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

SDP Team 9

Anjali Toly
Sanjana Kaza
Stephanie He
Thanathorn Sukprasert
Advisor: Professor McLaughlin

Background and Motivation

- 80-100 gallons of water per person per day for home uses [1]
  - 330 million people in the United States, in 2019 [2]
  - Up to 33 billion gallons of water being used in households per day [3]
- Water prices have risen close to 80% in the past decade [4]
- Our project aims to give households **a better understanding of their water consumption behaviors**.
  - Households would be able to identify where they can reduce their water consumption → reducing their water bill
  - If deployed on a large scale, households could collectively save the world's water supply.

Existing Solutions

- Commercial Solutions
  - TFX-5000 Ultrasonic Clamp-on Flow Meter
  - Flume 2 Smart Home Monitor

- Project Solutions
  - Water Flow Sensor with Piezo
  - Water Flow Rate and Volume Measurement Device

TFX-5000 Ultrasonic Clamp-on Flow Meter[6]

- No plumbing tools required
- Ultrasonic sensor
- Displays water usage
- External power supply
- Cost: $2,930

Drawbacks:

- Expensive
- Does not detect dripping
- Does not sync to an app

Flume 2 Smart Home Monitor [7]

- No plumbing tools required
- Magnetic field
- App for displaying information to user
  - Leak notifications
  - Daily/Weekly/Monthly report of total water usage
- External power supply
- Cost: $149

Drawback:

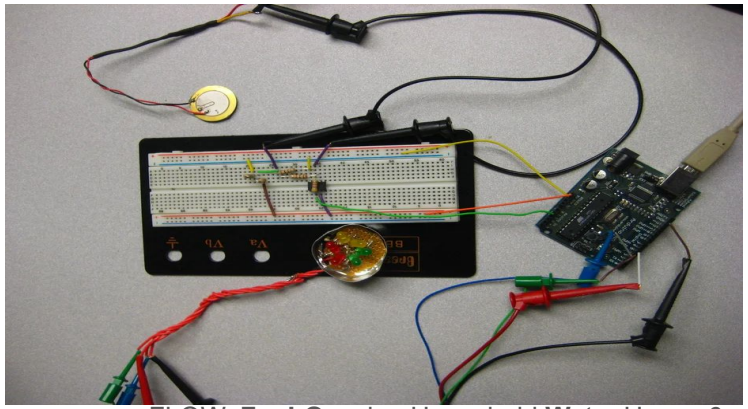
- Only shows overall water usage, not outlet specific

Water Flow Sensor with Piezo [8]

- No plumbing tools required
- Piezo vibration sensor
- LEDs change color depending on the amount of time the tap is running
- External power supply
- Cost: ~$50 (Arduino + sensor)

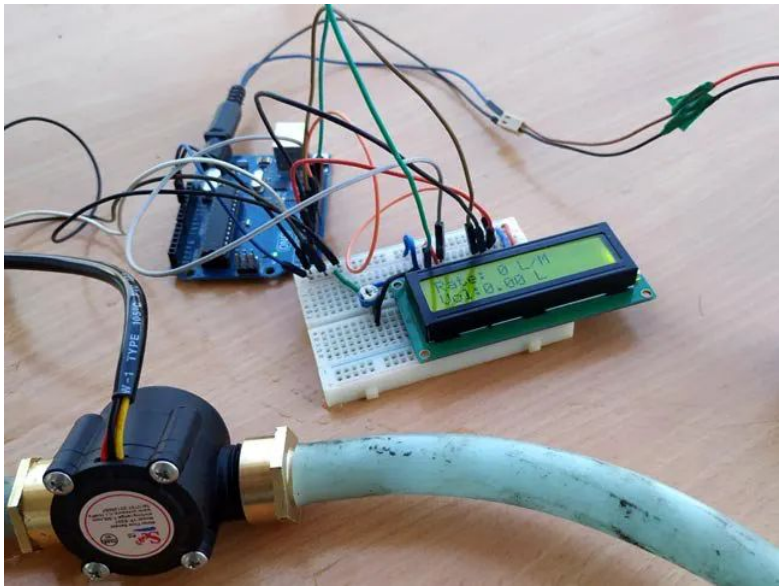
Drawbacks:

- Not an actual product (breadboarded)
- Does not detect dripping
- Does not measure the amount of water used
- Does not sync to an app



Water Flow Rate and Volume Measurement Device [9]

- Plumbing tools required
- Hall Effect sensor
- Displays water usage
- External power supply required
- Cost: ~$50 (Arduino + sensor)



Drawbacks:

- Not an actual product (breadboarded)
- Not compatible with some water outlets
  - For example, non-circular pipe
- Not sure whether this could detect the dripping problem
- Does not sync to an app

Comparison of Existing Products

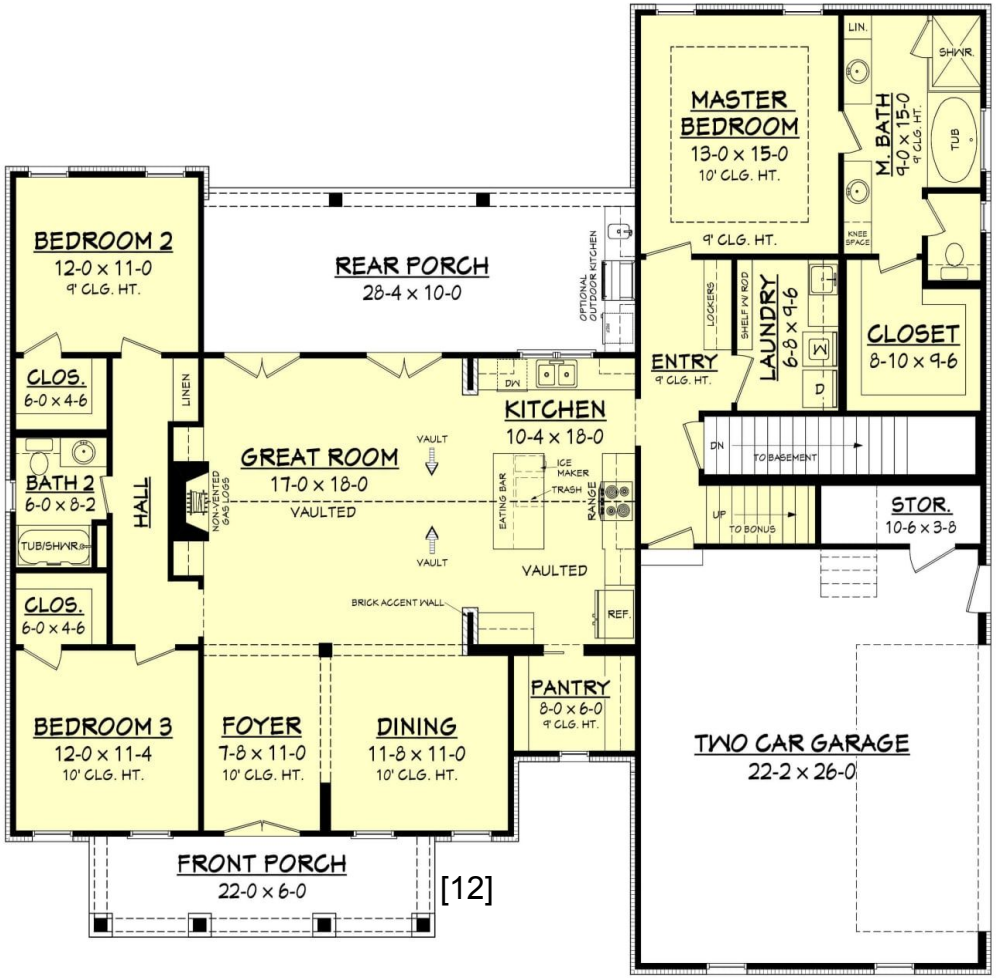
	Cost	Plumbing Tools Required	Application / User Interface	Communication (wireless?)	Detects Dripping	Power Source
TFX-5000	$2,930	No	No	Yes	No	External
Flume 2	$149	No	Yes	Yes	Yes	External
Piezo Water Flow Sensor	~$50	No	No	No	No	External
Hall effect water flow sensor	~$50	Yes	No	No	No	External

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 water flowing out of each water outlet**. Users can view their water consumption behavior from an app to which the devices are connected. The data will allow users to learn which appliance/faucets use the most amount of water. Moreover, users will also be notified if leaking is detected.

