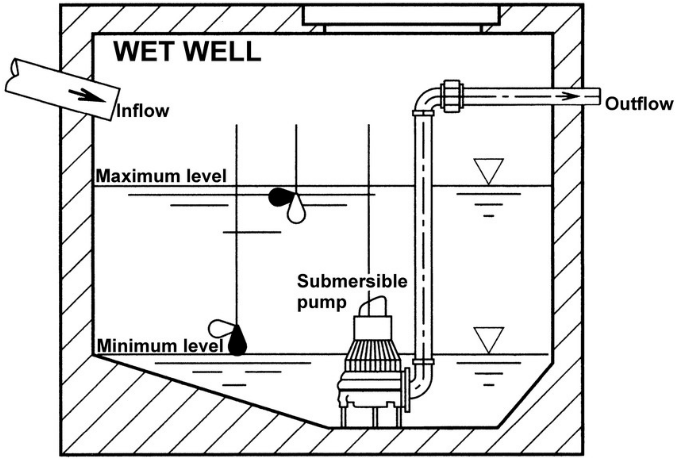
MESCC – CSLAB

Water Pumping System (WPS)
+
Remote Status Station (RSS)

Ricardo Mendes & Arthur Gerbelli



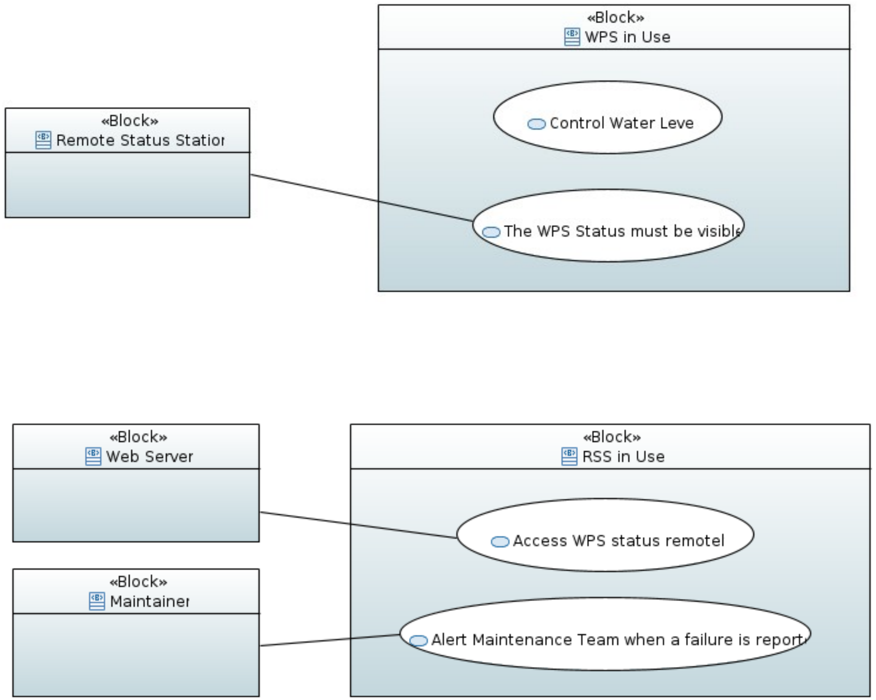
CONTENT

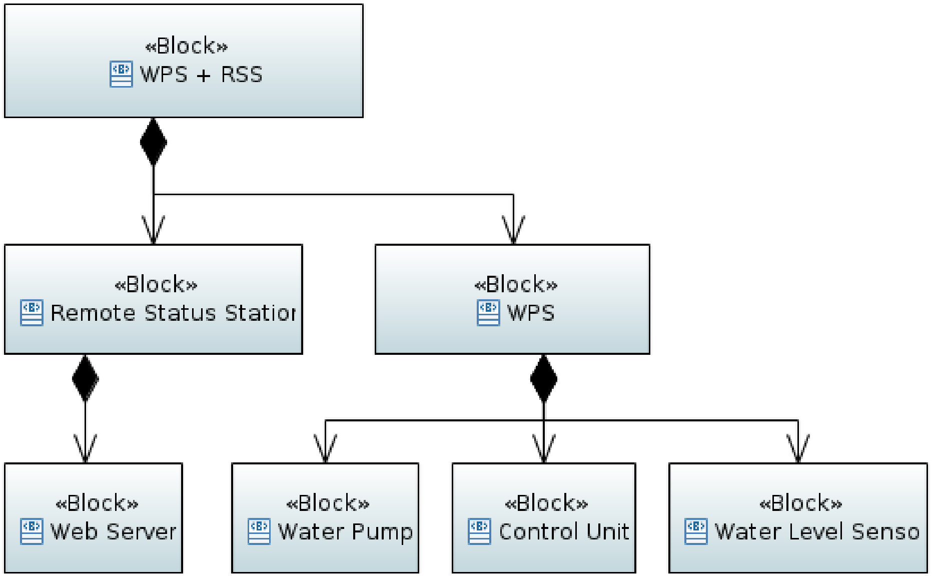
- Requirement Specification [Update]
- Implementation:
  - Concorrency and RealTime Scheduling
  - Communication Infrastructure
  - Implementation using Assembly
- Demo

REQUIREMENTS SPECIFICATION – Stakeholder Needs

- **SN-1.3** Every WPS will have two pumps and two water level sensors to achieve a certain level of redundancy and reliability on the system.
- **SN-1.4** To improve the system's performance, and given that we have one unused water pump, this pump should be used when the water level is above 2/3 of the well max capacity.
- **SN-1.5** In case that only one water pump is operational, the max capacity of the WPS shall be reduced.

