Blockchain-Based Multi-UAV Surveillance System

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Groupe BLEND : BLockchains for aEronautical aND Space systems
https://websites.isae-supaero.fr/blockchain/blockchains-at-isae-supaero

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Institut Supérieur de l'Aéronautique et de l'Espace
SUPAERO

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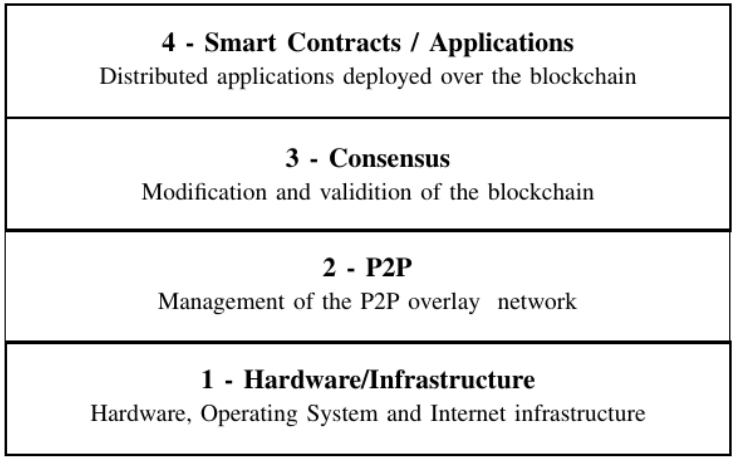
Context and objective

- Starting point : Bitcoin is one of the most **resilient system** in the world
- Objective : show that this resiliency can be applied in other contexts : network of autonomous drones
- Application to a scenario of a surveillance system based of a fleet of drones