Scope of the Problem

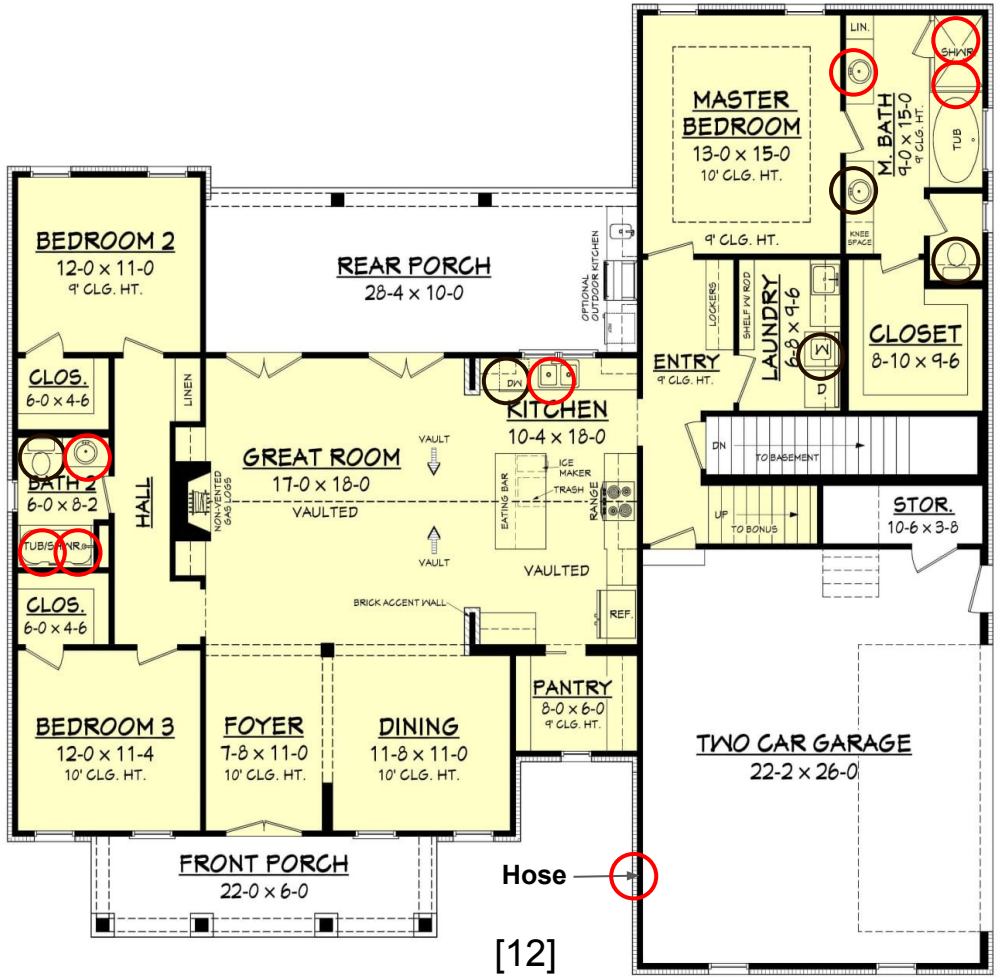
- Private residence
- Wifi is available in the house at a range of 150ft [10]
- Average size of home in MA: ~2,000 sq ft. [11]
- 4 person house
- Rooms
  - Bathrooms (2)
  - Kitchen
  - Laundry room



[12]

FLOW: **F**or **LO**wering Household **W**ater Usage 10

Rooms	Utilities	Device count
Kitchen	Dishwasher	1
	Sink	1
Bathroom (2)	Sink(+1)	2(+1)
	Toilet	2
	Shower head	2
	Shower faucet	2
Others	Washer	1
	Hose outlet	1
Total		12(+1)(+2) = 15



