

2nd ForDigital Blockchain Workshop

Design and Implementation of an Automated and Decentralized Pollution Monitoring System with Blockchains, Smart Contracts, and LoRaWAN

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Summary

- Introduction
- Design
- Implementation
- Conclusion
- Discussion



Introduction

- Population growing exponentially
- More waste production
 - Population: car fumes, incorrect waste disposal
 - Industries: illegal dumping, outdated technologies
- Problems:
 - Lung cancer, skin problems
 - Global Warming (drastic weather changes, ocean levels)
 - Impotable water → wildlife endangered
 - Depletion of natural resources



Introduction

- What to monitor?
 - Air: Carbon Monoxide (CO), Carbon Dioxide (CO₂), Nitrogen Dioxide (NO₂), and so on
 - Water: PH (changes with Acid Rain), Turbidity
- Current monitoring solutions
 - Centralized
 - Direct human interaction
 - High power consumption
 - High implementation cost
 - Lack of public access



Introduction

- **Proposed solution**
- Stores the monitored data in a blockchain (Ethereum)
 - Public available and accessible
 - Decentralized
 - Trust in the data
- Develop a Smart Contract
 - Compare data with regulated standards
 - Enforce penalties

Design

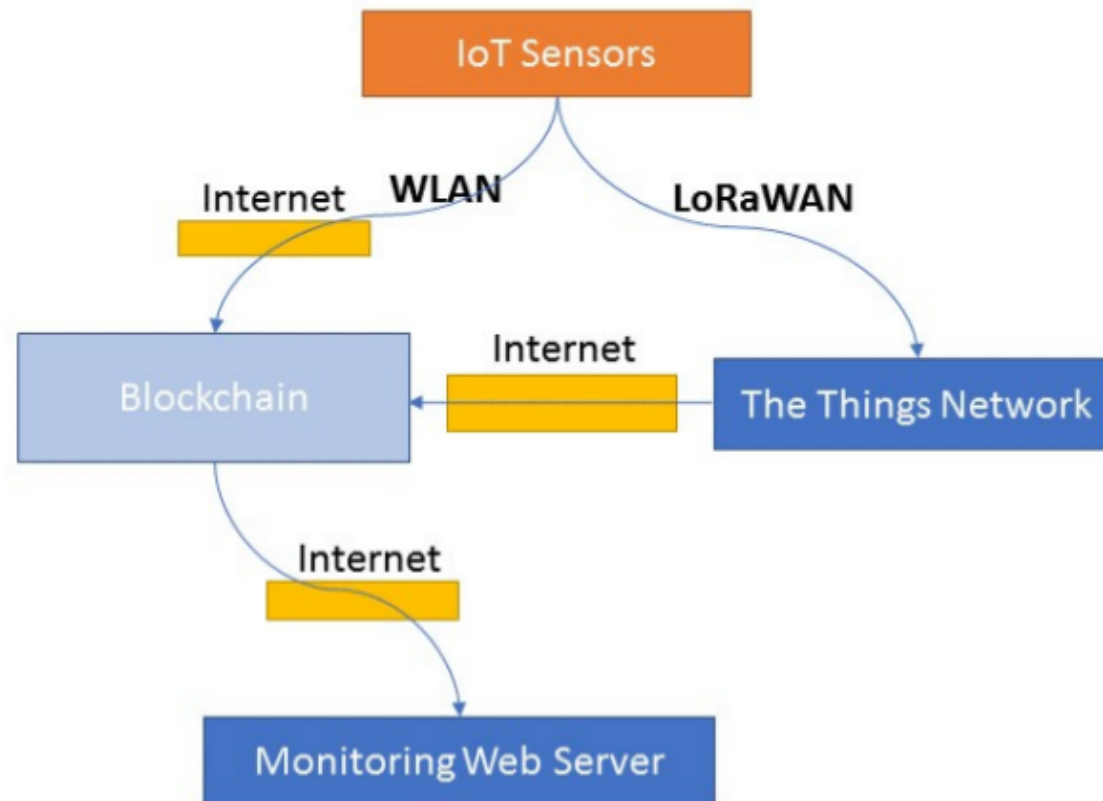


Fig. 1: PMS Architecture Design



Implementation

- Data collection
 - Arduino Uno (LoRa Sensor Node)
 - 4 Sensors
 - Raspberry Pi (Ethereum Light Client - ELC)
- Web Server to user interaction
- Three Approaches for BC interaction
 - 1) IoT sensors connected to LoRa sensor nodes (with the ELC installed) which are connected to the blockchain
 - 2) LoRa sensor nodes connected to LoRa gateway with a ELC connected to the blockchain
 - 3) IoT sensors connected directly to Ethereum full node (Web Server) via WLAN or LoRaWAN