Blockchain

Transaction

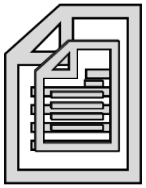
Internal Data

Ledger

Shared

Distributed

Immutable

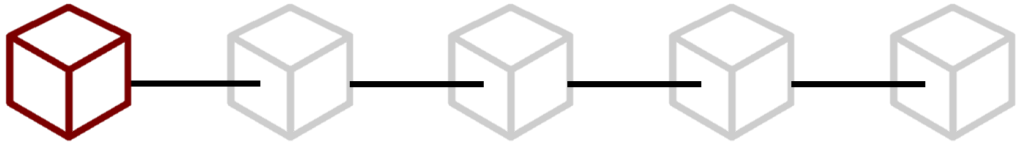


Common Ledger

Public

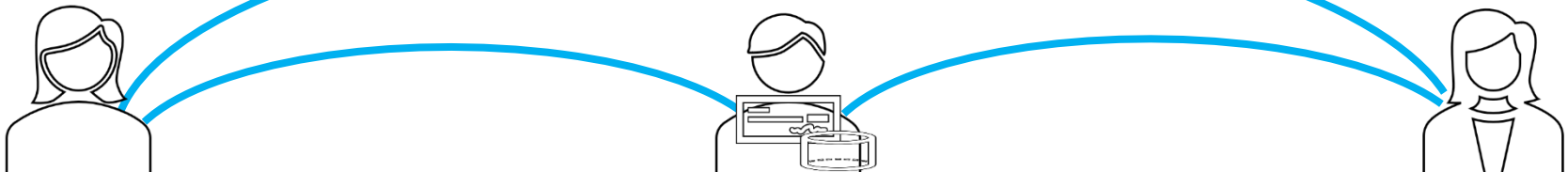
Private

Consortium



Block Chain

Consensus Mechanism



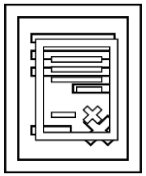
Smart Contract

Transaction

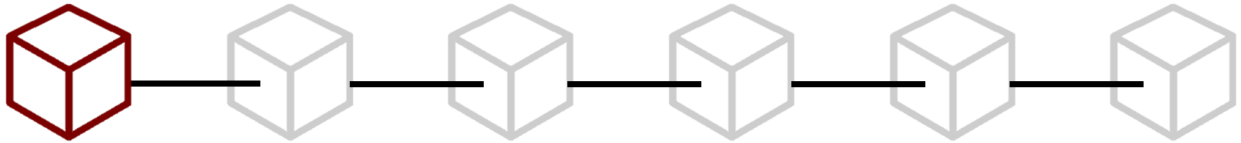
Internal Data

Ledger

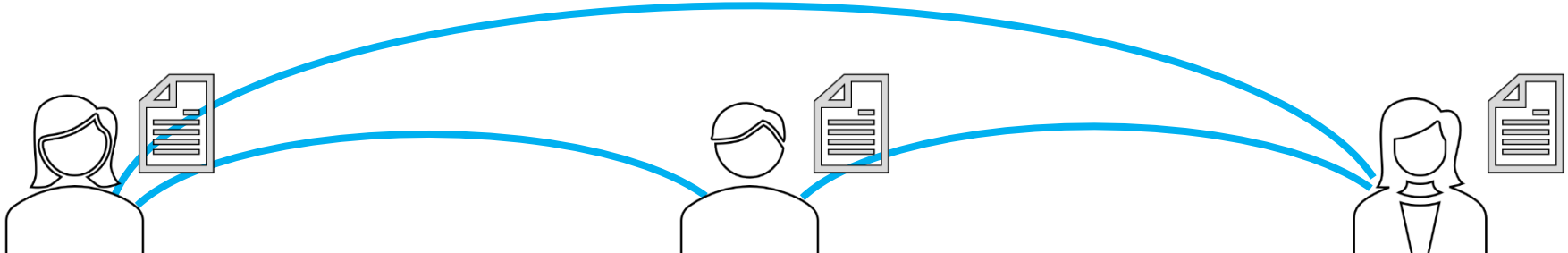
Irreversible Program

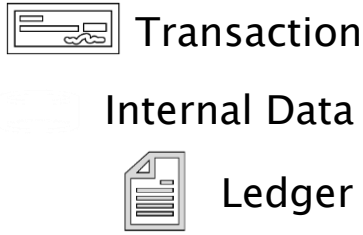


Smart Contract

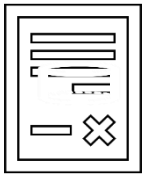


Block Chain

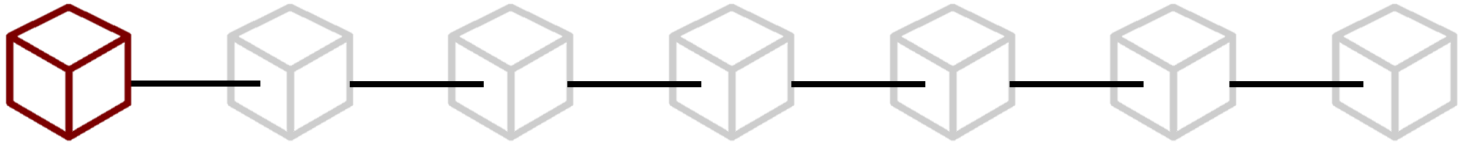




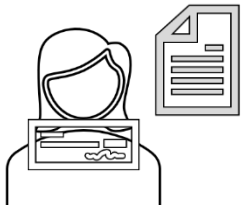
Deterministic

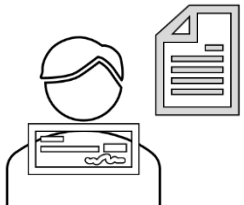


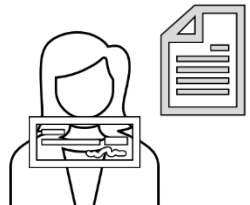
Smart Contract



Block Chain







Multi-UAVs Context

Surveillance Problem

Autonomous UAV

The UAV must operate autonomously and independently

Independent POIs

Points–of-interest are the targets to be visited by the UAVs

Unpredictability & Efficiency

Drone movements must not be predictable
The time between POI visits should be minimized

Blockchain Integration

Synchronize Data Between Nodes

(Doriya et al., 2015; Benavides et al., 2019)

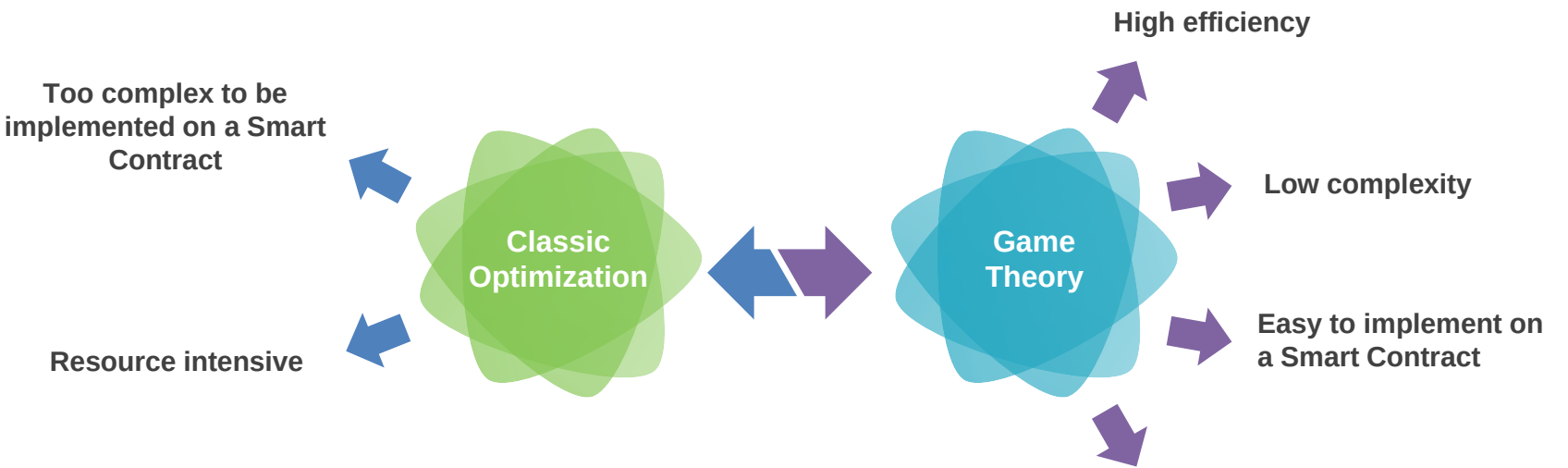
Resistance to Single-Point Failure

(Benavides et al., 2019; de Souza et al., 2016)

