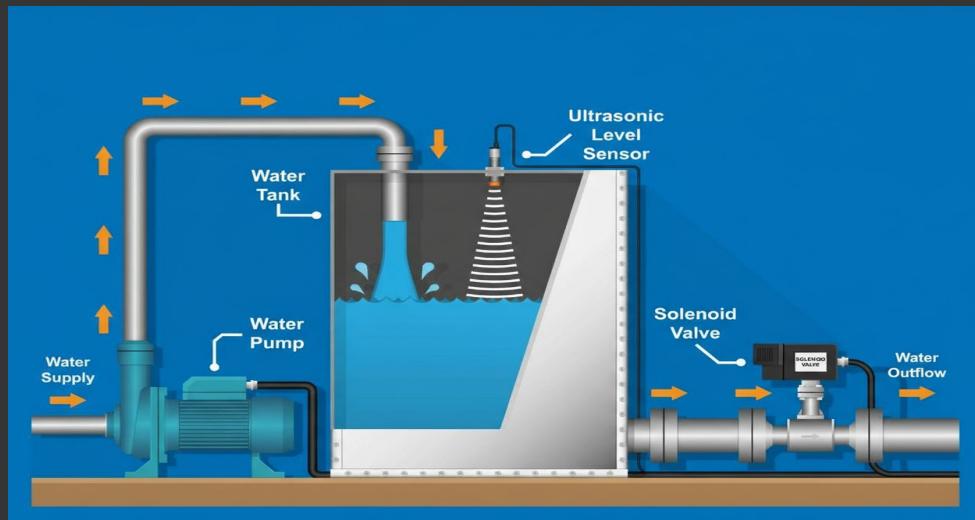


Wireless Clustered SCADA System



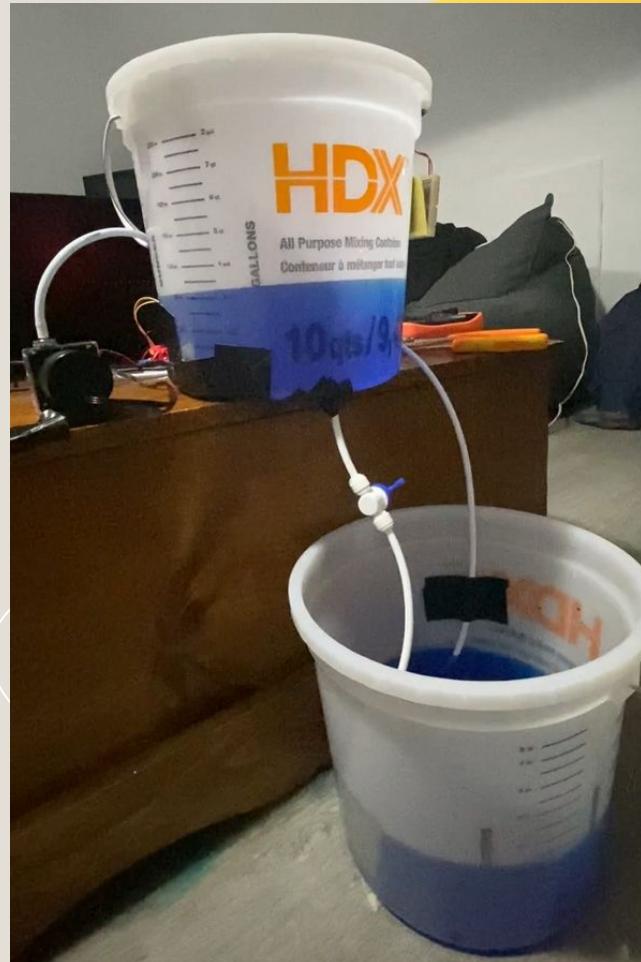
ENGG*4200: Final Project Presentation / Demo
Riley Johnson, Liam Hatala , Hassan Ahmad, Rehan Siddiqi

Introduction

Problem: Industrial SCADA systems rely heavily on physical wiring, increasing cost, complexity, and points of failure.