Implementation

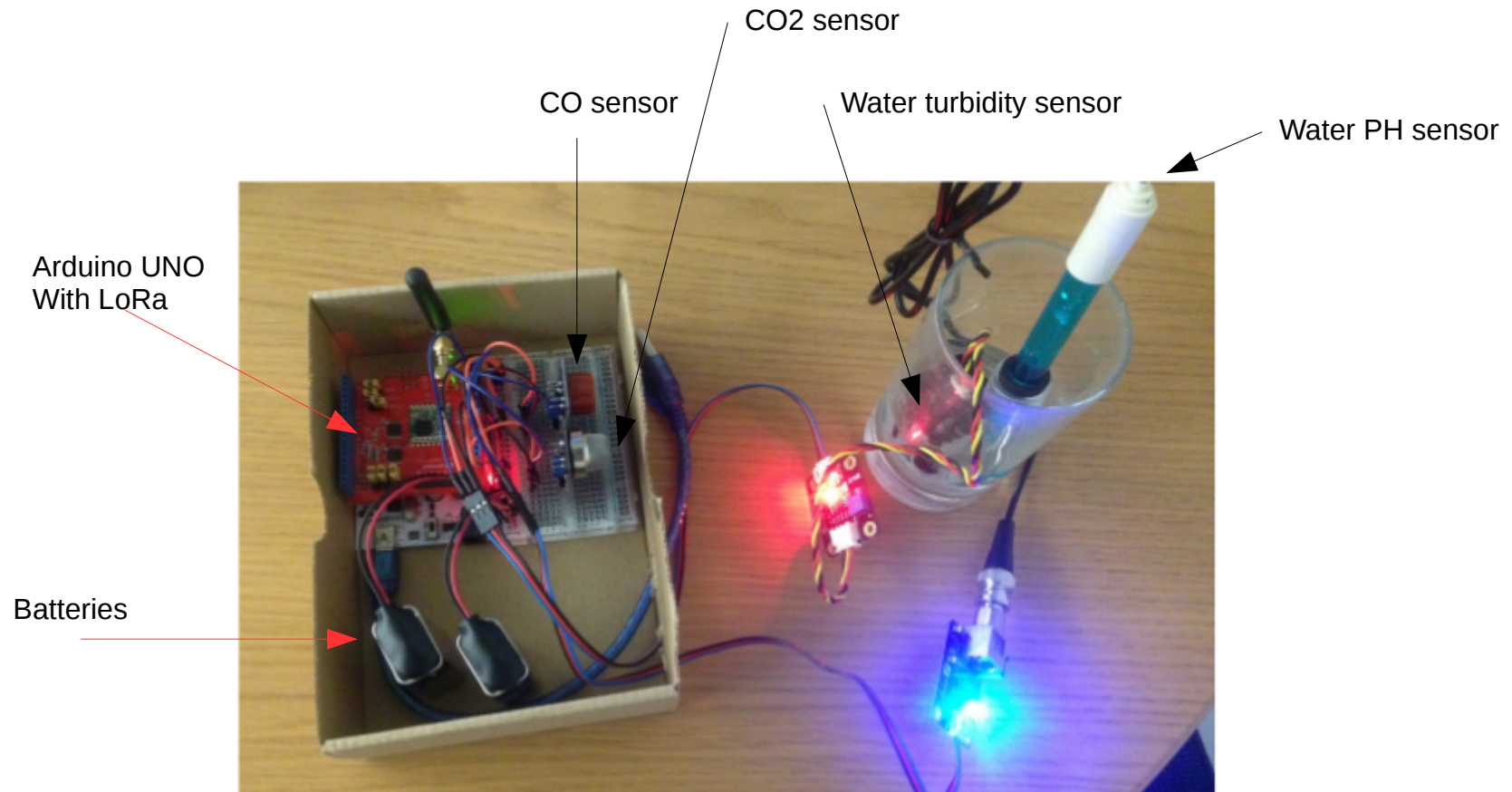


Fig. 2: Prototypical Implementation of a LoRa Sensor Node Including Four Sensors Attached to it

