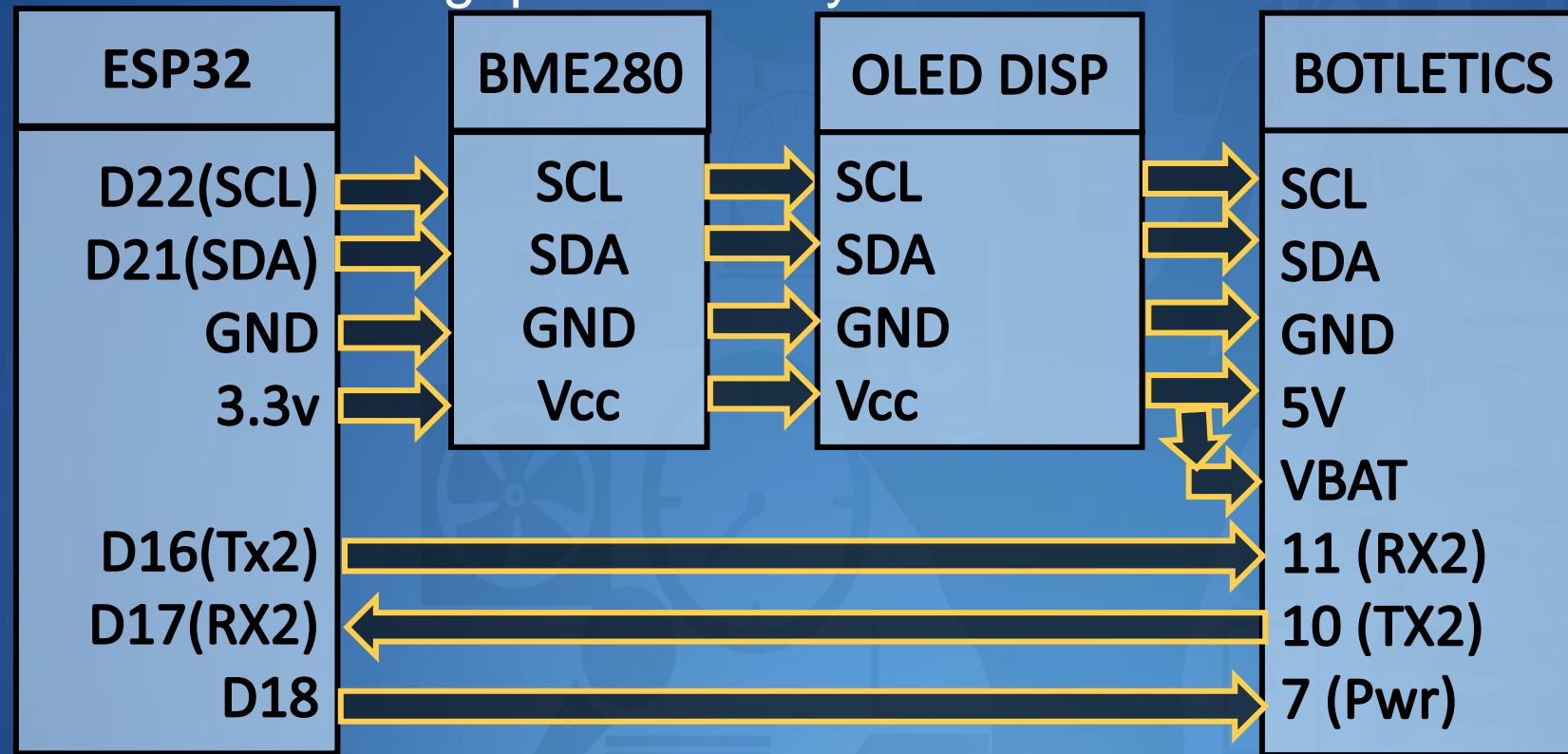
- ESP32 3.3 volt pin supplies power to all components
- Connect Botletics 5V to VBAT
- Add 3 wires: Rx, Tx, Power + I2C temperature sensor option