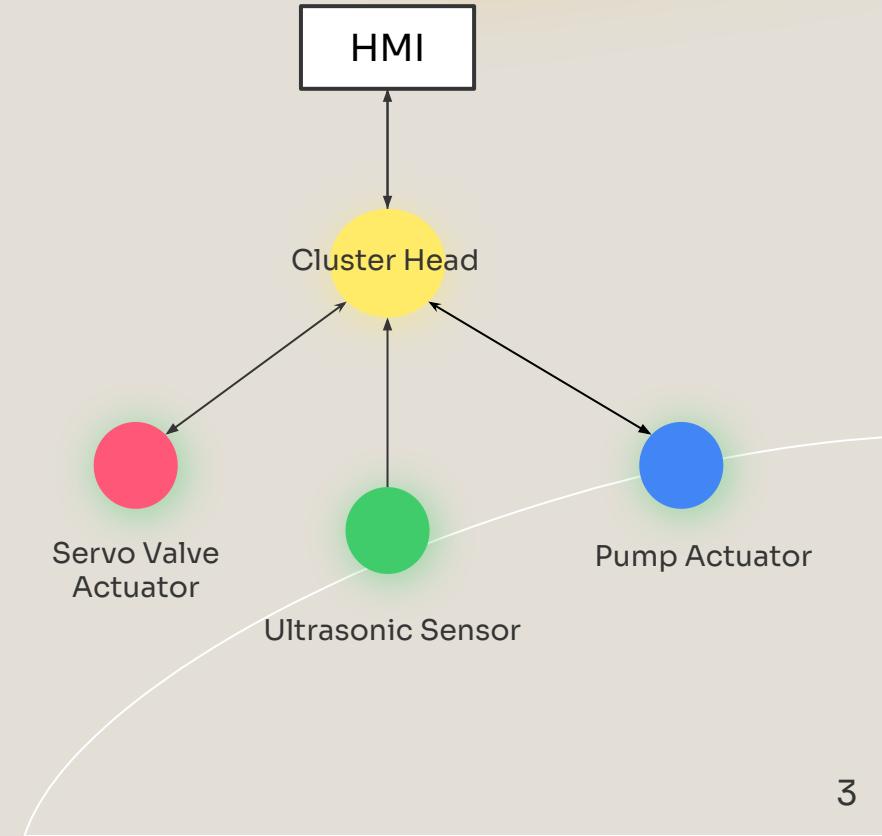
Goal: Build a fully wireless SCADA cluster using a clustered WSN to demonstrate modularity, reduced wiring, and reliable process control.

Prototype: Autonomous reservoir-level regulation using ESP-NOW communication and multi-node collaboration.



System Architecture

Node	Functionality
Cluster Head	Central coordinator; FreeRTOS tasks, round-robin polling, PID control, command coordination
Ultrasonic Sensor	Ultrasonic level sensing, filtered measurements, sends data to head node
Pump Actuator	Input water pump control via H-bridge, controlled via PID from head node
Servo Value	Set by user via HMI, represents user disturbance (outflow of tank)
Human-Machine Interface (HMI)	LCD interface, rotary input, real-time setpoint & PID visualization



Wireless Communication

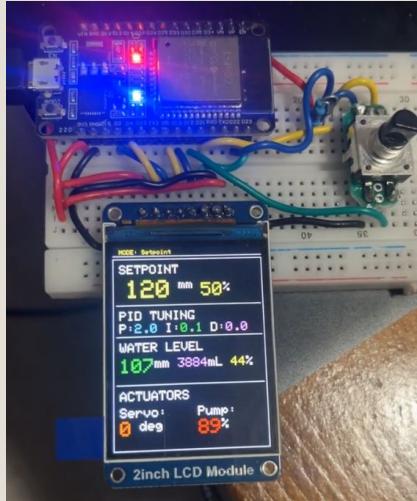
ESP-NOW Communication (2.4 GHz):

Low-latency peer-to-peer messaging, no router required, deterministic packet handling under FreeRTOS, fully modular cluster expansion.

Dynamic Network Initialization:

LEACH-inspired role negotiation implemented. Worked, but inconsistent boot timing.