Implementation

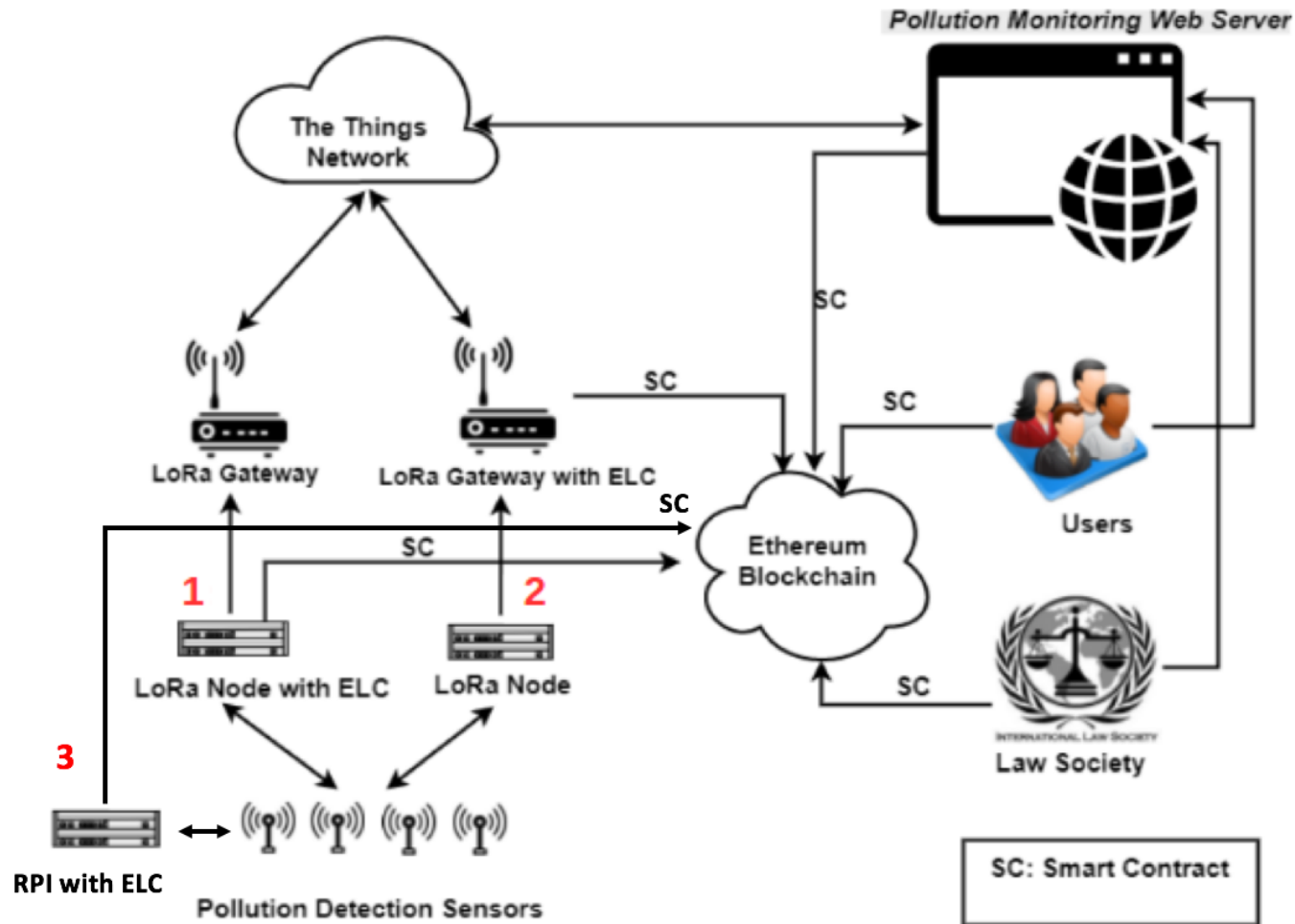


Fig. 3: Data Flow of the Approaches

Implementation

- **Smart Contract**
- Thresholds of the variables in SC are set according to the pollution standards

```
function setStandards() public{
    Colow=9;
    Cohigh=35;
    Co2low=250;
    Co2high=350;
    Turblow=0;
    Turbhigh=5;
    PHlow=6;
    PHhigh=9;}
function updateStandards(uint16 data11,uint16 data12,
    uint16 data21,uint16 data22,uint16 data31,uint16 data32
    ,uint16 data41,uint16 data42) public returns(bool
    success)
```

Implementation

- Data is compared to thresholds before its insertion

```
function compare(uint16 x11,uint16 x21,uint16 x31,uint16
x41) public returns(bool success)
{
    bool i=true;
    message.length=0;
    if((x11<Colow||x11>Cohigh)&& x11>0)
    {
        message.push("CO");
        i=false;
    }
    if((x21<Co2low||x21>Co2high)&& x21>0)
    {
        message.push("CO2");
        i=false;
    }
    if((x31<Turblow||x31>Turbhigh)&& x31>0)
    {
        message.push("Turbidity");
        i=false;
    }
    if((x41<PHlow||x41>PHhigh)&& x41>0)
    {
        message.push("PH");
        i=false;
    }
    return i;
}
function save(bytes32 Country,bytes32 Location,bytes32
deviceID,uint16 x11,uint16 x21,uint16 x31,uint16 x41)
public returns(bool success)
{