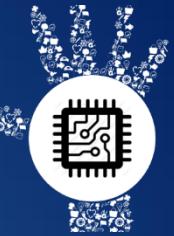
Ambient_HUB Power Issue



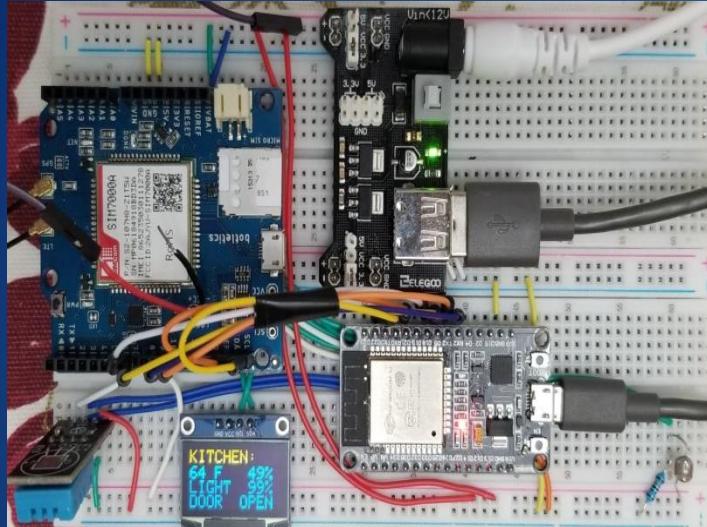
- Botletics Power On/Off can get out of sync with ESP32
 - Pulse width determines power state; 72ms pulse ON; 1.2 sec OFF
 - Condo living comes with noisy electromagnetic effects
 - Occasional hangup is cured by timer to reboot Hub



Hub Progression

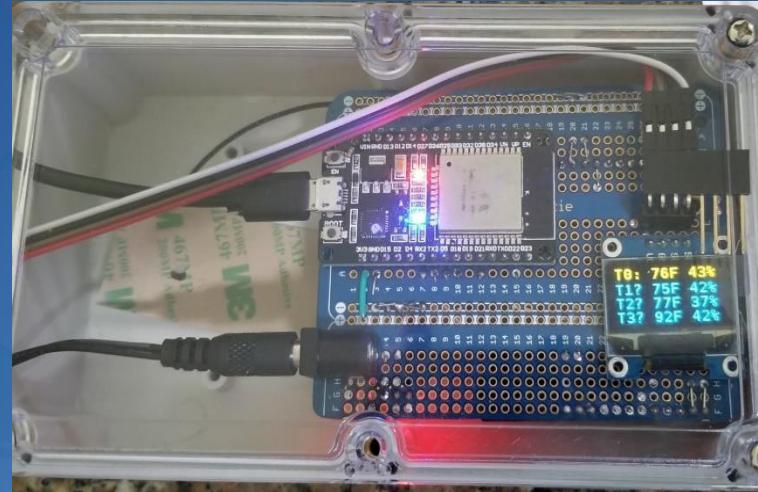


Oct 2020 Maine



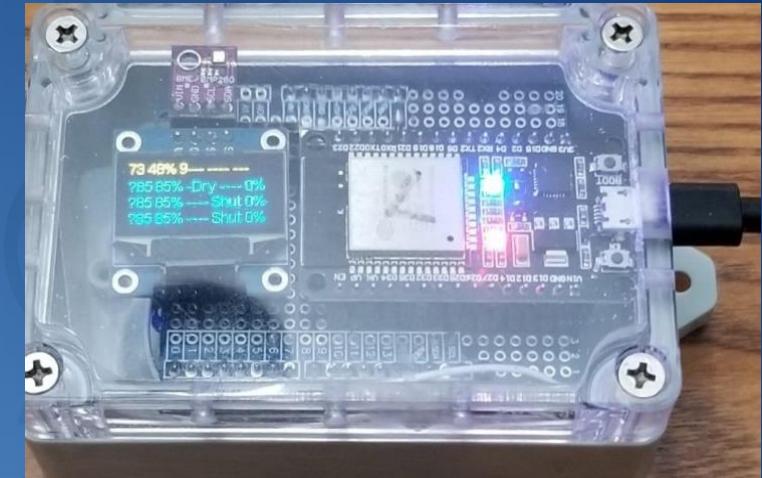
Breadboard
Botletics powered separately
DHT11 temp sensor
OLED display
Alert Mode
Optical sensor
Double wired