Final Design Choice: Switched to static MAC-based node mapping. Ensures deterministic startup & guaranteed network formation.



```
;22.817 -> [CONTROL] Command sent to Pump  
;22.849 -> [CONTROL] Status sent to HMI  
;23.174 -> [POLL] Polled HMI  
9:23.174 -> HMI SETPOINT from HMI lct:69:20:92:60:30  
9:23.174 -> SD = 160 mm, Kp.x10 = 20, Ki.x10 = 1, Kd.x10 = 0  
9:23.174 -> SERVO SETPOINT from HMI lct:69:20:92:60:30: 0 deg  
9:23.238 -> [POLL] Polled Sensor  
29:23.270 -> Received SENSOR DATA from b0:a7:32:2b:6c:08  
29:23.270 -> Count: 11502  
29:23.270 -> Distance (raw): 92 mm  
29:23.270 -> [PID] SP: 160.00 mm, Water level: 160.00 mm, Error: -0.00 mm  
29:23.270 -> [PID] Kp: 2.00, Ki: 0.10, Kd: 0.00, ui -4-10  
1:29:23.270 -> [PID] Pump: 0 %, Servo disturbance: 0 deg  
1:29:23.270 -> [CONTROL] Status sent to Pump  
1:29:23.270 -> [CONTROL] Status sent to HMI  
1:29:23.270 -> [POLL] Polled Sensor  
01:29:23.620 -> HMI SETPOINT from HMI lct:69:20:92:60:30  
01:29:23.620 -> SD = 160 mm, Kp.x10 = 20, Ki.x10 = 1, Kd.x10 = 0  
01:29:23.620 -> SERVO SETPOINT from HMI lct:69:20:92:60:30: 0 deg  
01:29:23.652 -> [POLL] Polled Sensor  
01:29:23.722 -> Received SENSOR DATA from b0:a7:32:2b:6c:08  
01:29:23.722 -> Count: 11504  
01:29:23.722 -> Distance (raw): 92 mm  
01:29:23.725 -> [PID] SP: 160.00 mm, Water level: 160.00 mm, Error: -0.00 mm  
01:29:23.725 -> [PID] Kp: 2.00, Ki: 0.10, Ed: 0.00, ui -4-16  
01:29:23.725 -> [CONTROL] Command sent to Pump  
01:29:23.725 -> [CONTROL] Status sent to HMI  
01:29:23.725 -> [POLL] Polled Sensor  
01:29:24.080 -> HMI SETPOINT from HMI lct:69:20:92:60:30  
01:29:24.080 -> SD = 160 mm, Kp.x10 = 20, Ki.x10 = 1, Kd.x10 = 0  
01:29:24.080 -> SERVO SETPOINT from HMI lct:69:20:92:60:30: 0 deg  
01:29:24.117 -> [POLL] Polled Sensor  
01:29:24.177 -> Received SENSOR DATA from b0:a7:32:2b:6c:08  
01:29:24.177 -> Count: 11510  
01:29:24.177 -> Distance (raw): 98 mm  
01:29:24.177 -> [PID] SP: 160.00 mm, Water level: 160.00 mm, Error: -2.00 mm  
01:29:24.177 -> [PID] Kp: 2.00, Ki: 0.10, Ed: 0.00, ui 7.15  
01:29:24.177 -> [PID] Pump: 84 %, Servo disturbance: 0 deg  
01:29:24.177 -> [CONTROL] Status sent to Pump  
01:29:24.177 -> [CONTROL] Status sent to HMI  
01:29:24.177 -> [POLL] Polled HMI
```

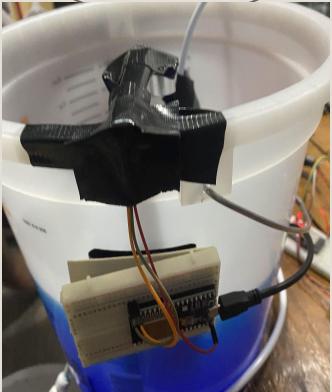
Data Processing and Control Logic

Sensor Nodes

Ultrasonic sensor readings include ± 3 mm noise

Filtered values are transmitted to the Cluster Head via ESP-NOW

Provide continuous water-level feedback for the control loop

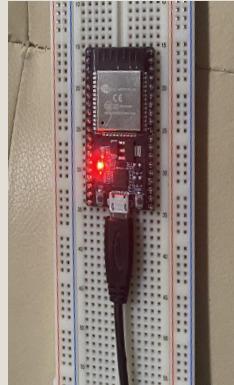


Cluster Head

Runs the round-robin polling task to request new sensor and HMI data

Executes the PID algorithm to compute pump output

Sends updated control commands to actuator nodes

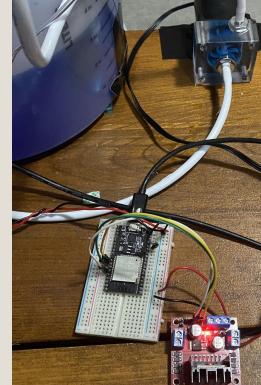


Actuator Nodes

Not truly PWM-compatible; thus, H-bridge required

Operated reliably within the usable 10–12 V range

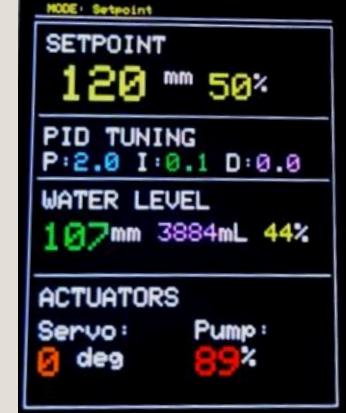
Responds to PID command values from the Cluster Head



HMI

Allows the manual adjustment of setpoint, PID parameters, and servo angle.

