For **LO**wering Household **W**ater Usage

SDP Team 9

CDR

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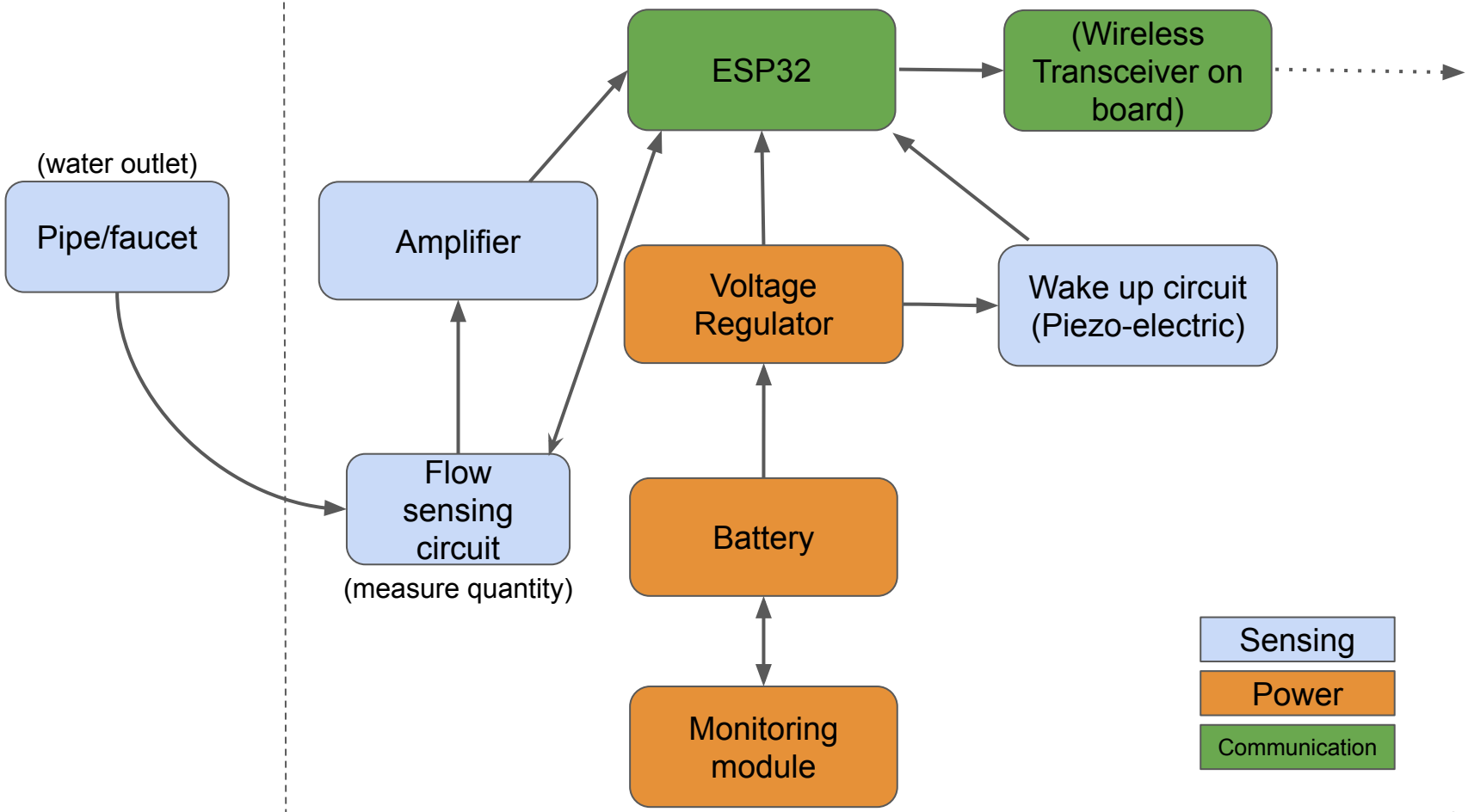
Problem Statement

According to the United States Geological Survey, each person uses about 80-100 gallons of water per day for indoor home uses [1]. The majority of the households cannot monitor which home fixture or water outlet dispenses the most amount of water. **The system we aim to create will measure the quantity of by each water outlet**. Users can view their monthly water consumption from an app to which the sensor nodes are connected. The data will allow users to learn their water consumption behaviour.


ESP32
(Wireless Transceiver on board)
(water outlet)
Pipe/faucet
Amplifier
Voltage Regulator
Wake up circuit (Piezo-electric)
Flow sensing circuit
(measure quantity)
Battery
Monitoring module
Sensing
Power
Communication

From MDR

From MDR, we broke down the whole system into different subsystems and aspects that we had to fulfill:

- Choice of flow rate sensor
- Power
- Orientation and Calibration
- PCB
- Data visualization

Choice of Flow Rate Sensor

- Work done during winter break
  - Electret Microphone
    - One microphone
      - Not able to relate the sensor signal to water flow rate.
    - Two microphones
      - The time difference was unreliable.
  - Ultrasonic Sensor
    - Ultrasonic sensor with > 1 MHz do not have external circuitry.
    - Very less resources available for making one.
- Survey indicated users are fine with an in-line sensor.

From MDR

From MDR, we broke down the whole system into different subsystems and aspects that we had to fulfill:

- Choice of flow rate sensor
- Power
  - Decision driven by cost
- Orientation and Calibration
- PCB
- Data visualization