May 2021 Florida
4.5x3.5x2"



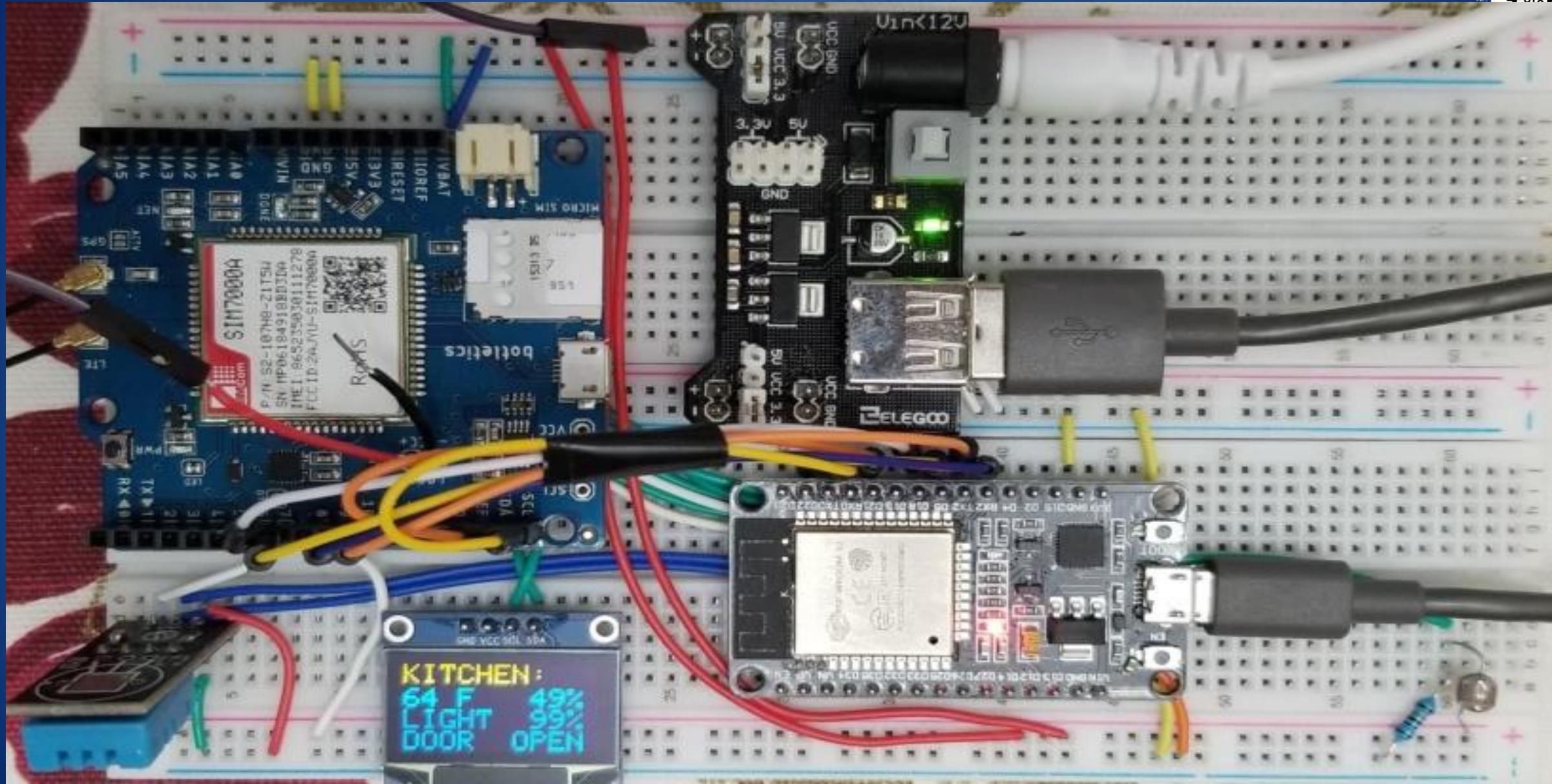
ElectroCookie PCB shield
Botletics powered separately
External BME280 temp sensor
OLED display
Alert Mode