    bool i=compare(x11,x21,x31,x41);
    if(i==false){//comment this line for storing all
```

Implementation

- Data is compared to thresholds before its insertion

```
data[index.length].deviceId=deviceID;
data[index.length].Country=Country;
data[index.length].Location=Location;
data[index.length].CO=x11;
data[index.length].CO2=x21;
data[index.length].Turbidity=x31;
data[index.length].PH=x41;
cdata[Country].flag=i;
index.push(index.length);
//}comment this line for storing all the data
return true;
}

function retrievedata(bytes32 Country,bytes32 Location,
bytes32 deviceID) public constant
returns(bytes32 x,uint16 y,uint16 z,uint16 k, uint16 j,
bytes32[] f)
{
    x=deviceID;
    for(uint i=0;i<index.length;i++){
        if((data[i].Country==Country)&&(data[i].Location
==Location)&&(data[i].deviceId==deviceID))
        {y=data[i].CO;
        z=data[i].CO2;
        k=data[i].Turbidity;
        j=data[i].PH;}}
        compare(y,z,k,j);
        return(x,y,z,k,j,message);   }}}
```



Conclusion

- First Pollution Monitoring System to rely on blockchains and Smart Contracts in Ethereum
- Combine blockchain-based systems and IoT-based applications
- Provide tamper resistant data
- Data public available
- Automate violation detection

Discussion

Thank you!

Questions?

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