Cost Analysis

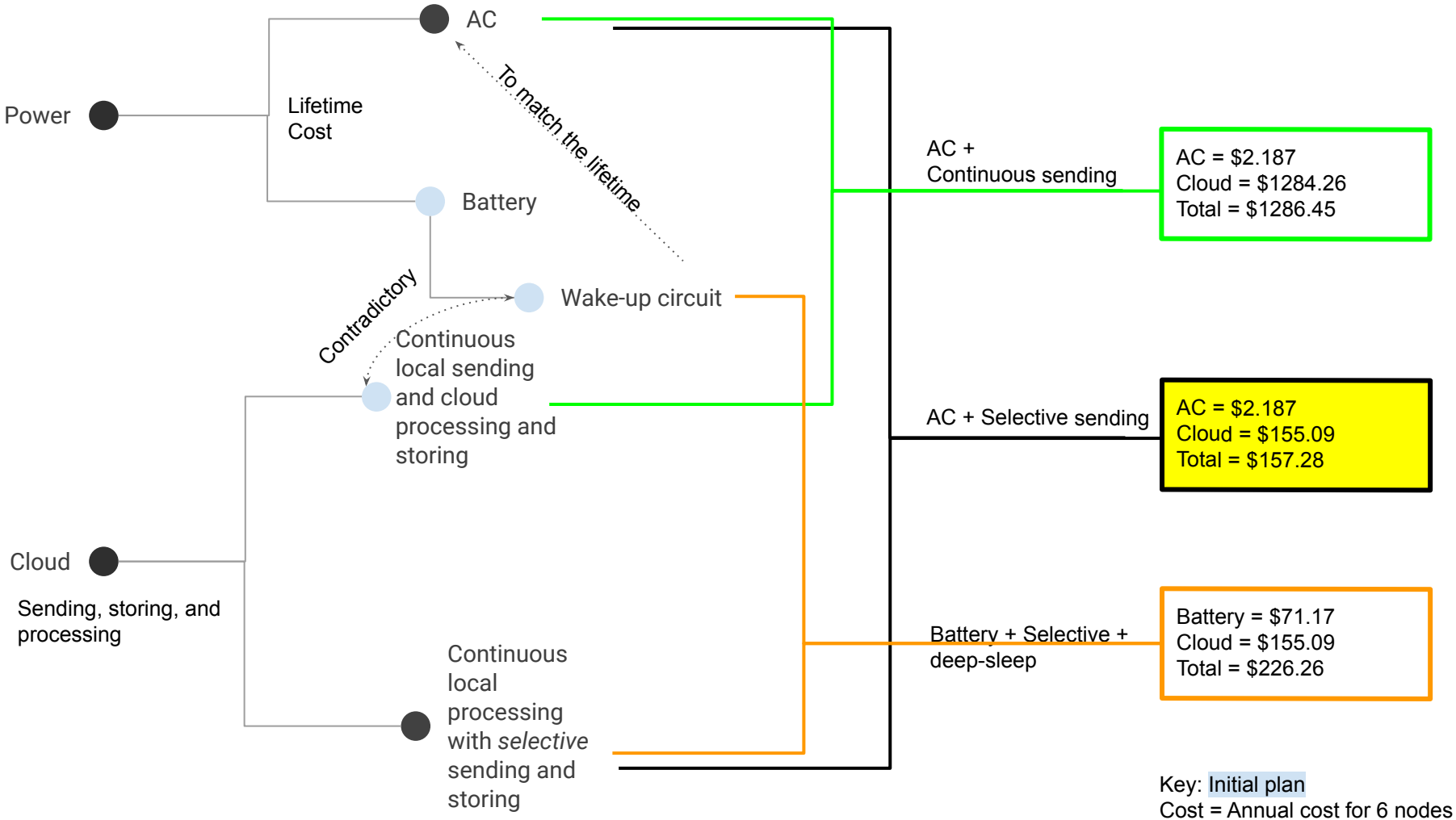
- Initial cost is fixed at $15 per node.
    - PCB ($5) + Hall effect flow rate sensor ($10)
- *Design choices* will impact the *recurring* costs:
    - *Choice* of power supply
        - AC power supply - impacts recurring electric bill cost
            - Requires AC adapter to plug into wall outlet
        - Battery - cost to replace batteries over time
            - Requires a Wake-up circuit (proposed during MDR)
    - *Choice* of where to do data processing
        - Data sending, processing, storing in the cloud - each of these items incurs a cost from the cloud service provider
            - Requires balance between processing vs in the cloud
            - This impacts the way the local processor is operated

Energy-Cost Tradeoff (AC vs. Battery)

Execution	**Current Drawn —---------- Energy Consumed**	**Annual AC Cost – 6 nodes (20 cents / kWh) [3]**	**Annual Battery Cost – AA batteries, 6 nodes (no deep sleep)**	**Annual Battery Cost – AA batteries, 6 nodes (with deep sleep)**
Local Operation (LO)	32 mA			
Local Operation + Sending data to the cloud (LOC)	115 mA			
Continuous sending for one day (24 hours LOC)	0.0138kWh	$5.96	$2,893.72 ● 8,760 AA batteries/year ● 4 AA /day/node	
Selective data sending for one day (3 hours LOC, 21 hours LO)	0.005064kWh	$2.19	$729.38 ● 2,208 AA batteries/year ● 4 AA /4 days/node	$71.17 ● 216 AA batteries/year ● 4 AA/40 days/node

Cloud Cost Tradeoff

Execution	**Yearly cloud service for 1 node**	**Yearly cloud service for 6 nodes**
Continuously retrieve, process and store (24 hours)	$214.04	$1,284.26
Selectively retrieve, process, and store (3 hours retrieval/day)	$25.85	$155.09


AC
Power
Lifetime
Cost
To match the lifetime
Battery
Contradictory
Wake-up circuit
Continuous
local sending
and cloud
processing and
storing
Cloud
Sending, storing, and
processing
Continuous
local
processing
with *selective*
sending and
storing
AC +
Continuous sending
AC = $2.187
Cloud = $1284.26
Total = $1286.45
AC + Selective sending
AC = $2.187
Cloud = $155.09
Total = $157.28
Battery + Selective +
deep-sleep
Battery = $71.17
Cloud = $155.09
Total = $226.26
Key: Initial plan
Cost = Annual cost for 6 nodes

Survey Results

- We conducted a survey to a group of parents in Acton, MA. A total of 30 people responded to the survey.
- Location of installation
  - Every outlet in the house → locations where the water cannot be physically gauge
  - Washer, dishwasher
- Plumbing
  - 50% of people surveyed know how to do basic plumbing.
  - If a tutorial video was provided, people could do the installation by themselves without the need of a plumber.
  - Majority of homeowners have common plumbing tools like wrenches, teflon tape, and vice grips
- Data visualization
  - Total monthly water consumption of each outlet