Oct 2021 Maine
4x2.7x1.5"

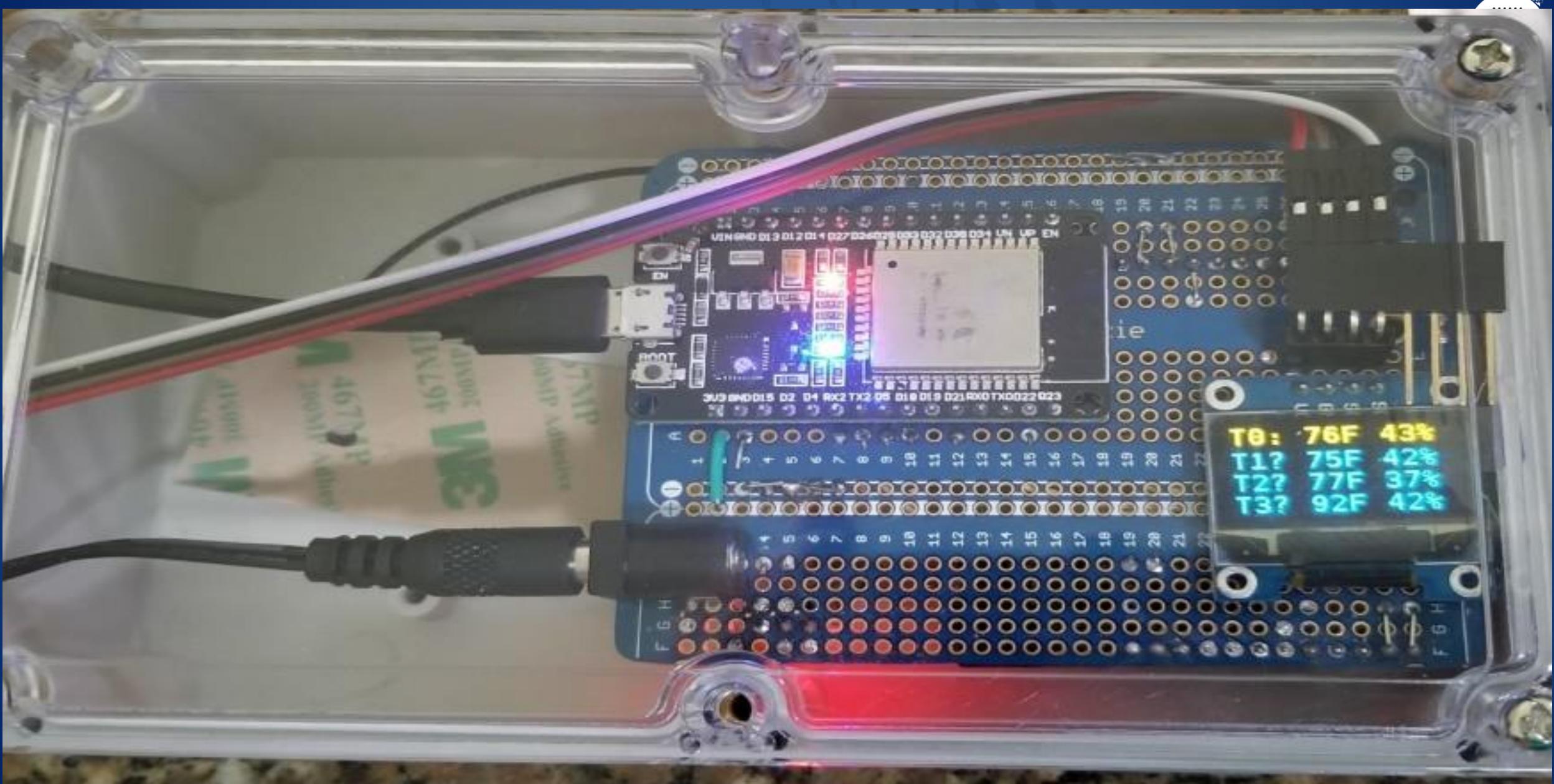


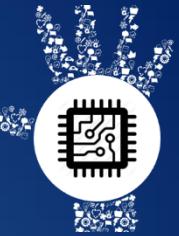
Arduino PCB shield
Botletics powered by ESP32
Internal BME280 temp sensor
OLED display
Snooze Mode
Ventilation holes drilled in case