FLOW: **F**or **LO**wering Household **W**ater Usage 11

System Specifications

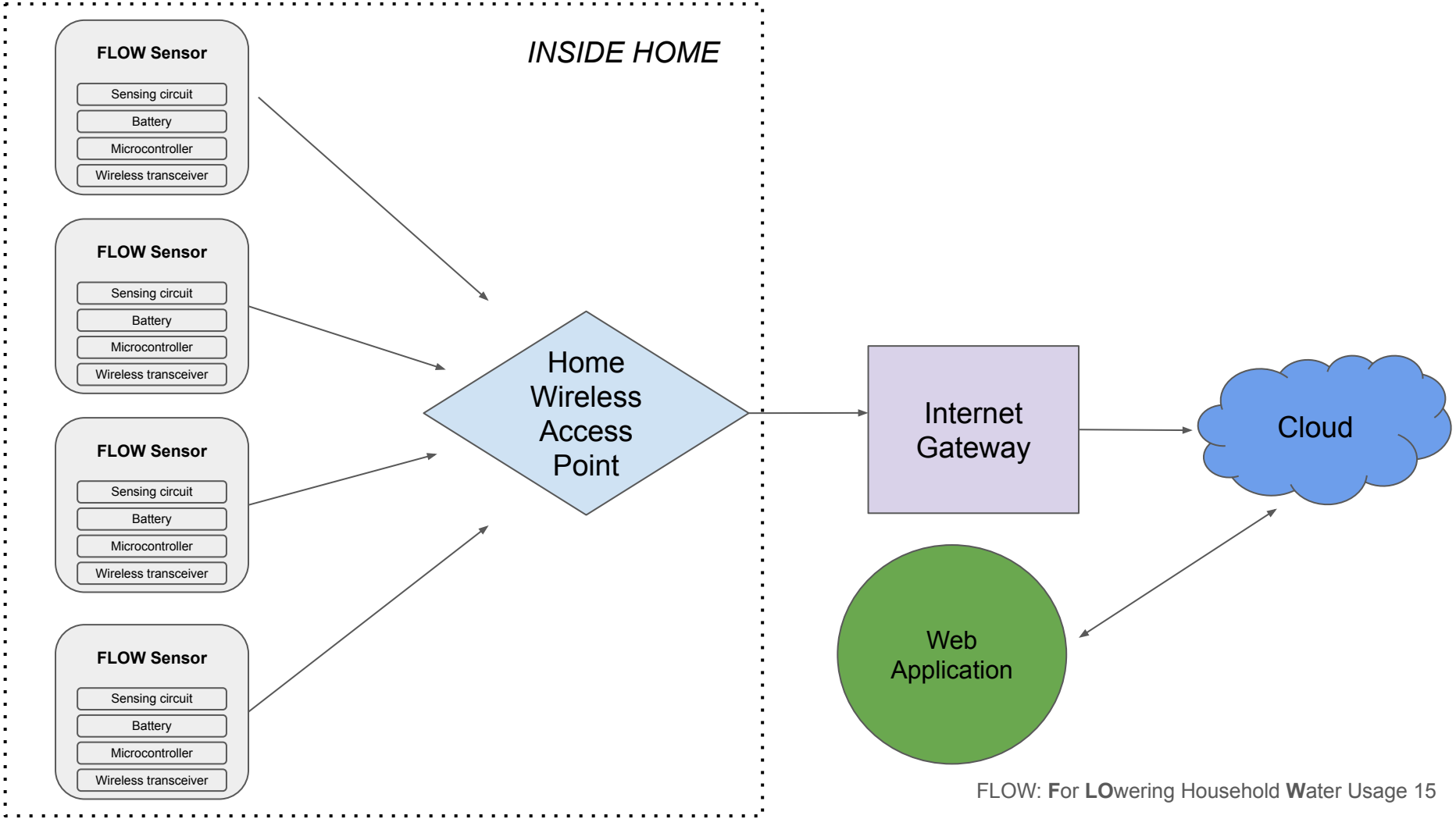
- Measure the **quantity** of water coming out of each water outlet
- Sensors measure quantity of water with an accuracy of <tbd>
- Real time monitoring of the amount of water used
- Installation of the sensor by the homeowner, without requiring plumbing tools
- Installation on the outside of the pipe and out of view of the user