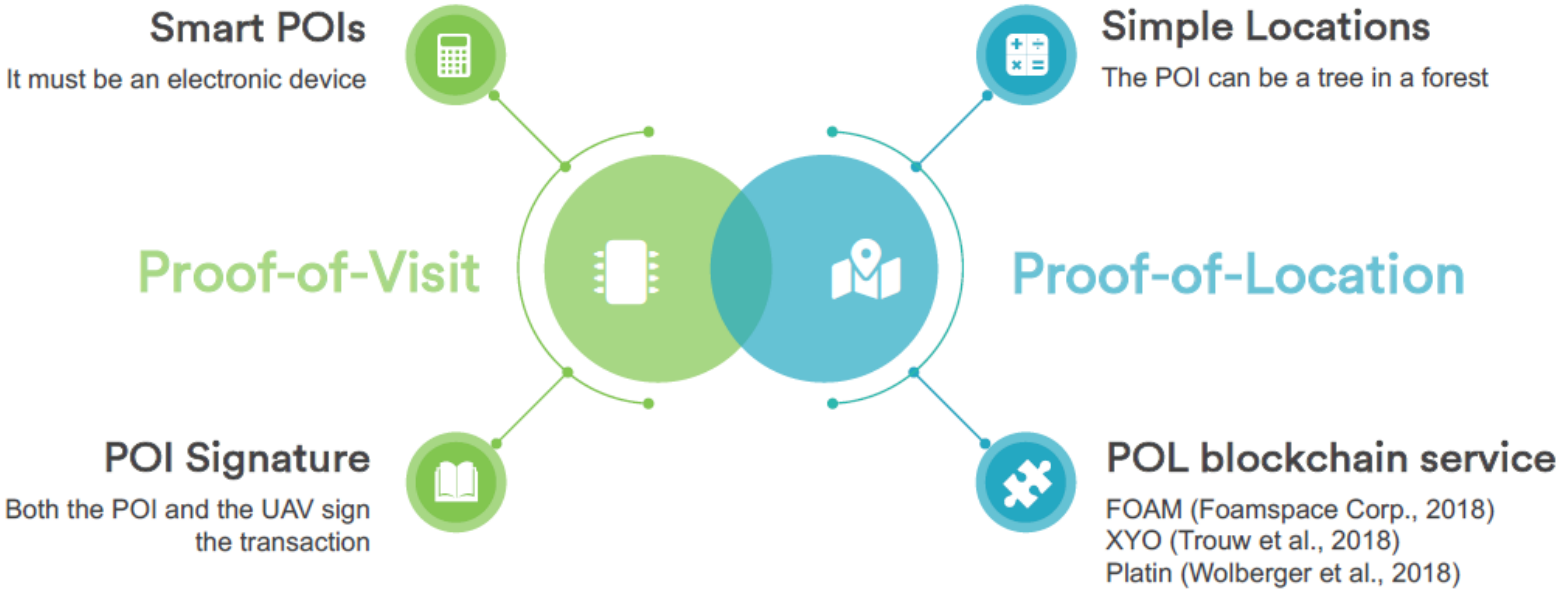
Transparency

Anonymity

Decision-Making Algorithm



POV & POL


Smart POIs
It must be an electronic device
Simple Locations
The POI can be a tree in a forest
Proof-of-Visit
Proof-of-Location
POI Signature
Both the POI and the UAV sign the transaction
POL blockchain service
FOAM (Foamspace Corp., 2018)
XYO (Trouw et al., 2018)
Platin (Wolberger et al., 2018)

Smart Contracts

Defines the POIs and UAVs participating in the system

User Manager

Collects the subscriptions (tokens) of the POIs to the system in an escrow account