REQUIREMENTS SPECIFICATION – Use Cases & System's Structure





REQUIREMENTS SPECIFICATION – Hazards Analysis

- **Description**: The two level sensors give contradictory readings.
- **Cause**: Sensor malfunction, connection issues.
- **Effect**: Inappropriate system behavior.
- **Mitigation**: If the reading of both sensor are too unequal, there must be a way to distinguish between the wrong and the correct data. There are three possible ways to deal with the issues: choose a master and a slave sensor, retain the previous input and compare it with the current one, or choose the worst case. Trigger the alarm if the system in unable to achieve a consensus.

- **Description**: Control Unit stops working.
- **Cause**: Malfunction, bug.
- **Effect**: Total failure of the system.
- **Mitigation**: Implement redundancy by having a cluster of nodes running the Control Unit. If the number of nodes is 3 we can implement a voting system and run the same process with the same input in parallel. This would improve the system's fault tolerance.

REQUIREMENTS SPECIFICATION – Requirements Update

1.4: A second pump shall be turned on only when the water level is above 2/3 the maximum water level.
1.5: When only one pump is available, the maximum water level shall be reduced to 2/3.
1.6: If the readings of the sensor are uneven to a level of 20cm, the system should choose the worst case scenario.

2.3: The RSS shall have an independent power supply from the WPS.
2.4: The alarm on the RSS shall have an independent power supply from the RSS itself and from the WPS.

4.1: To improve the system's communication reliability, a cluster of 2 MQTT brokers shall be deployed.

IMPLEMENTATION – Concorrency and Real Time Scheduling

Hardware specification for an ESP-WROOM-32:

- Clock rate: 80 to 240 MHz
- Clock cycle per instruction (CPI): 2 clock cycles — for instructions following ALU and branch instructions. 4 clock cycles — in other cases.
- FreeRTOS -> **fixed priority preemptive scheduler with time slicing**

```
$ avr-objdump -m avr -S control-unit.ino.cpp.o | wc -l
  output -> 448
```

$$CPU\ Time = \frac{Instruction\ count * CPI}{Clock\ Rate}$$

$$CPU\ Time = \frac{448 * 4}{80000} = 0,0224\ seconds$$

IMPLEMENTATION – Concorrency and Real Time Scheduling

The Control Unit will run three tasks:

- T1: Retrieve data from sensors (TCP Client);
- T2: Process data and give instructions to pumps;
- T3: Publish WPS status to MQTT broker (MQTT client).

Task	Ci	Ti
1	60	100
2	25	200
3	35	250

... and **share one specific resource**: a data structure with the WPS status, pump status, water level status and alert status.

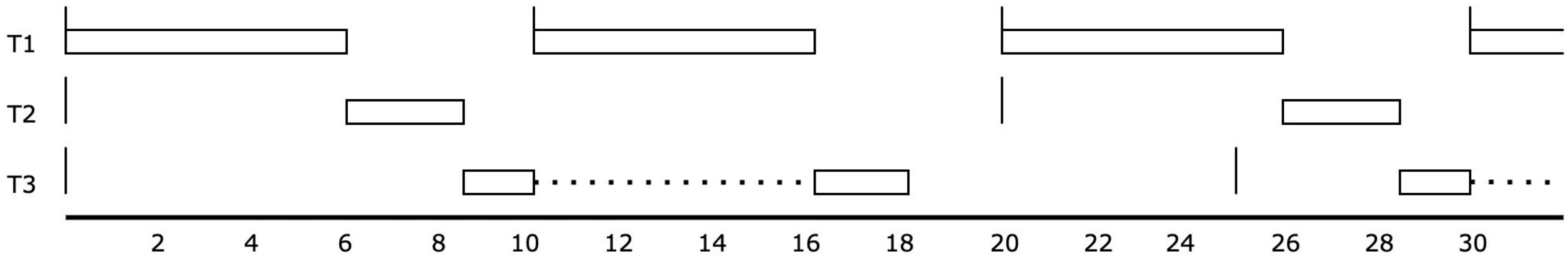
IMPLEMENTATION – Concorrency and Real Time Scheduling