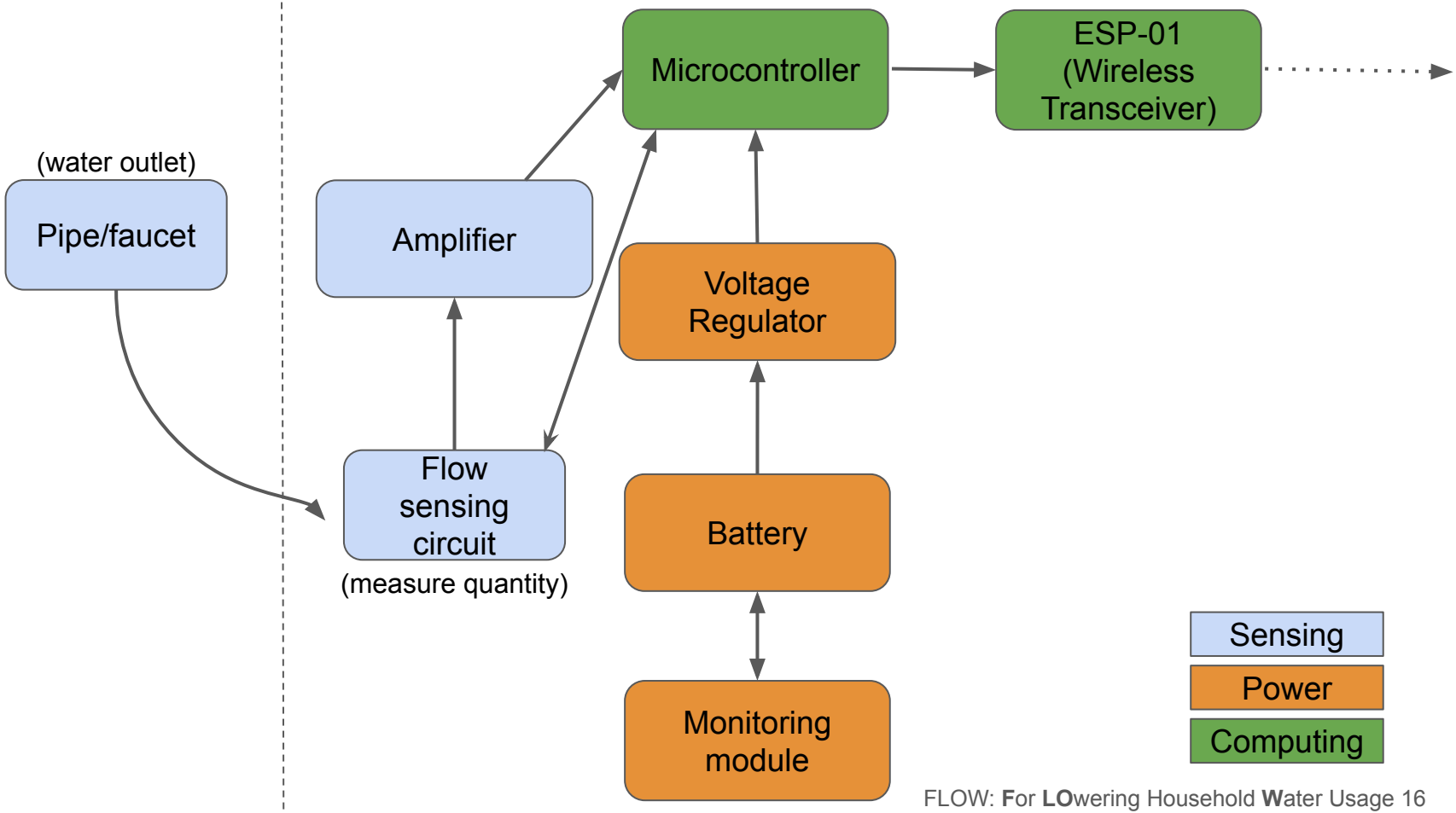
System Specifications cont.

- System capability is up to 15 sensors per house
- Sensor output is communicated wirelessly to the app throughout the house
- Data transfer via home WIFI
- Sensor lifetime exceeds <tbd> months
- Low voltage battery operated system
- Sensors capable of detecting dripping at water outlets, down to a flow rate of <tbd>
- Web app to display information to user showing water usage for each outlet in real time

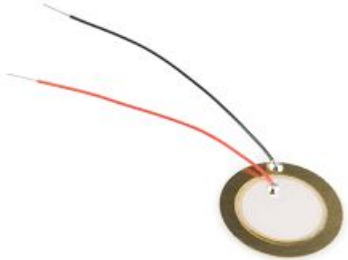
System Specifications cont.

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 sensor by the homeowner, without requiring a plumber • Low voltage battery operated system • Sensor output is communicated wirelessly through the house • Data transfer via home WIFI and internet access point to the cloud	• Sensors measure quantity of water with an accuracy of <tbd> • Sensor lifetime exceeds <tbd> months • System capability is up to 15 sensors per house • Sensors 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


INSIDE HOME
FLOW Sensor
Sensing circuit
Battery
Microcontroller
Wireless transceiver
FLOW Sensor
Sensing circuit
Battery
Microcontroller
Wireless transceiver
FLOW Sensor
Sensing circuit
Battery
Microcontroller
Wireless transceiver
FLOW Sensor
Sensing circuit
Battery
Microcontroller
Wireless transceiver
Home Wireless Access Point
Internet Gateway
Cloud
Web Application


Microcontroller
ESP-01
(Wireless
Transceiver)
(water outlet)
Pipe/faucet
Amplifier
Voltage
Regulator
Flow
sensing
circuit
(measure quantity)
Battery
Monitoring
module
Sensing
Power
Computing

Sensors We Are Exploring/Considering



Vibration sensor

[13]

Electret microphone

[14]

Hall Effect sensor

[15]