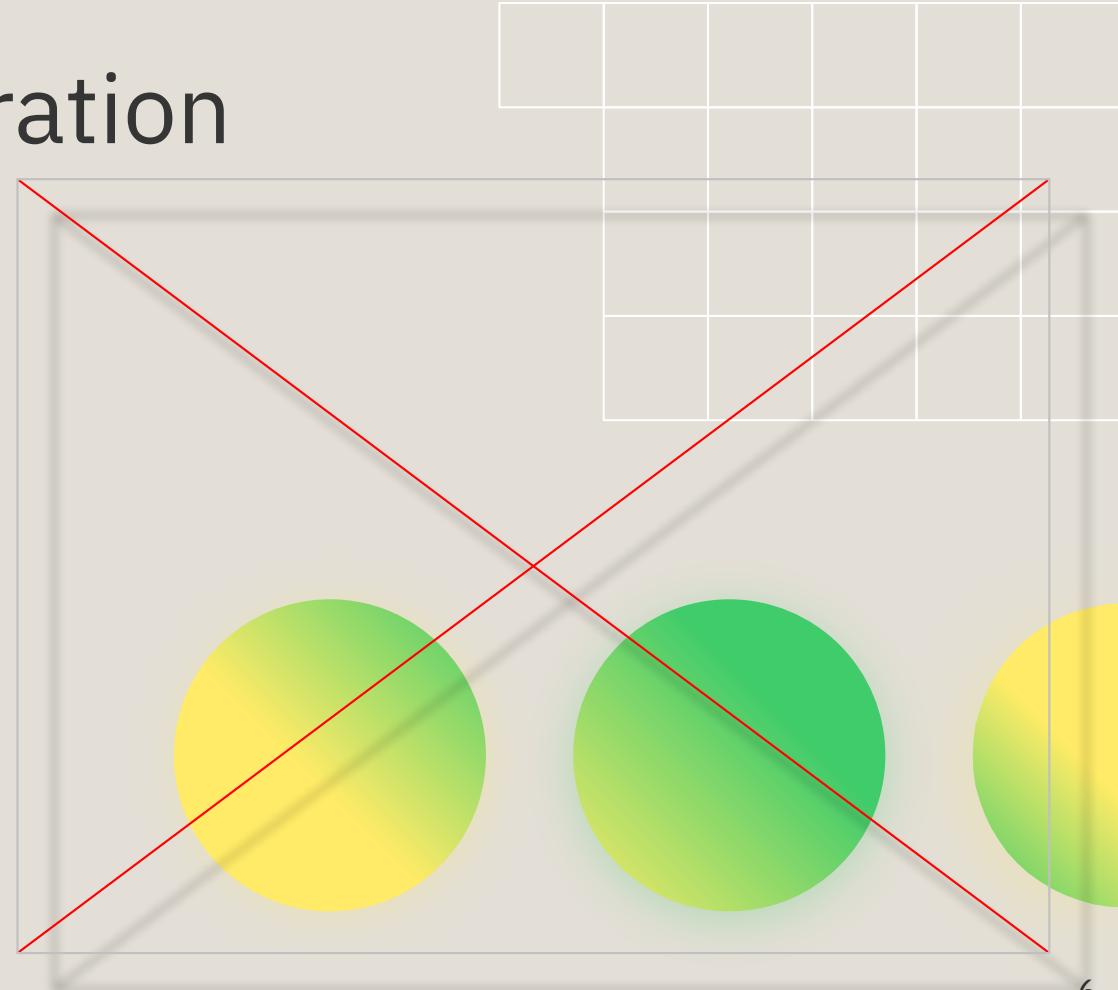
Displays control values from head node and displays on the screen.