Subscription

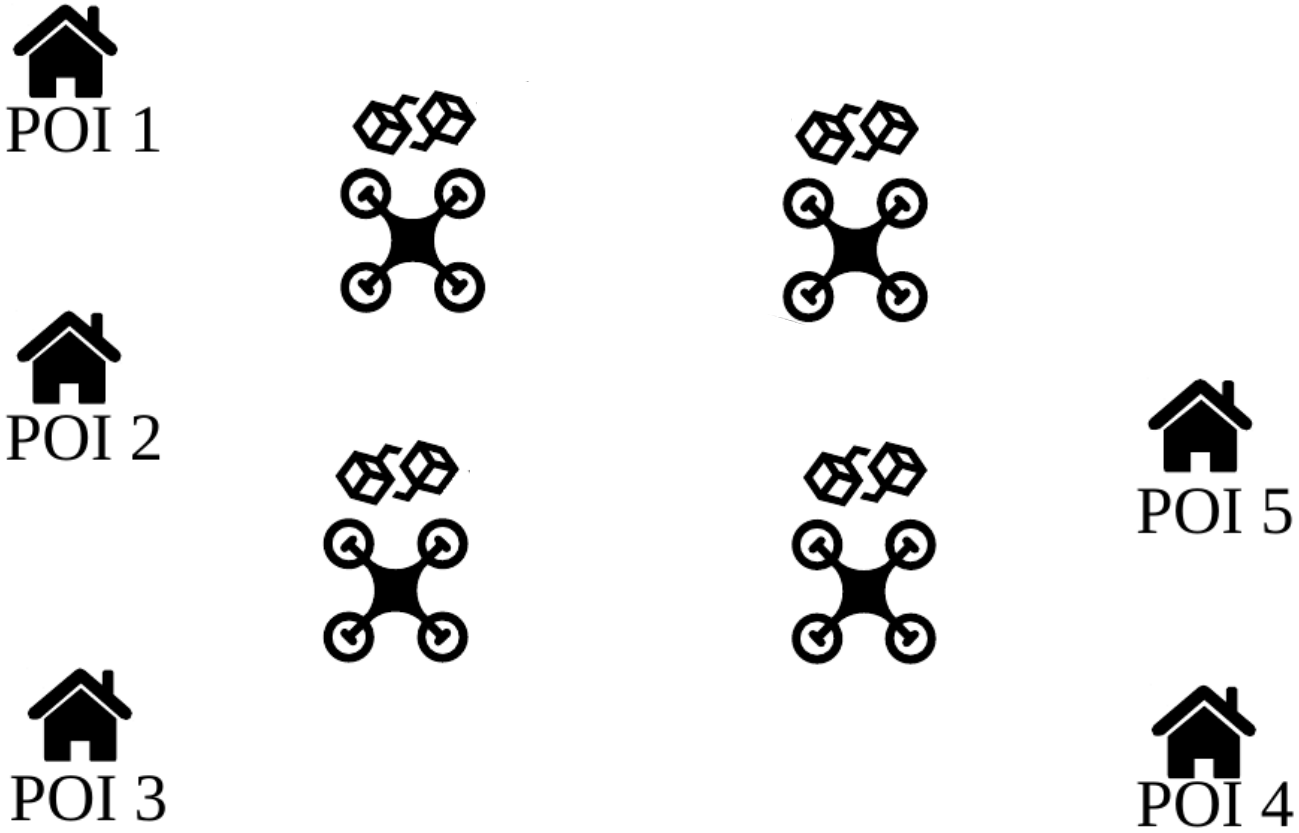
After a UAV stores a POV, it defines the next POI to visit by computing the one minimizing the utility function

Decision

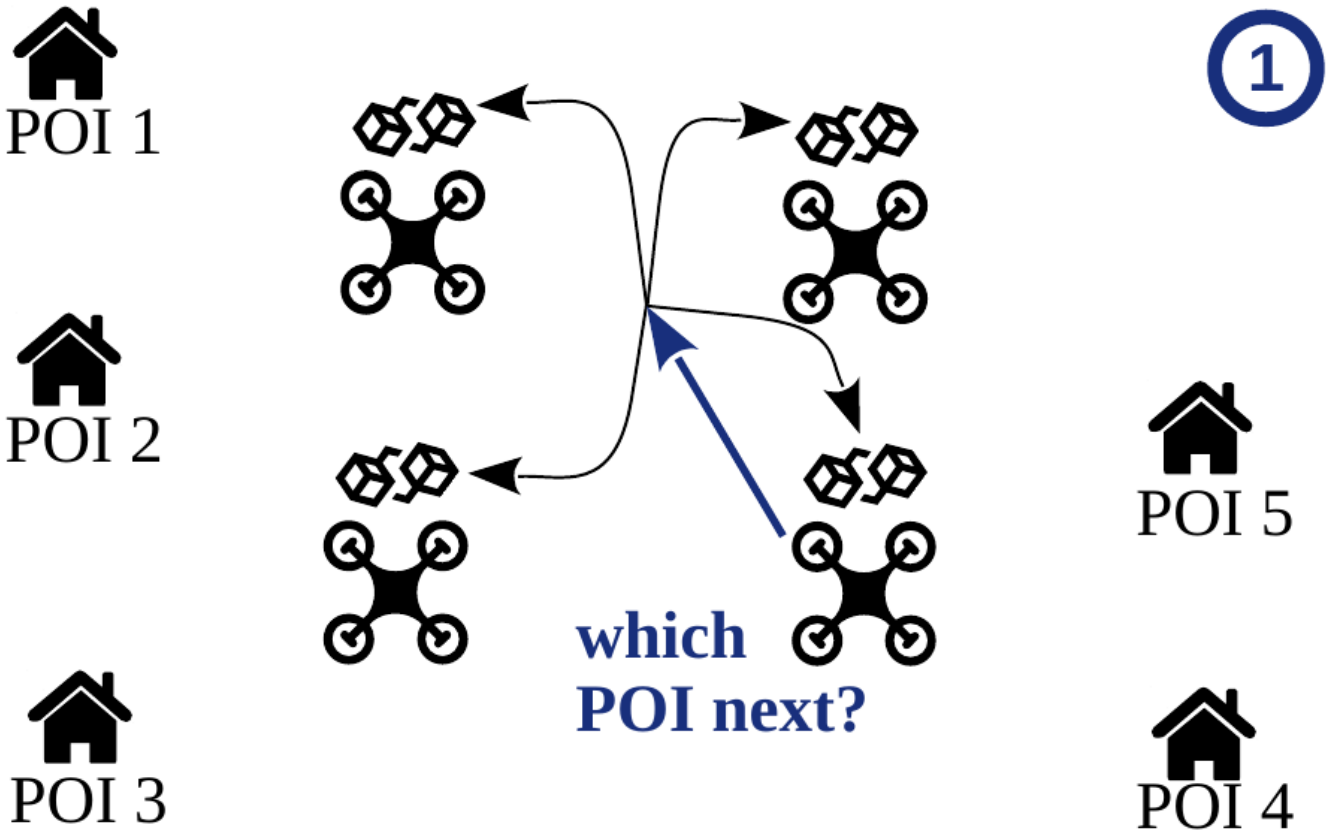
After a POV, it rewards the UAV and the system administrator