Ultrasonic sensor

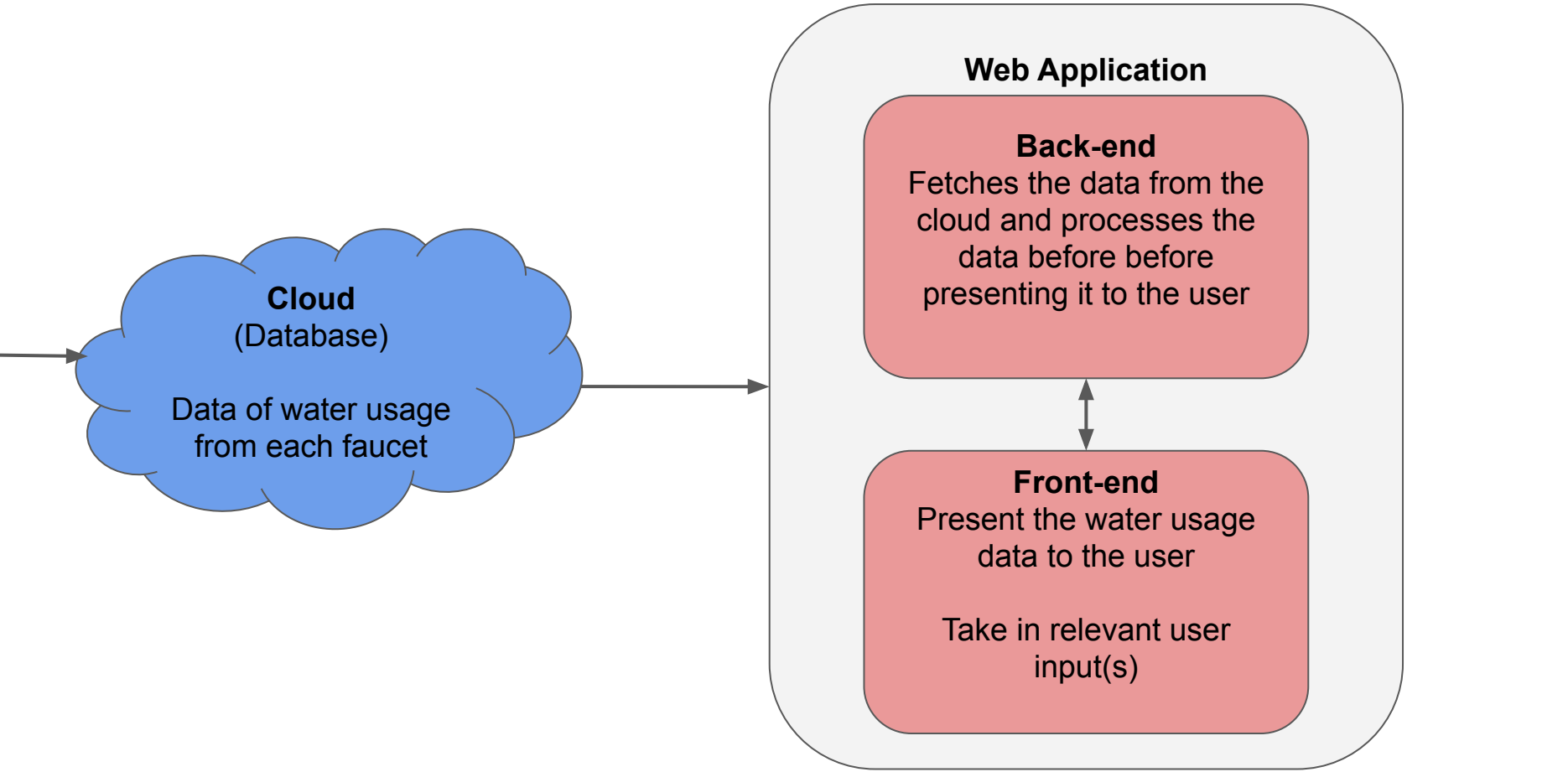
[16]

Microcontrollers We Are Considering

- Microcontrollers
  - 8-bit
    - ATmega328P [17]
      - Operating voltage: 1.8V-5V
      - Power consumption at 1MHz, 1.8V: Active: 0.2mA
  - 32-bit
    - AM3358 (BeagleBone Black) [18]
      - Operating voltage: 5V
      - Power consumption@5V: 210-460 mA (min-max):

Wireless Transceivers We Are Considering

- WIFI
  - ESP32 WIFI Module [19]
    - 3.3V DC
    - Power consumption: Active: > 240mA, Modem Sleep: 3-20mA
    - 5 µA deep sleep current
    - Range: > 100m
- Bluetooth
  - HC-05 [20]
    - 5V DC
    - Power consumption: 30mA
    - Range: < 100m


Cloud
(Database)
Data of water usage from each faucet
Web Application
Back-end
Fetches the data from the cloud and processes the data before before presenting it to the user
Front-end
Present the water usage data to the user
Take in relevant user input(s)

MDR Deliverables

- Sensor selection and design
- Wireless Network selection and design
- Prototype of a set of sensors (at least 3)
  - Measure the flow
  - Relay their data to the cloud via a wireless access point
- Sensors measure the volume of water used for each sensor placement with at least <tbd> percent accuracy.
- Functional web app that can display water usage information

MDR Verification Plan

Volume Checking:

- Place a container with a known volume under the tap. Place device on the tap and turn the tap on. Once the tap is turned off, check the volume of the water calculated by the device against the amount in the container.