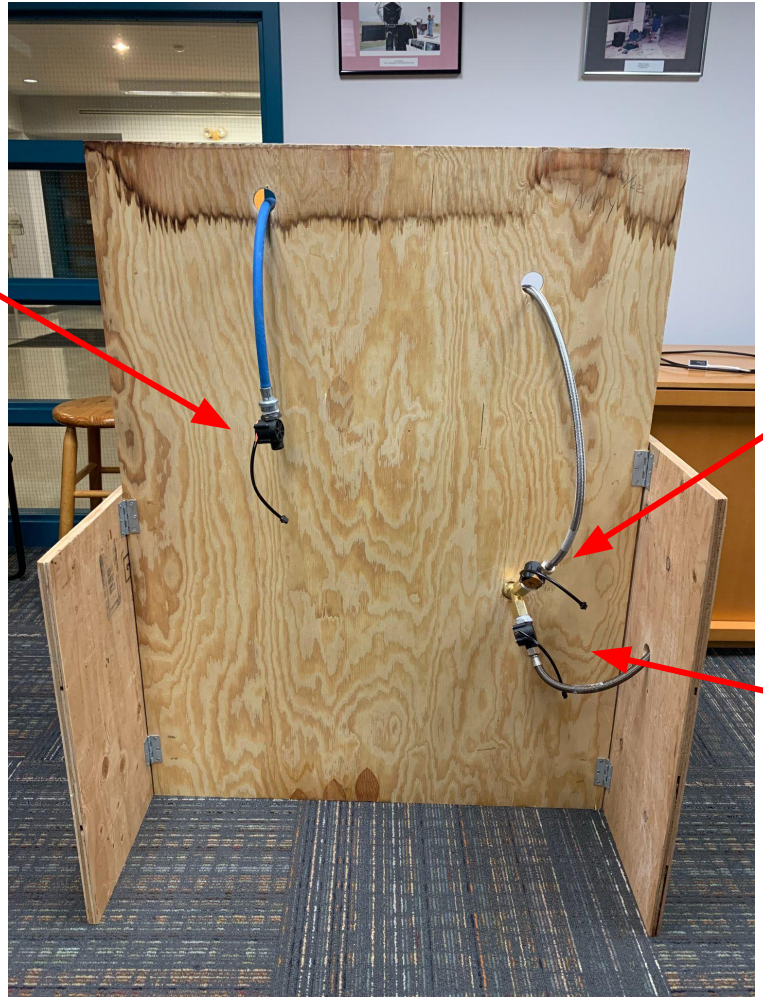
Orientation and Calibration

- Horizontal (start of the line): sensor placed horizontally, near water source
- Horizontal (end of the line): sensor placed horizontally, water comes straight out of the sensor, away from the water source
- Vertical (start of the line): sensor placed vertically, near water source
- We plan to put switches onto the PCB so the user can indicate where they are placing that specific sensor

$$calibration\ factor = \frac{pulse\ count}{time\ (seconds)} * \frac{1}{flow\ rate\ (L/min)}$$

https://docs.google.com/spreadsheets/d/1K6irMV7HSS9KohmgTR-hn4Gaswl9F7rIqph3x_uw2vk/edit#gid=0

Vertical down



Vertical up

Horizontal

Calibration Factor Derivation

$$Flow\ Rate = \frac{1000}{msec} * \frac{pulse\ count}{calibration\ factor}$$

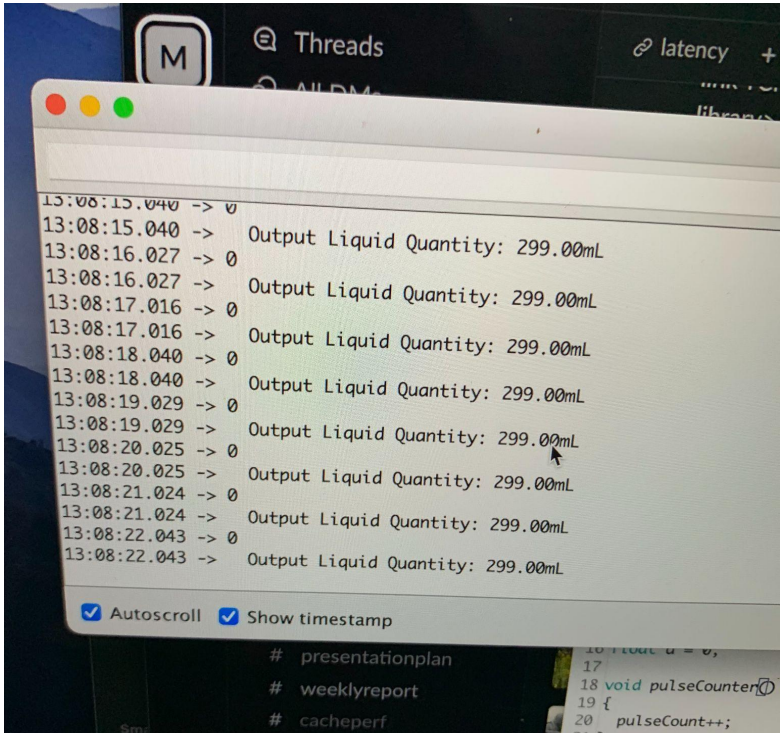
$$Flow\ Rate = \frac{1000}{msec} * pulse * \frac{L}{min} * \frac{second}{pulse} = \frac{L}{min}$$

$$Flow\ Rate = \frac{1000}{msec} * pulse\ count * \frac{1}{calibration\ factor}$$

$$calibration\ factor = \frac{pulse\ count}{time\ (seconds)} * \frac{1}{flow\ rate\ (L/min)}$$