Reward

Smart Contracts



Smart Contracts



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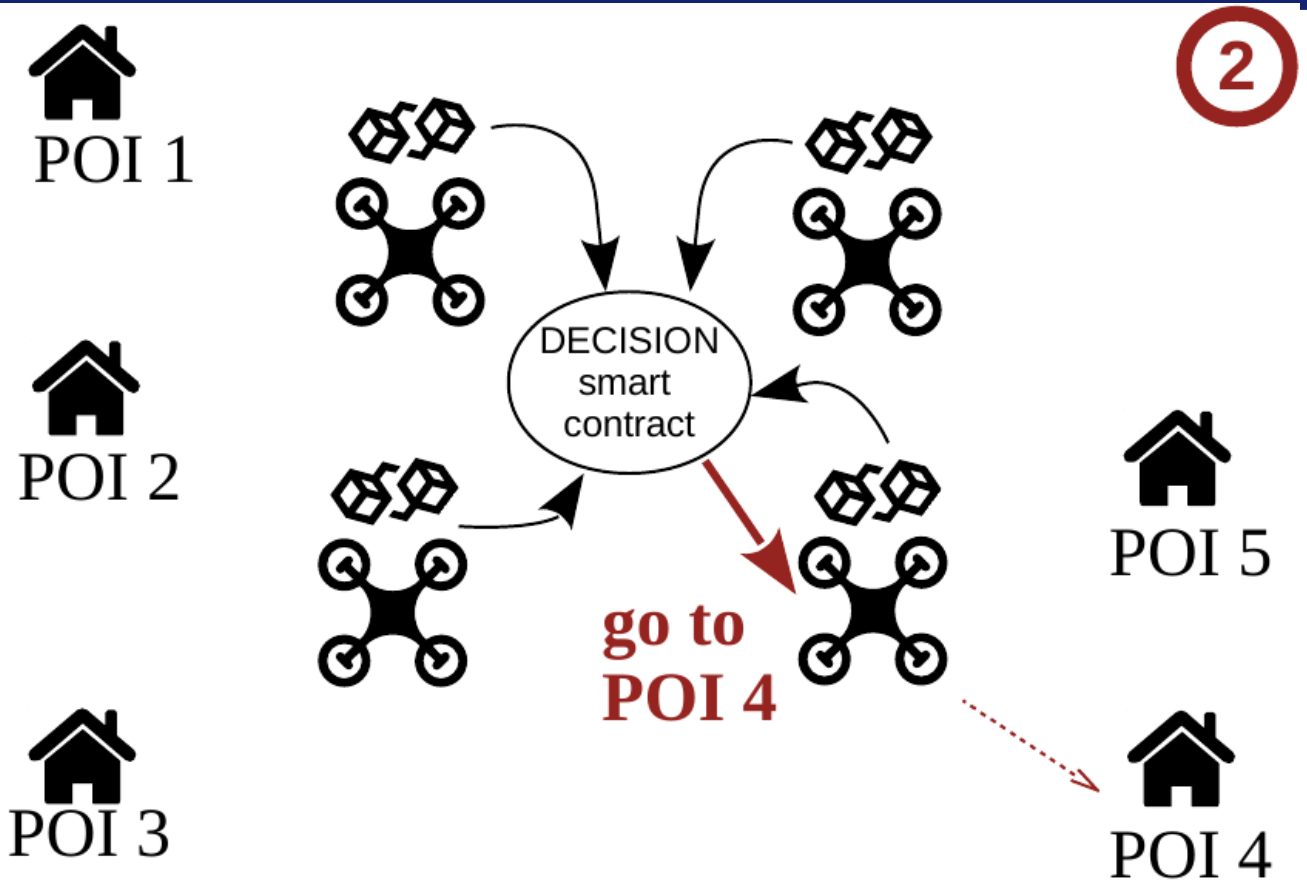