Real Time Monitoring:

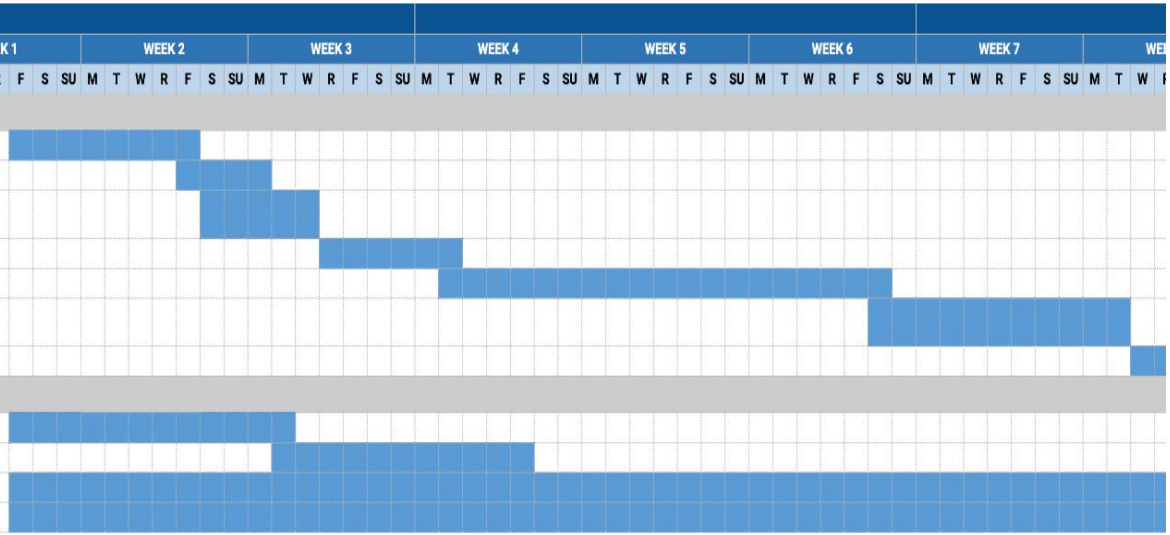
- The data generated by the sensor should be displayed on the local computer while water flows out of the faucet

Wireless Communication:

- The information in the cloud is the same as the information displayed on the local computer

Gantt Chart

TASK NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION
1	**Flow Sensing Circuit**				
1.1	Sensor selection	SH & TS	10/1/21	10/8/21	7
1.2	Build breadbord with selected sensor	SH	10/8/21	10/11/21	3
1.3	Write code for sensing facuet turning on	SK & SH & TS	10/9/21	10/13/21	4
1.4	Test turning on	All	10/14/21	10/19/21	5
1.5	Write code to calculate water flow	SK & TS	10/19/21	11/6/21	17
1.6	Testing and debugging water flow code	AT & SK & TS	11/6/21	11/16/21	10
1.7	Testing multiple sensors	All	11/17/21	11/29/21	12
2	**Application**				
2.1	Set up cloud	AT & SK	10/1/21	10/11/21	10
2.2	User interface design	All	10/11/21	10/22/21	11
2.3	Front-end design	SH & TS	10/1/21	11/29/21	58
2.4	Back-end design	AT & SK	10/1/21	11/29/21	58



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

Anticipated Expenditures

Item	Cost
Parts for Flow sensing circuit	$100
3D printed items (from M5)	$0
Extra components (not from M5)	$30
Initial PCB	$120
Final PCB revisions	$200
Cloud service (free 12-month trial)	$0
Website Hosting	$50
Total	$500

	Cost	Plumbing Tools Required	Application / User Interface	Communication (wireless?)	Detects Dripping	Power Source
TFX-5000	$2,930	No	No	Yes	No	External
Flume 2	$149	No	Yes	Yes	Yes	External
Piezo Water Flow Sensor	~$50	No	No	No	No	External
Hall effect water flow sensor	~$50	Yes	No	No	No	External
FLOW	Low cost	No	Yes	Yes	Yes	Low voltage battery operated

Works Cited

[1] “Water Q&A: How much water do I use at home each day?,” *United States Geological Survey*. [Online]. Available: 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. [Accessed: 27-Sep-2021].