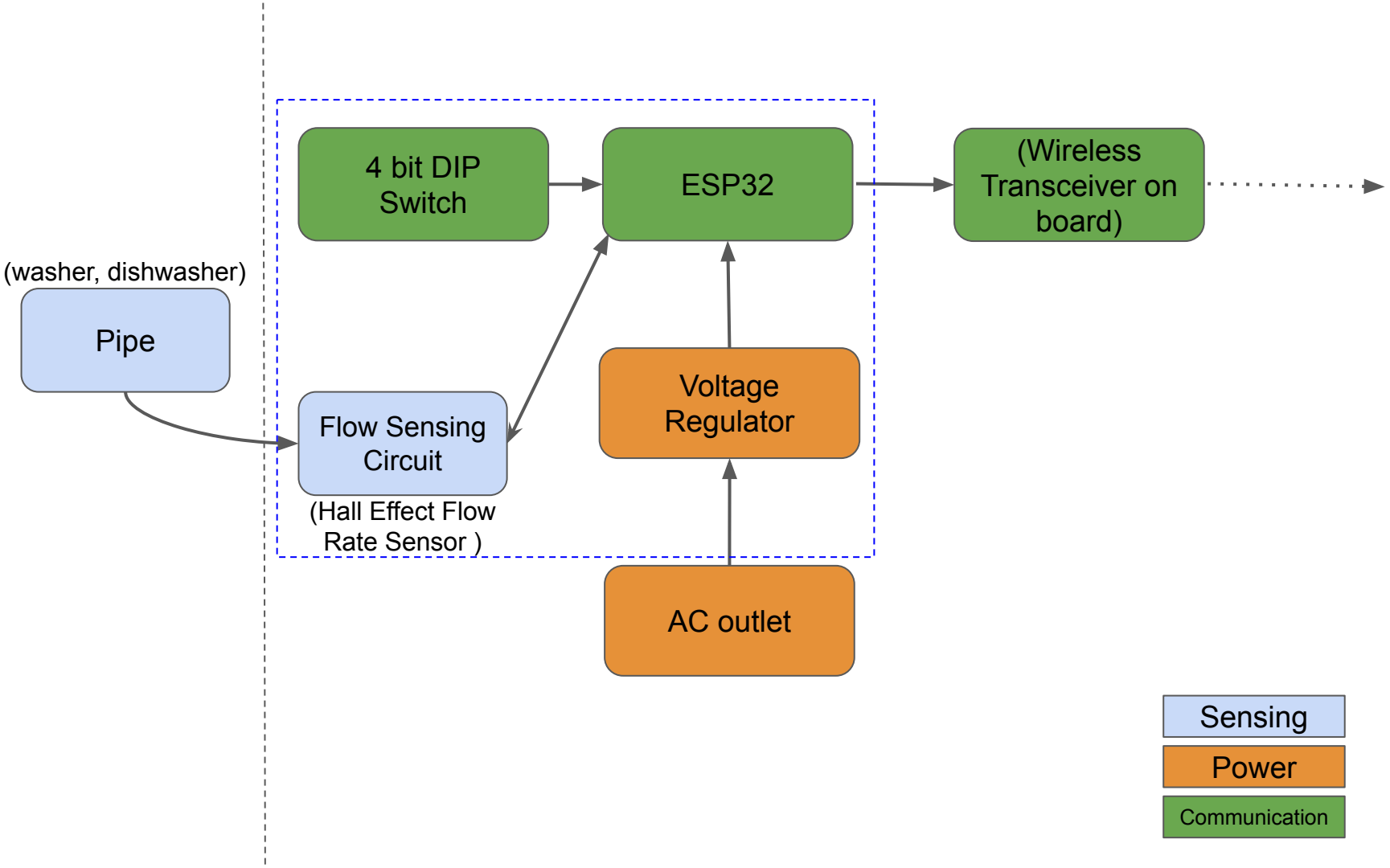
The pulse count in the original equation is # pulses/second.