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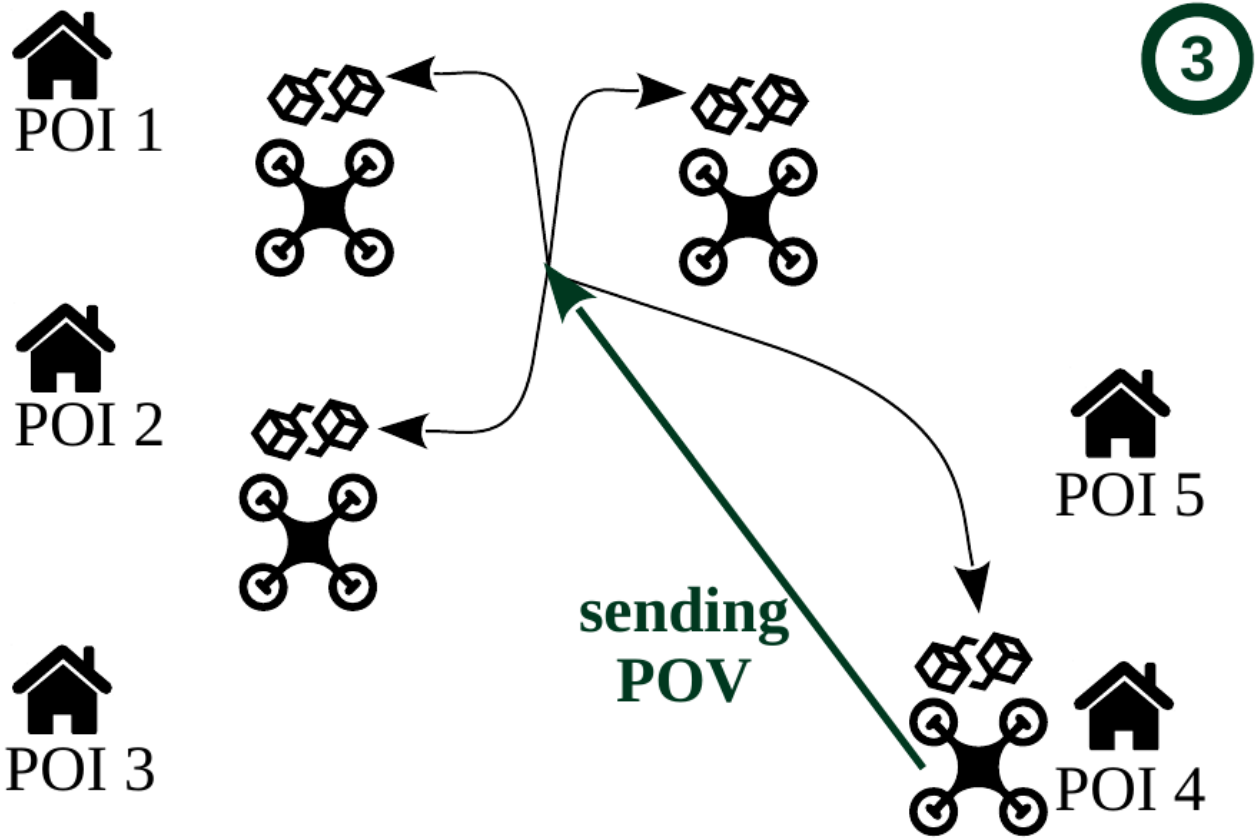
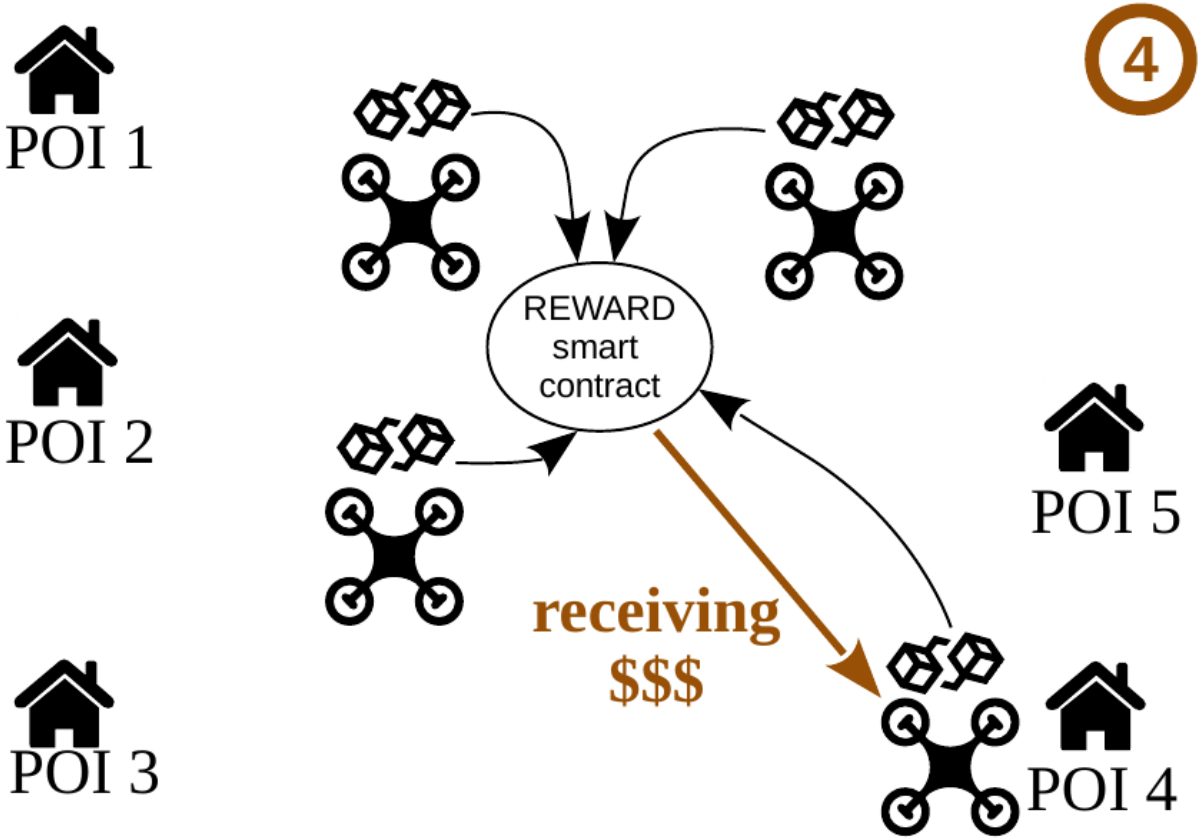