Hub Progression - Oct 2020 Maine

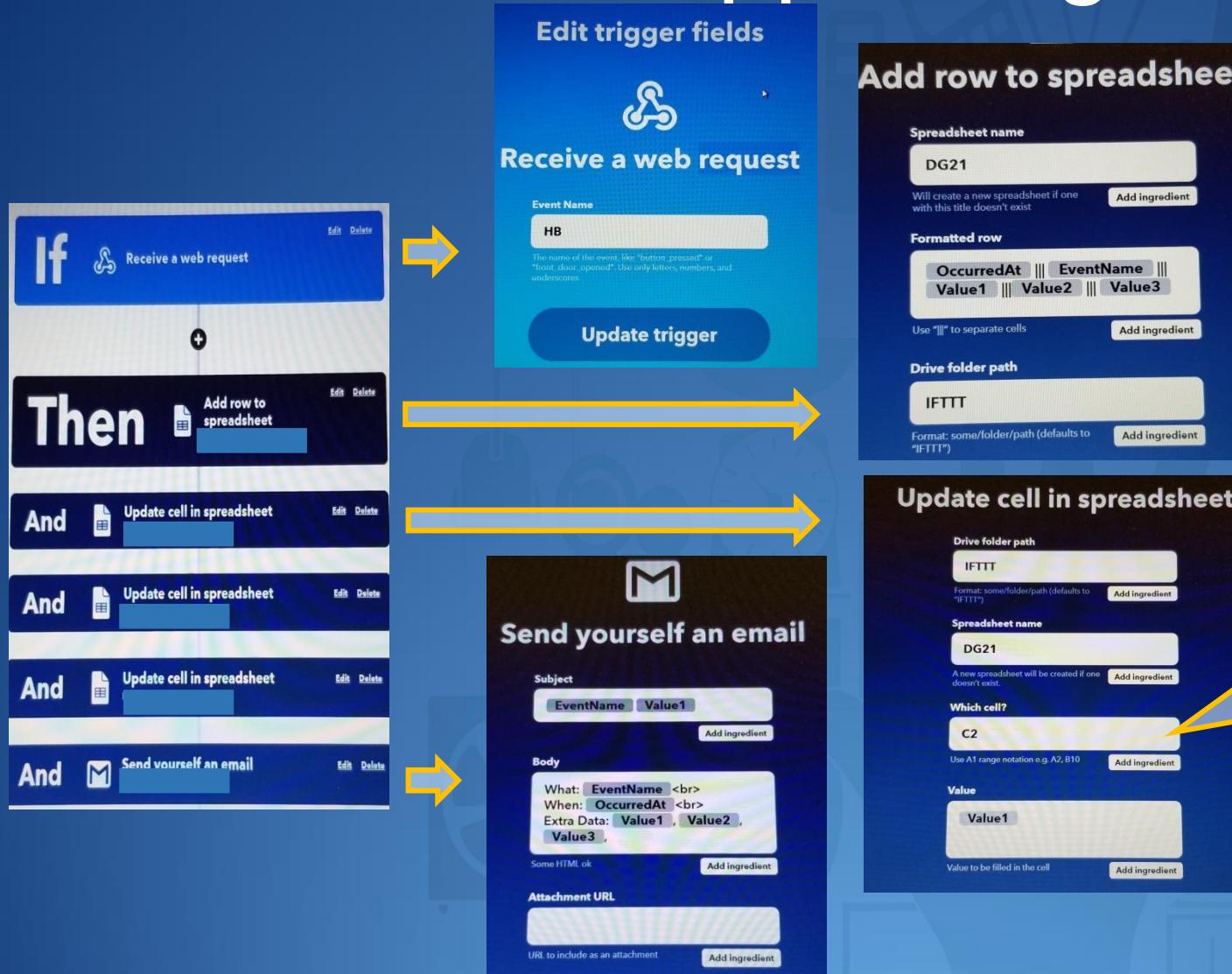


Hub Progression – May 2021 Florida



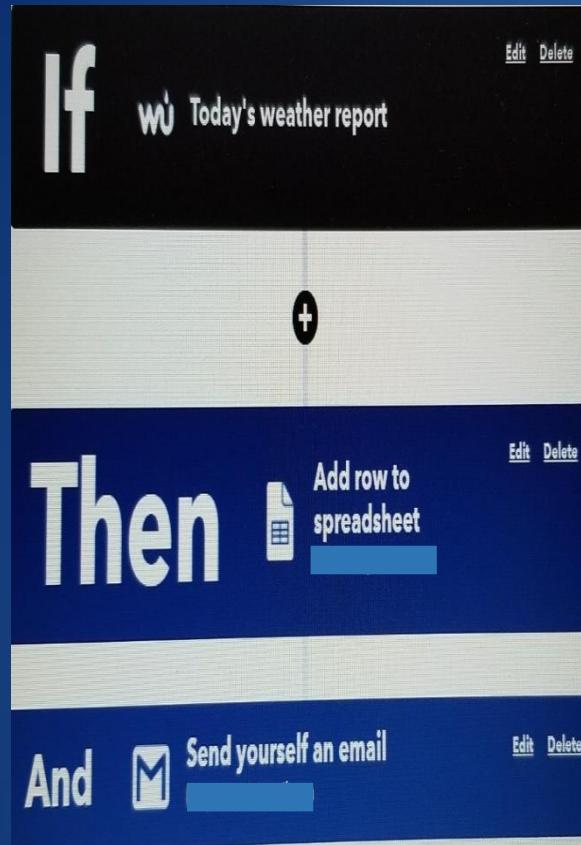


IFTTT Event Applet Ingredients



Cells A2, B2, and C2 are updated with date time, Web event name (HB for heartbeat or AL for ALERT), and the JSON Value1 so that Home Assistant can be used to monitor those cells instead of chasing after the newest row.

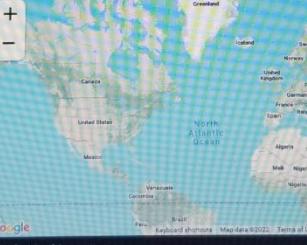
IFTTT Weather Applet Ingredients



Today's weather report

Time of day
06 AM

Location
51 Wild Dunes Way, Old Orchard E



Weather in this area

Add row to spreadsheet

Spreadsheet name

DG21

Will create a new spreadsheet if one with this title doesn't exist

Add ingredient

Formatted row

```
CheckTime ||| Weather |||
CurrentTempFahrenheit |||
Humidity ||| CurrentCondition
||| =IMAGE(""
CurrentConditionImageURL ";1)
||| ForecastUrl
```

Use "|||" to separate cells

Add ingredient

Drive folder path

IFTTT

Format: some/folder/path (defaults to "IFTTT")

Add ingredient

Send yourself an email

Subject

temp CurrentTempFahrenheit
TodaysCondition today!