Accuracy

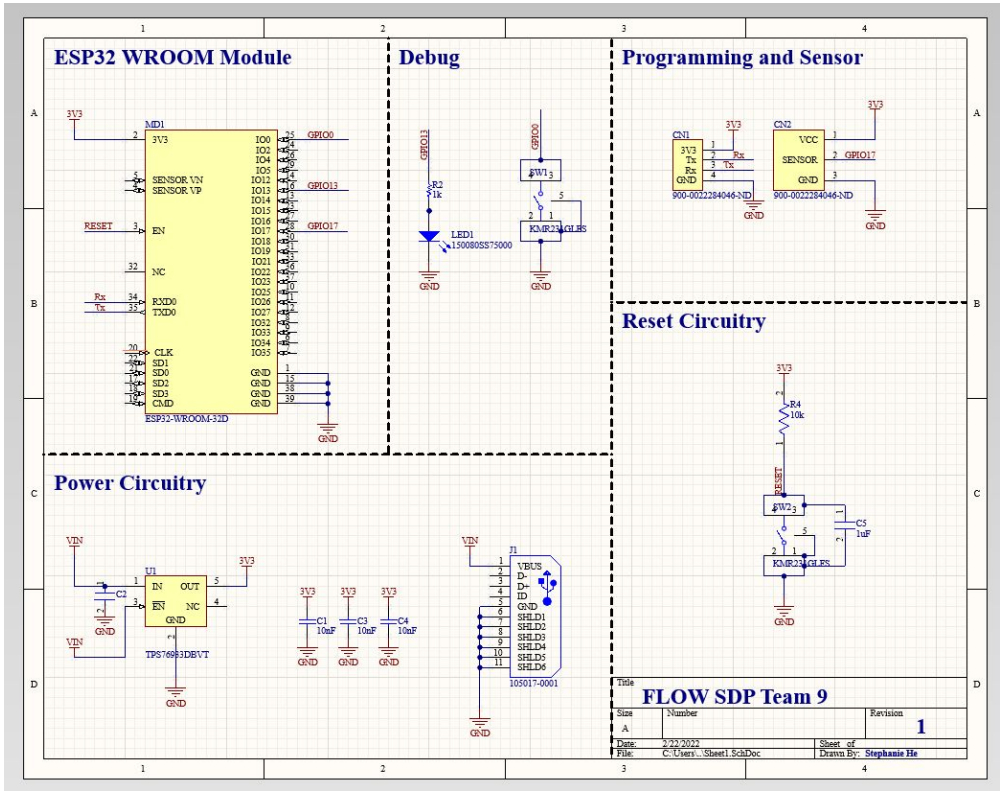


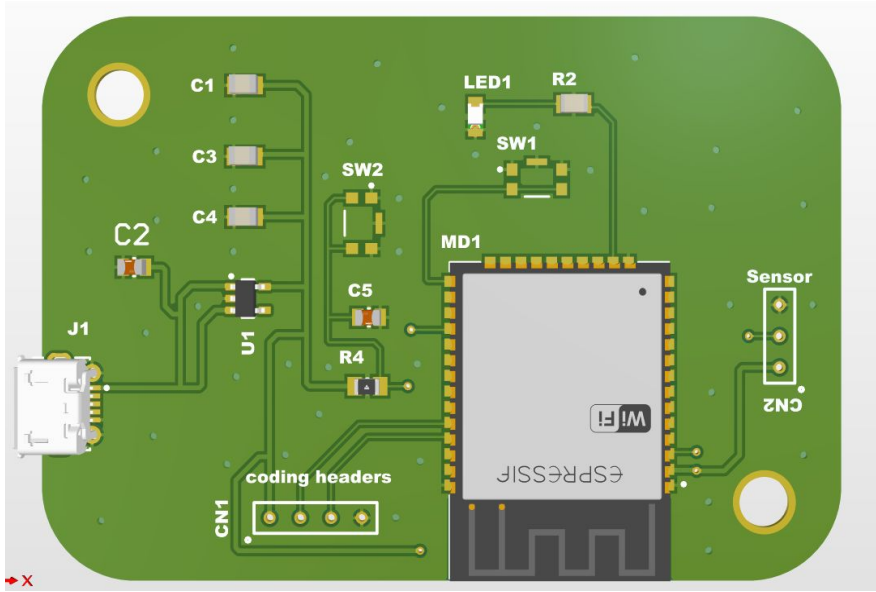
299 mL showing on serial monitor

Jug with 300mL of water

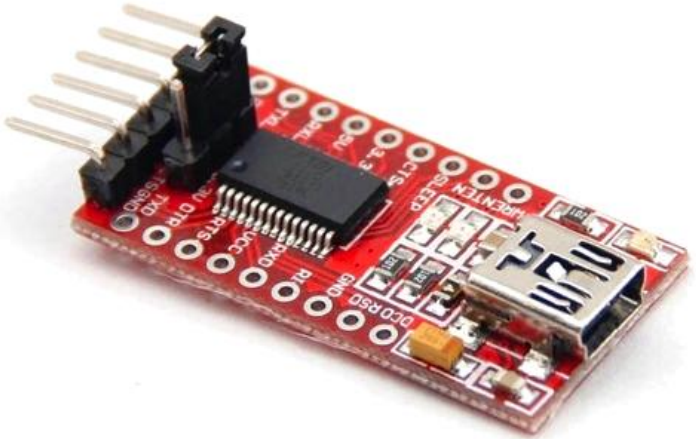

4 bit DIP Switch
ESP32
(Wireless Transceiver on board)
(washer, dishwasher)
Pipe
Flow Sensing Circuit
(Hall Effect Flow Rate Sensor)
Voltage Regulator
AC outlet
Sensing
Power
Communication