Smart Contracts



Decision algorithm

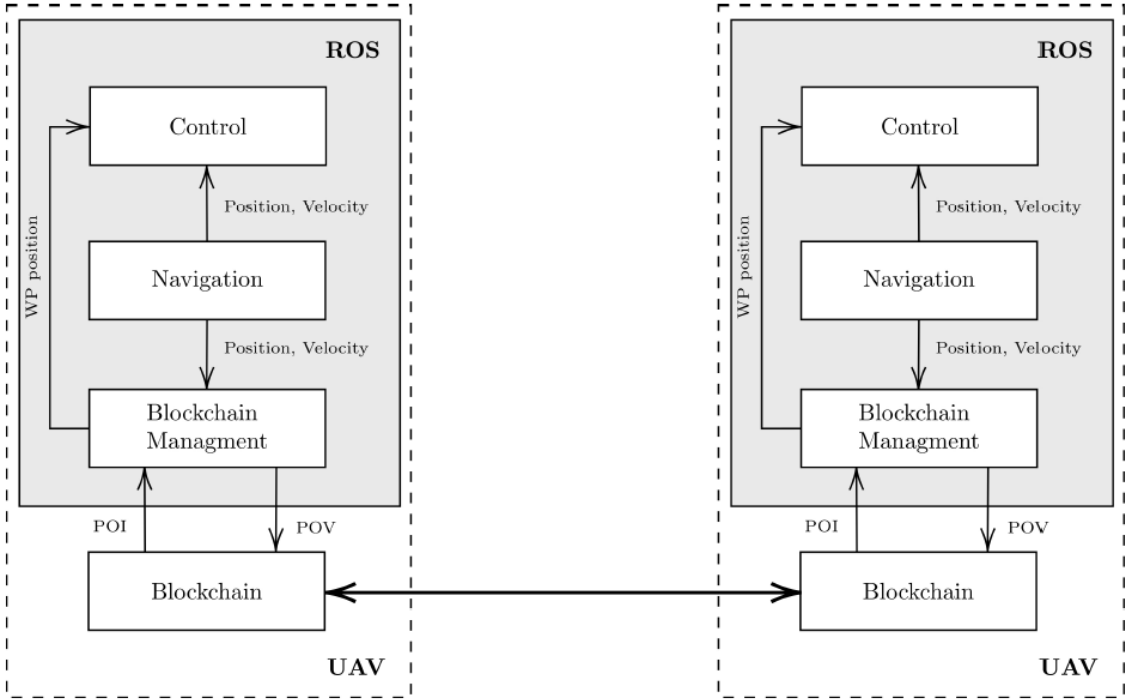
- The choice of the next POI is done by minimizing a utility function based on :
  - the **path cost** (e.g. distance) for the UAV to move from its current position to a given POI;
  - the **weighted sum of all other UAVs inverted distance**.
  - the **negative of the expected reward** to reach a POI (idleness of the POI).

- It was shown that minimizing each utility function individually is the best choice for the group.