[2] “U.S. and world Population clock,” *United States Census Bureau*. [Online]. Available: https://www.census.gov/popclock/. [Accessed: 27-Sep-2021].

[3] R. W. Hofste, P. Reig, and L. Schleifer, “17 countries, home to one-quarter of the world's Population, face extremely high water stress,” *World Resources Institute*, 06-Aug-2019. [Online]. Available: https://www.wri.org/insights/17-countries-home-one-quarter-worlds-population-face-extremely-high-water-stress. [Accessed: 28-Sep-2021].

[4] N. Lakhani, “Millions of Americans can't Afford water, as Bills Rise 80% in a decade,” *Consumer Reports*, 23-Jun-2020. [Online]. Available: https://www.consumerreports.org/personal-finance/millions-of-americans-cant-afford-water-as-bills-rise-80-percent-in-a-decade/. [Accessed: 28-Sep-2021].

[5] Water Research Foundation, *How Much Water Do We Use?* 2016.

[6] “Dynasonics: Tfx-5000 Ultrasonic Clamp-On Meter,” *Badger Meter*. [Online]. Available: https://www.badgermeter.com/products/meters/ultrasonic-flow-meters/tfx-5000-ultrasonic-clamp-on-flow-meter/. [Accessed: 27-Sep-2021].

[7] “Monitor your WATER Use: Stop Leaks Fast: Flume 2 smart water monitor,” *Flume*, 23-Aug-2021. [Online]. Available: https://flumewater.com/product/. [Accessed: 27-Sep-2021].

Works Cited cont.

[8] Staceyk and Instructables, “Low cost water flow sensor and ambient display,” *Instructables*, 09-Nov-2017. [Online]. Available: https://www.instructables.com/Low-Cost-Water-Flow-Sensor-and-Ambient-Display/. [Accessed: 27-Sep-2021].

[9] SAROSH_AHMAD, “Water flow rate and volume measurement using Arduino in 2020,” *Arduino Project Hub*, 15-May-2020. [Online]. Available: https://create.arduino.cc/projecthub/SAROSH_AHMAD/water-flow-rate-and-volume-measurement-using-arduino-in-2020-5377df. [Accessed: 27-Sep-2021].

[10] Openweb Blog, “How far will your wifi signal reach?,” *OpenWeb.co.za*, 07-Oct-2018. [Online]. Available: https://openweb.co.za/how-far-will-your-wifi-signal-reach/. [Accessed: 27-Sep-2021].

[11] A. Lefton and S. Coelho, “This is the average home size in every state,” *Bob Vila*, 24-Apr-2020. [Online]. Available: https://www.bobvila.com/slideshow/this-is-the-average-home-size-in-every-state-53461. [Accessed: 27-Sep-2021].

[12] *Floor Plan*. House Plan Zone. https://hpzplans.com/products/park-lane-house-plan.

[13] *Piezo Element*. Sparkfun. https://www.sparkfun.com/products/10293.

[14] *Electret Microphone*. Sparkfun. https://www.digikey.com/en/products/detail/cui-devices/CMA-6542PF/1869980.

[15] *Hall Effect Sensor*. Amazon. https://www.amazon.com/DIGITEN-Sensor-Effect-Flowmeter-Counter/dp/B07QNN2GRV/ref=sr_1_15?dchild=1&keywords=arduino+hall+effect+sensor&qid=1632946819&sr=8-15

[16] *Sensor: Ultrasonic Transducer.* Transfer Multisort Electronik. https://www.tme.eu/en/details/sens-c4016l8a40/ultrasonic-sensors/sencera/c4016l8a402/

Works Cited cont.

[17] Microchip, “megaAVR® Data Sheet.” Microchip, 2018.

[18] Texas Instruments, “AM335x Sitara™ Processors.” Texas Instruments, 2020.

[19] Last Minute Engineers, “Insight into esp32 sleep modes & their power consumption,” *Last Minute Engineers*, 18-Dec-2020. [Online]. Available: https://lastminuteengineers.com/esp32-sleep-modes-power-consumption/. [Accessed: 27-Sep-2021].

[20] “Wireless communications circuits and systems,” *Amazon*, 2004. [Online]. Available: https://www.amazon.com/Wireless-Bluetooth-Receiver-Transceiver-Transmitter/dp/B01MQKX7VP. [Accessed: 29-Sep-2021].

Thank you for your time!

Any questions?