PCB Schematic and Board without Switch



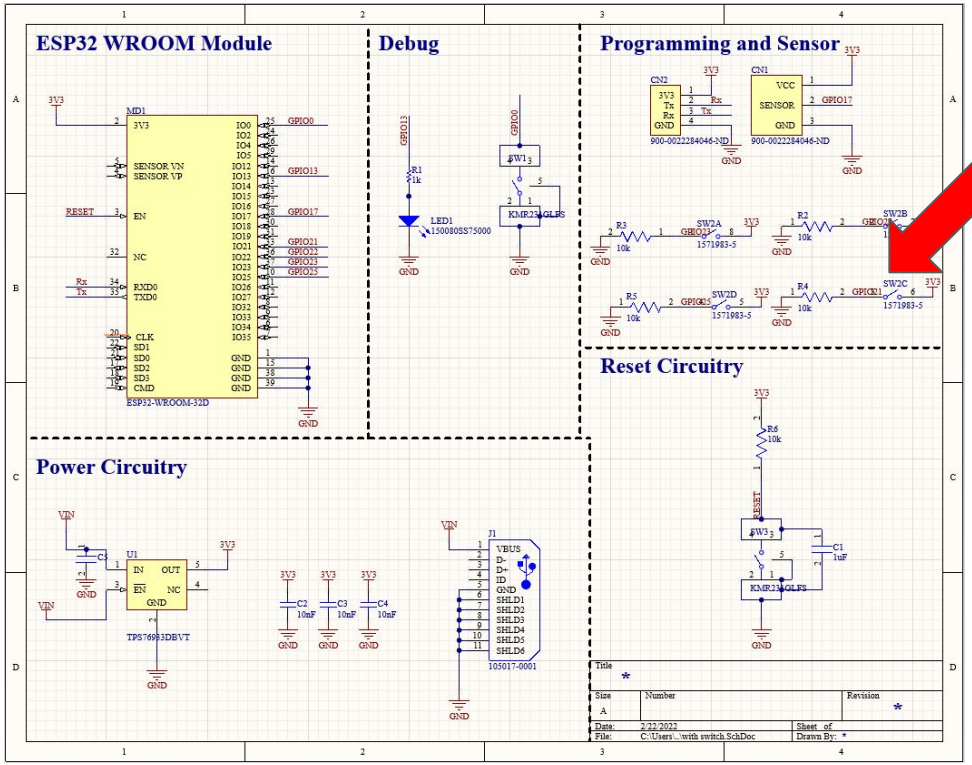


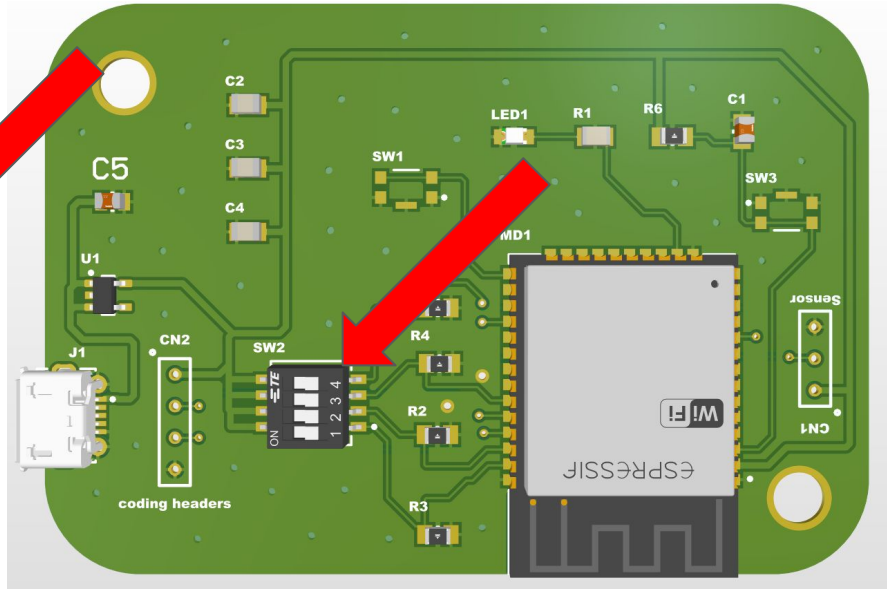
FTDI Serial to USB converter



[4]

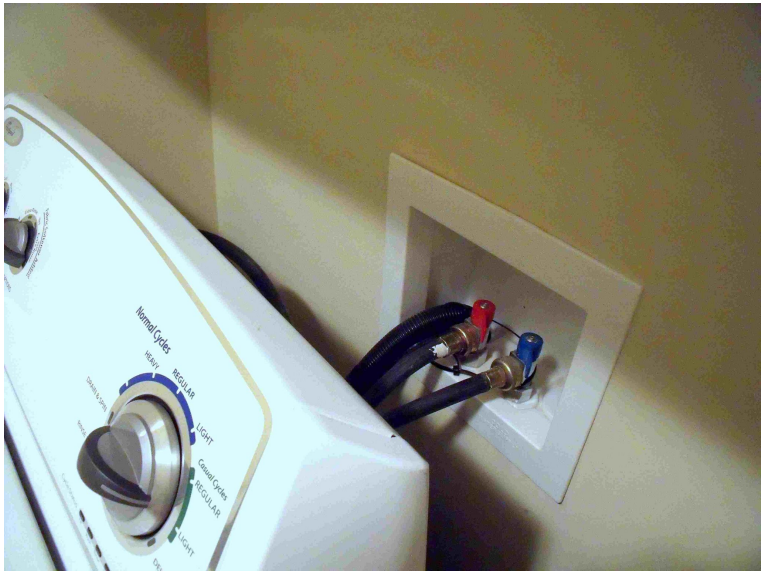
PCB Schematic and Board with 4-bit DIP SPST Switch





Locations

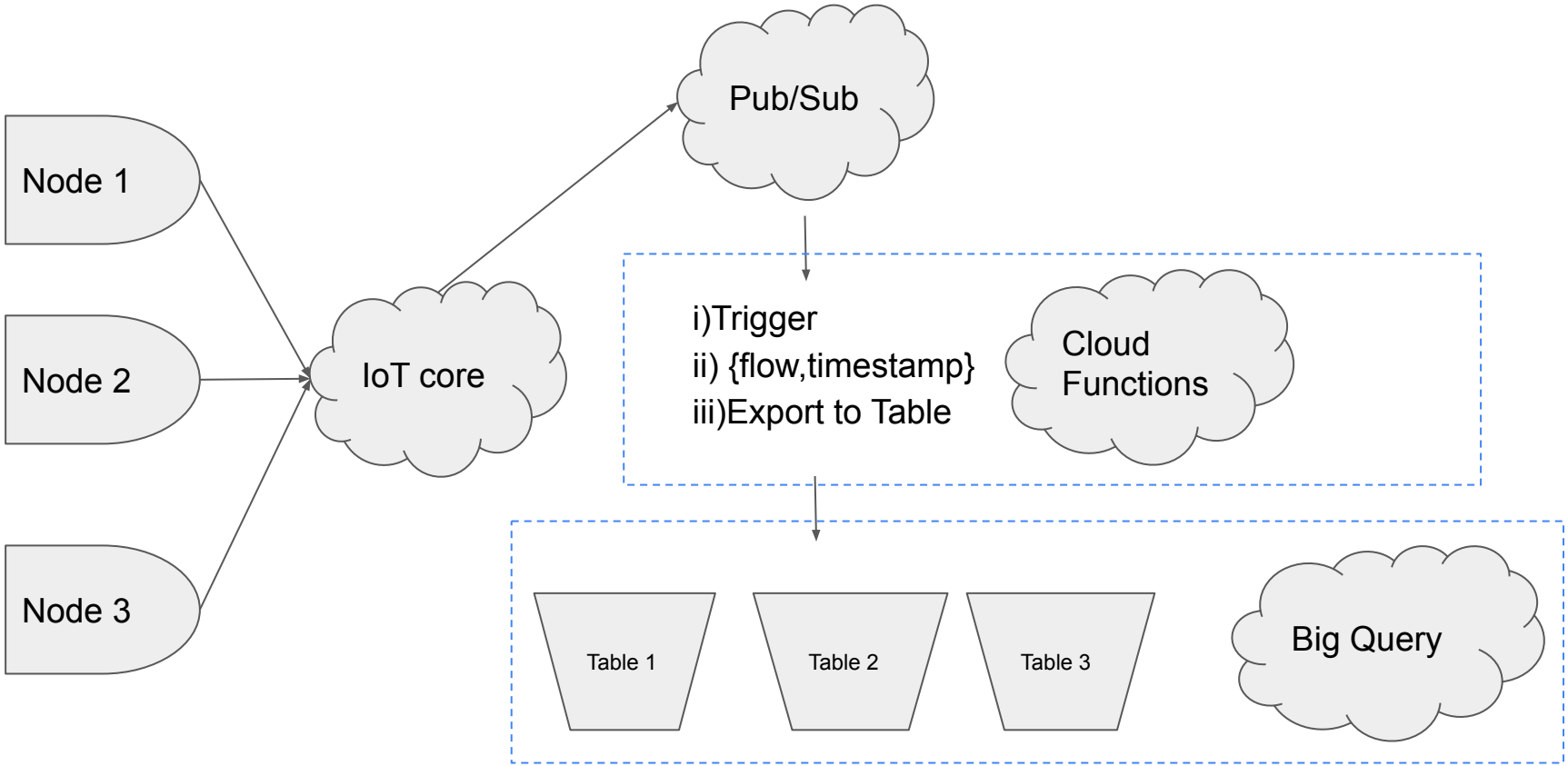
- Sink + dishwasher
- Washing machine line