$$U = \frac{60}{100} + \frac{25}{200} + \frac{35}{250} \qquad = 0,865$$

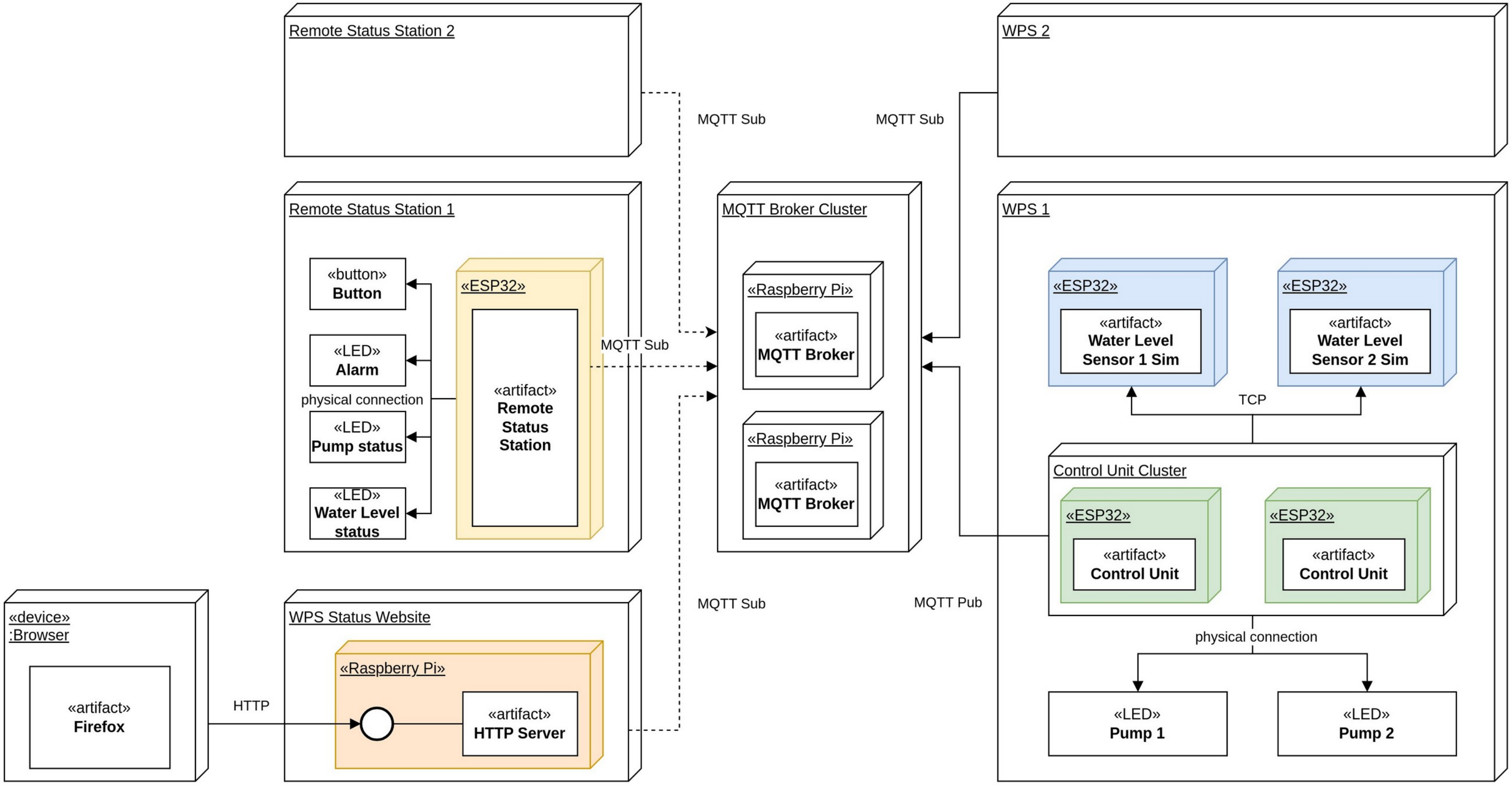
CPU utilization doesn't exceed 100%
but cannot confirm that it is schedulable!

$$LUB = 3(2^{\frac{1}{3}} - 1) \approx 0,78$$

$$1 \geq 0,865 \geq 0,78$$



IMPLEMENTATION – Communication Infrastructure



IMPLEMENTATION – Assembly Implementation

```
.global getMask

getMask:    entry a1, 48
            movi a5, 0          # init increment
            mov a6, a2          # save inputed water level
            movi a2, 1          # init return value

loop:
            addi a5, a5, 1      # increment by one
            beq a5, a6, end     # branch to 'end' if not equal
            slli a2, a2, 1      # left shif by 1, i.e. 0001 -> 0010
            j loop              # jump to loop

end:
            retw.n
```

```c
void implementMask(int8_t mask)
{
  int8_t n_bit = 0;
  while (n_bit < MAX_LEVELS) {
    if (mask & 0x01) {
      digitalWrite(STATES[n_bit], HIGH);
    }
    else {
      digitalWrite(STATES[n_bit], LOW);
    }
    n_bit++;
    mask = mask >> 1;
  }
}
```

DEMO