Add ingredient

Body

```
<img src=
TodaysConditionImageURL >
<br>
<br>
With a high of
HighTempFahrenheit F and a low
of LowTempFahrenheit F.
Currently, it's
CurrentTempFahrenheit F and
CurrentCondition outside.<br>
<br>
Current wind speeds:
WindSpeedMph from the
WindDirection <br>
<br>
Pollen: PollenCount <br>
<br>
Sunrise: SunriseAt <br>
<br>
Sunset: SunsetAt <br>
<br>
UV index: UvIndex <br>
<br>
Humidity: Humidity %<br>
<br>
via ForecastUrl <br>
<br>
CheckTime
```

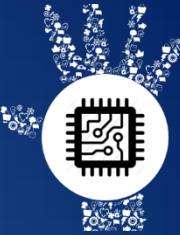
Some HTML ok

Add ingredient

Attachment URL

TodaysConditionImageURL

Ambient_AP Software Parameters



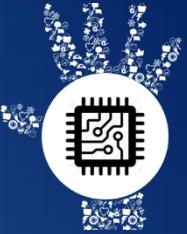
- In the first section at the top of the software:
- Comment one of the following lines (//) to select processor
 - #define ESP32
 - // #define ESP8266 (commented by default)
- Choose between alert mode or Snooze mode (default)
 - const int sleepSeconds = 8*60; //sleep time in seconds (default)
// 0 if no sleep (alert mode)
 - const long awakeSeconds = 2*60; //interval in seconds to stay
//awake as server;
 - If sleepSeconds is set to 0, awakeSeconds is ignored

Ambient_AP Software Parameters



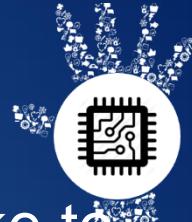
- Each sensor needs unique display title and ssid; uncomment one triplet and comment the others before compiling
 - //uint8_t sensorID = 1;
 - //#define displayTitle " ~AMBIENT_1~"
 - //const char* ssid = "AMBIENT_1";
- uint8_t sensorID = 2;
- #define displayTitle " ~AMBIENT_2~"
- const char* ssid = "AMBIENT_2";
- //uint8_t sensorID = 3;
- //#define displayTitle " ~AMBIENT_3~"
- //const char* ssid = "AMBIENT_3";

Ambient_HUB Software Parameters



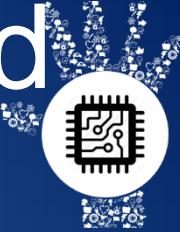
- Enter your IFTTT key in place of ENTER_KEY
 - `#define IFTTT_HB_URL "http://maker.ifttt.com/trigger/HB/with/key/ENTER_KEY"`
- Choose between alert mode or snooze mode (default)
 - `const int espSleepSeconds = 48*60; //sleep time in seconds (default)`
`// 0 if no sleep (alert mode)`
 - `const long espAwakeSeconds = 12*60; // interval in seconds to stay`
`//awake as HUB;`
 - If `espSleepSeconds` is set to 0 (alert mode), `espAwakeSeconds` is ignored

Gotcha's – A Consolidated List



- Voltage to the Botletics pin cannot drop below 3.0v while current could spike to 600 ma during connection and data transfer on LTE-M; 2A on NB-IoT
 - Software selects LTE-M band
- LIPO batteries built for toys have different polarity than those built for electronics??; doublecheck your battery polarity if you use one
- WEMOS D1 Mini (esp8266) can have inadequate rf range, possible wifi library issues, and interfere with each other if >1?
- Verify regulators on ESP32's! Need xx1117 or equivalent to handle LTE-M
- SIM sockets can be tinny, easily bent – Handle with care!
- Put a timer with battery backup to reset the hub periodically!

Hologram: Cellular Connectivity to the Cloud

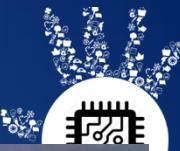


- Dashboard for deployed device management and control
- Data can be massaged and routed to other services
- Messages can be sent to devices from the dashboard
- Individual sensors can be analyzed
- For example: the next slide reveals that IFTTT may be throttling by refusing data periodically