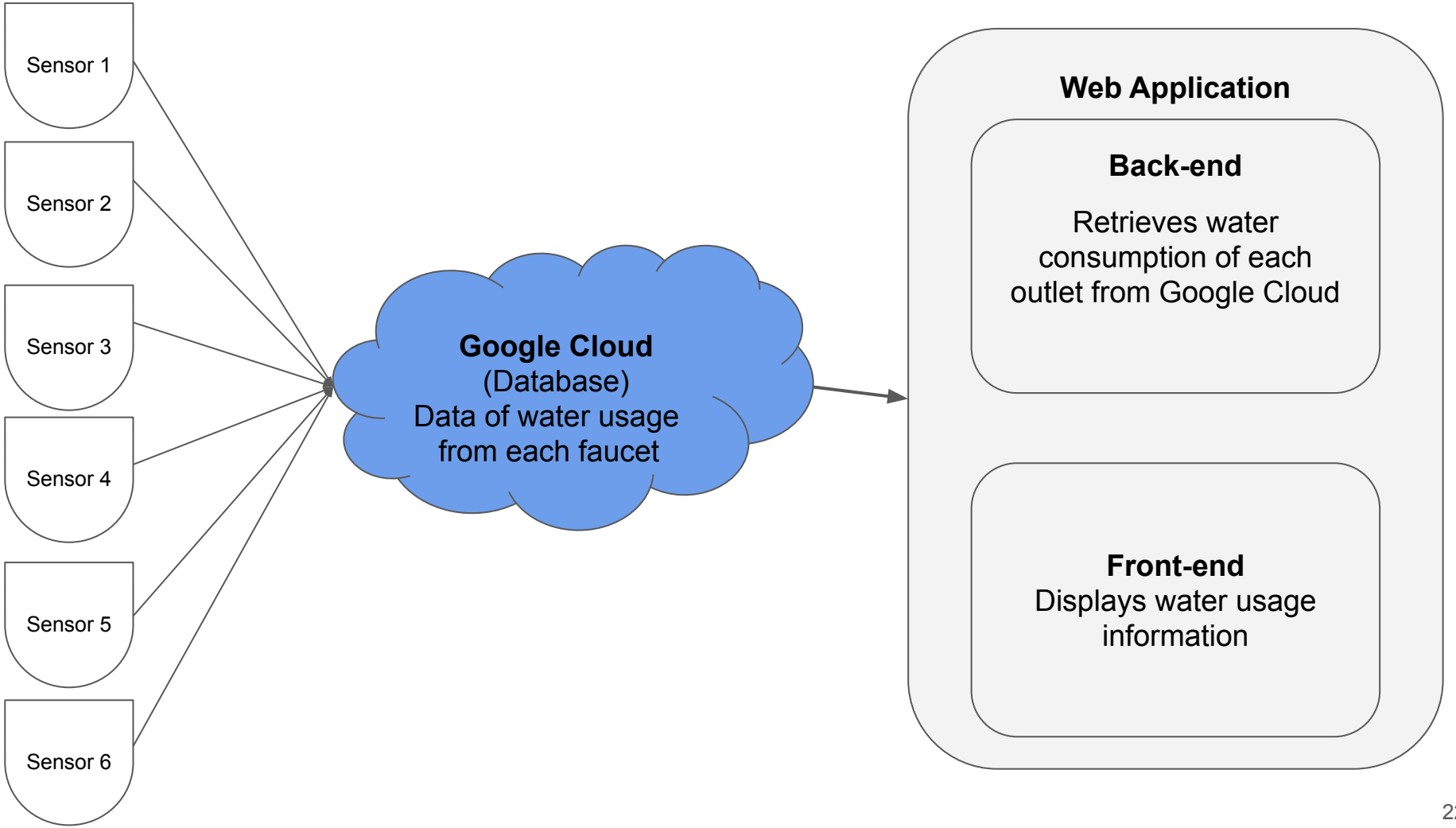


[5]

[6]

Cloud flow


Node 1
Node 2
Node 3
IoT core
Pub/Sub
i)Trigger
ii) {flow,timestamp}
iii)Export to Table
Cloud Functions
Table 1
Table 2
Table 3
Big Query


Sensor 1
Sensor 2
Sensor 3
Sensor 4
Sensor 5
Sensor 6
Google Cloud
(Database)
Data of water usage
from each faucet
Web Application
Back-end
Retrieves water
consumption of each
outlet from Google Cloud
Front-end
Displays water usage
information

Software Libraries

Client-Server	**IoT messaging protocol**	**For Google Cloud connection**	**Backup for Adafruit**
WiF_Client.h	MQTT.h	CloudIoTCore.h	Adafruit_MQTT.h
Wifi.h		CloudIoTCoreMqtt.h	Adafruit_MQTT_Client.h
WiFiClientSecure.h			