System Demonstration

Key Stages:

1. System fills the tank toward the setpoint.
2. System reaches and maintains the setpoint.
3. System responds to a disturbance (fully open valve).
4. System responds to a disturbance (half open valve).
5. Setpoint increased again and valve is closed.
6. Setpoint reached.

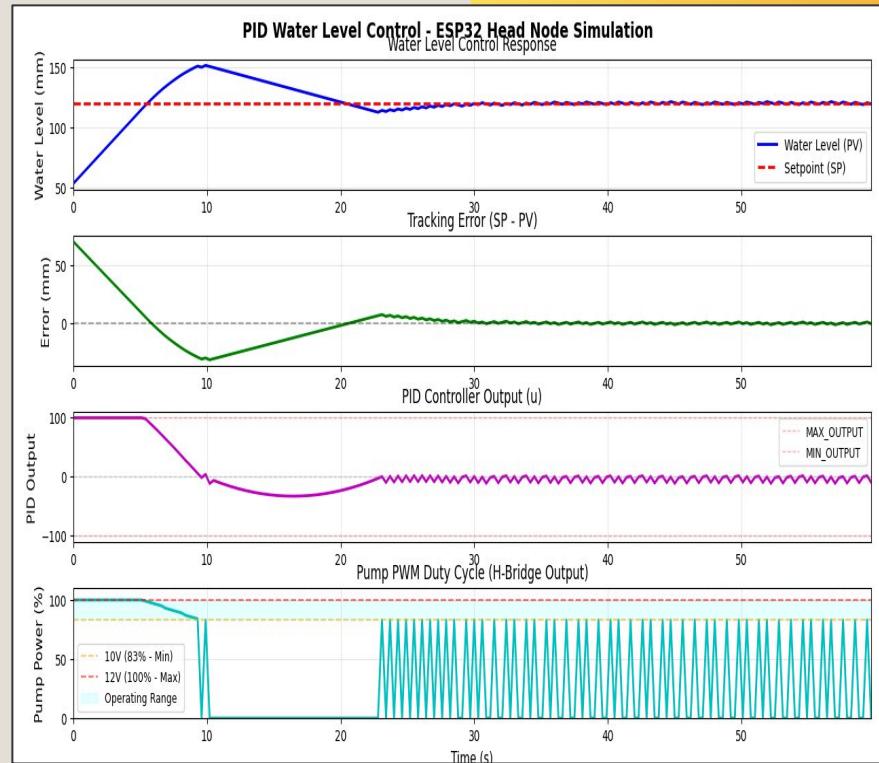


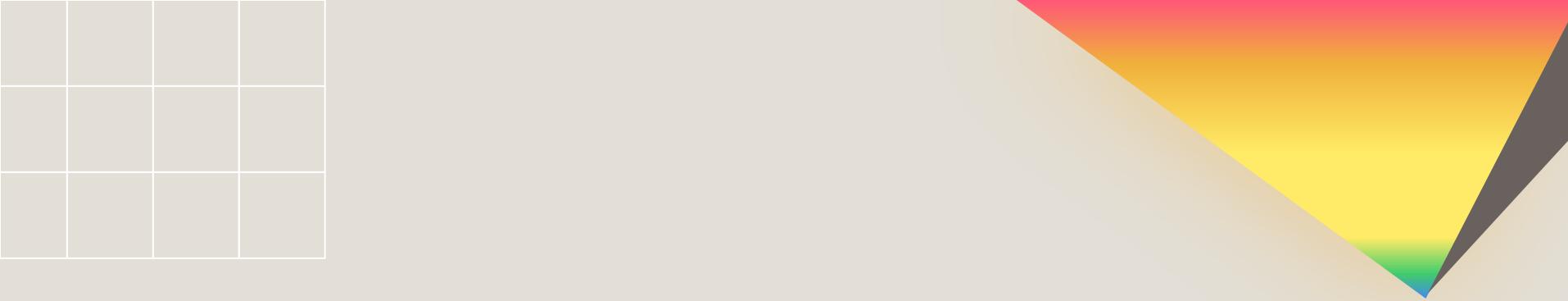
Results & Conclusion

Results: The wireless SCADA cluster successfully achieved stable water level regulation with reliable ESP-NOW communication between all nodes.

Challenges and Solutions: Hardware limitations such as limited servo motor torque and restricted pump control were resolved through manual disturbance testing, and live PID tuning.

Conclusion: The prototype proved that a clustered wireless architecture can operate as a functional SCADA system with reduced wiring and strong modular scalability.





Thank you. Any questions?

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