OR

It might be a software issue to test on my duplicate system

Hologram Dashboard Provides Connection Details



Connection Overview

CARRIER
US Cellular Corp

LAST CONNECTED
24 minutes ago

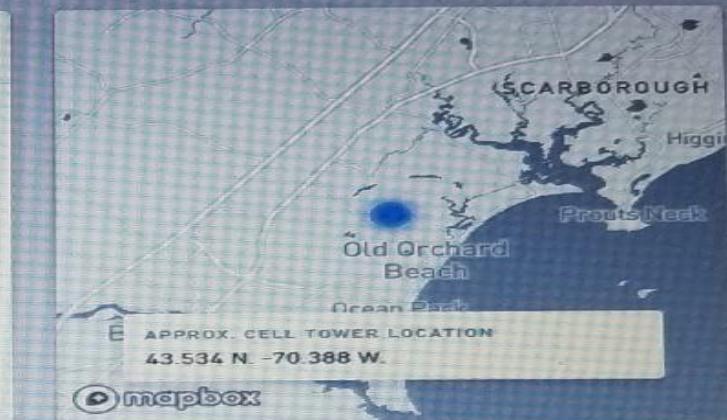
SESSION START
January 7, 2022 12:59:06 PM EST

SESSION END
January 7, 2022 12:59:31 PM EST

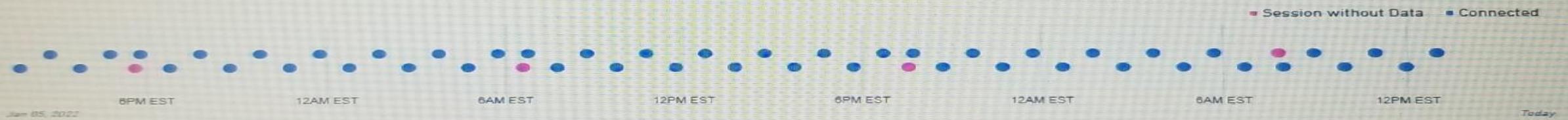
APN
hologram

USAGE THIS PERIOD
520.53 KB

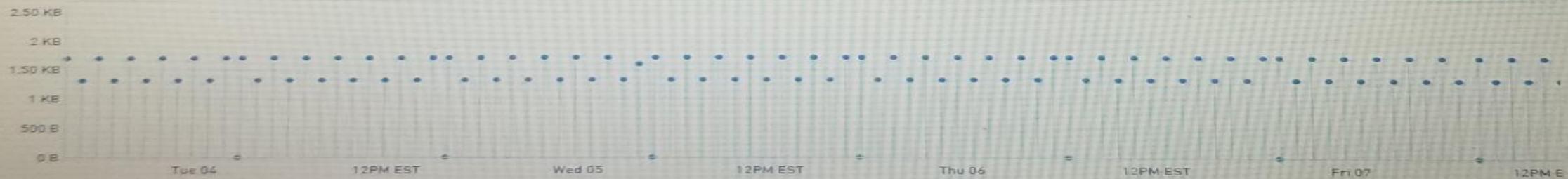
BYTES THIS SESSION
1.32 KB



Network Connections in the Last 48 Hours



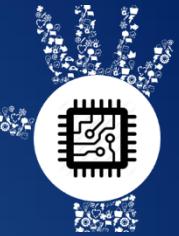
Recent Data Sessions





References

References



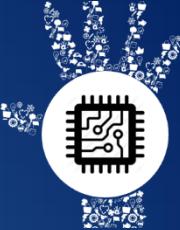
- Paul McWhorter Arduino
 - A series of YouTube videos which show you how to install the IDE and get started programming the Arduino microcontroller
- Random Nerd Tutorials
 - Step by step instructions explaining various arduino-based esp32 and esp8266 microcontrollers, projects, protocols, and much more. They include plenty of working project code



References

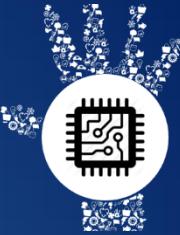
- The Guy with the Swiss Accent
- Hands on Tech The Villages Florida
- See H.O.T meeting 11/30/2017 and on-ramp material for detailed steps to set up IFTTT account and the Arduino IDE
- Botletics Wiki, Botletics GitHub

FCC Notice (47 CFR 2.803)



- The following notice accompanies the Botletics shield:
- “This kit is designed to allow:
- (1) Product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and...

...FCC Notice (47 CFR 2.803) para 2



- ...(2) Software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.”