Code Snippet

```
/*
 *  - configure and initialize PCNT
 *  - set up the input filter
 *  - set up the counter events to watch
 */
static void pcnt_example_init(void)
{
    pcnt_config_t pcnt_config = {
        .pulse_gpio_num = PCNT_INPUT_SIG_IO,
        .channel = PCNT_CHANNEL_0,
        .unit = PCNT_TEST_UNIT,
        .pos_mode = PCNT_COUNT_INC,
        .neg_mode = PCNT_COUNT_DIS,
        .counter_h_lim = PCNT_H_LIM_VAL,
    };
    pcnt_unit_config(&pcnt_config);

    pcnt_set_filter_value(PCNT_TEST_UNIT, 100);
    pcnt_filter_enable(PCNT_TEST_UNIT);

    pcnt_set_event_value(PCNT_TEST_UNIT, PCNT_EVT_THRES_1, PCNT_THRESH1_VAL);
    pcnt_event_enable(PCNT_TEST_UNIT, PCNT_EVT_THRES_1);
    pcnt_event_enable(PCNT_TEST_UNIT, PCNT_EVT_ZERO);
    pcnt_event_enable(PCNT_TEST_UNIT, PCNT_EVT_H_LIM);

    pcnt_counter_pause(PCNT_TEST_UNIT);
    pcnt_counter_clear(PCNT_TEST_UNIT);

    pcnt_isr_register(pcnt_example_intr_handler, NULL, 0, &user_isr_handle);
    pcnt_intr_enable(PCNT_TEST_UNIT);

    pcnt_counter_resume(PCNT_TEST_UNIT);
}

void app_main()
{

    pcnt_evt_queue = xQueueCreate(10, sizeof(pcnt_evt_t));
    pcnt_example_init();

```

Data Visualization

- From our survey, most people want to see total quantity of water coming out of a specific water outlet
  - Ex. Dishwashing machine usage so far this month: 20 gallons
- Total monthly water consumption of each outlet
- Display outlets in order of highest to lowest consumption
  - Highlighting most used
- Allow users to view comparisons of outlet usage for better understanding
  - Pie chart
  - Bar graph
  - Etc…
- If possible, provide usage stats for each outlet
  - For example, track time of usage in the past day
- Make web app more user-interactive and professional

Data Analysis

- Provide personalised suggestions to the user
- Based on the user’s use case
- Compare their usage with state’s monthly average
- Long term visualisation of their usage
    - Provide insights on their most spending days or times
- Give suggestions for water bill reduction

Self installation by us! Without a plumber!

System Specifications (MDR)

Functional Specification	Characteristic Specification	Performance Requirement	*Design Goal*
• Measure the **quantity** of water coming out of each water outlet • Web App to display information to user showing water usage for each outlet in real time	• Installation of the flow sensor nodes by the homeowner, without requiring a plumber • Low voltage battery operated system • Flow sensor nodes output is communicated wirelessly through the house • Data transfer via home WIFI and internet access point to the cloud	• Flow sensor nodes measure quantity of water with an accuracy of **90%** • Flow sensor node lifetime exceeds **<tbd>** months • System capability is up to 15 flow sensor nodes per house • flow sensor nodes capable of detecting dripping at water outlets, down to a flow rate of **<tbd>**	• Installation on the outside of the pipe and out of view of the user

System Specifications (CDR: modified)

Functional Specification	Characteristic Specification	Performance Requirement	*Design Goal*
• Measure the **quantity** of water coming out of each water outlet • Web App to display information to user showing water usage for each outlet in real time	• Installation of the flow sensor nodes by the homeowner, without requiring a plumber • Low voltage ~~battery~~ operated system • Flow sensor nodes output is communicated wirelessly through the house • Data transfer via home WIFI and internet access point to the cloud	• Flow sensor nodes measure quantity of water with an accuracy of **90%** • Flow sensor node lifetime exceeds 36 months • System capability is up to ~~15~~ **6** flow sensor nodes per house • ~~flow sensor nodes capable of detecting dripping at water outlets, down to a flow rate of <tbd>~~	• Installation on the outside of the pipe and out of view of the user

FPR Plan

- Combine PCB and mock up together
  - Total 6 PCBs
  - 3 on mock up
  - 3 elsewhere
  - 6 nodes simultaneously sending data
- 3D print a package for the board
- Send data with all 6 sensors to the cloud and display on website
- Finish website
- Make any revisions to PCB
  - Wire voltage correctly
  - Increase hole size for header connectors
- Implement 4 bit DIP switch with wroom module

Team Responsibilities

- Head of Hardware: Stephanie
- Frontend developer: Anjali
- Backend Developer: Sanjana
- Team Coordinator: Thanathorn

Gantt Chart

TASK NUMBER	TASK TITLE	TASK OWNER	DURATION	WEEK 1							WEEK 2							WEEK 3							WEEK 4							WEEK 5							
				M	T	W	R	F	S	SU	M	T	W	R	F	S	SU	M	T	W	R	F	S	SU	M	T	W	R	F	S	SU	M	T	W	R	F	S	SU	M
1	**PCB and Sensors**																																						
1.1	Integrating PCB with mock up	All	2 weeks																																				
1.2	PCB modification	TS & SH	2 weeks																																				
3	**Application**																																						
3.1	Completing web application	SK & AT	2 weeks																																				
3.2	Data Analysis	SK	2 weeks																																				
3.2	Wrapping up	All	2 weeks																																				

https://docs.google.com/spreadsheets/d/1W_RimOb7iqgFxVbxXvdJyEs-ZJ6X8mxSJoRQ8jliOiA/edit#gid=1115838130

Project Expenditures (current)

Item	Cost
Components for Flow sensing circuit	$86.73
PCB	$42.20
PCB components	$116.14
Cloud service (free trial)	$0
Website Hosting	$0
Previous expenses	$94
Total	$339.07

Expected Expenditures

Item	Cost
Flow sensors	$20
PCB (second iteration)	$25
PCB components	$0
Cloud service (free 12-month trial)	$0
Website Hosting	$0
Anything else we need	$115.93
Total	$150.93

Works Cited

[1]https://www.usgs.gov/special-topic/water-science-school/science/water-qa-how-much-water-do-i-use-home-each-day?qt-science_center_objects=0#qt-science_center_objects.

[2] https://www.electronicshub.org/arduino-water-flow-sensor-interface/

[3]https://www.energybot.com/electricity-rates/massachusetts/#:~:text=Massachusetts%20Energy%20Market%20Data,-Last%20updated%20February&text=The%20average%20Massachusetts%20residential%20electricity,higher%20than%20the%20national%20average).

[4]https://cavisynth.com/product/ftdi-programmer/

[5] https://www.thespruce.com/diy-washer-repairs-prevent-service-call-2147303

[6]https://structuretech.com/dishwasher-drains/

Thank You!

Any questions?