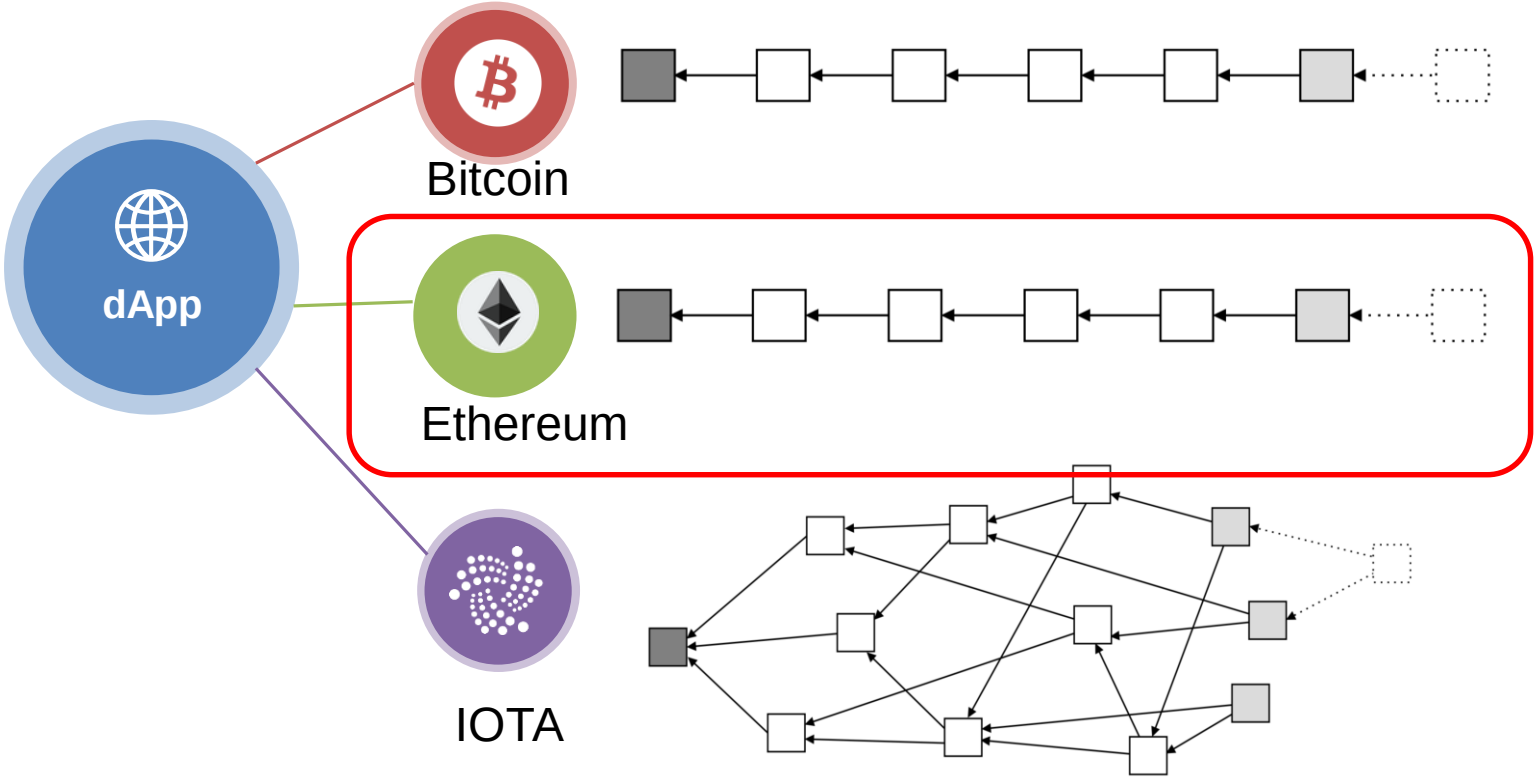
Embedded UAV System

Communication handled by the Blockchain

Each UAV runs a blockchain node

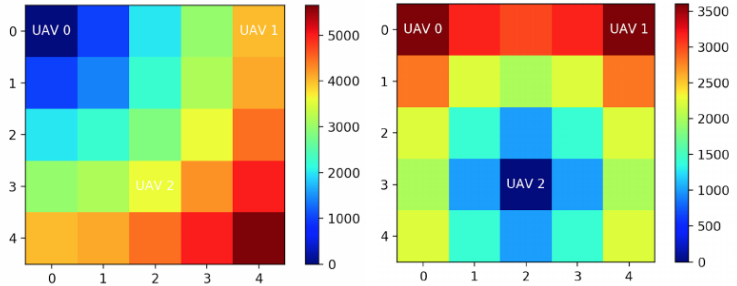


Blockchain Choice



Choices

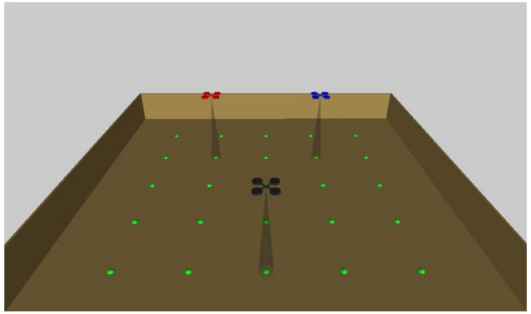
- Blockchain Ethereum : client Besu
- Smart contracts : written in solidity
  - SUBSCRIPTION: collects the subscriptions (in tokens) of the POIs to the system in an escrow account;
  - DECISION : defines the next POI – based on game theory
  - REWARD : rewards the UAVs

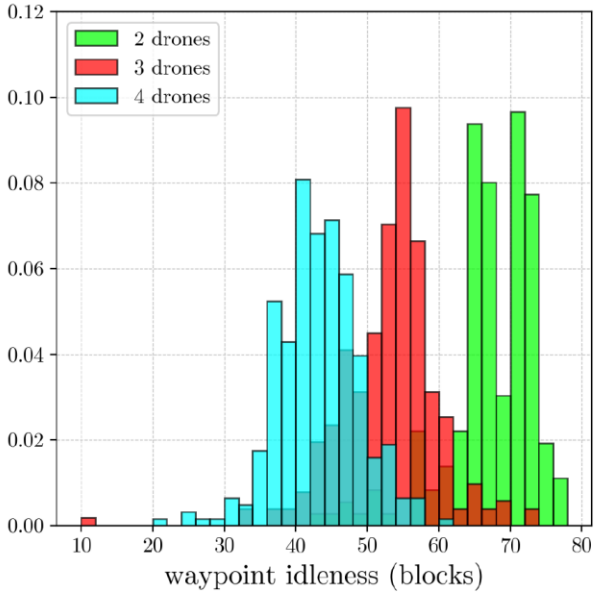


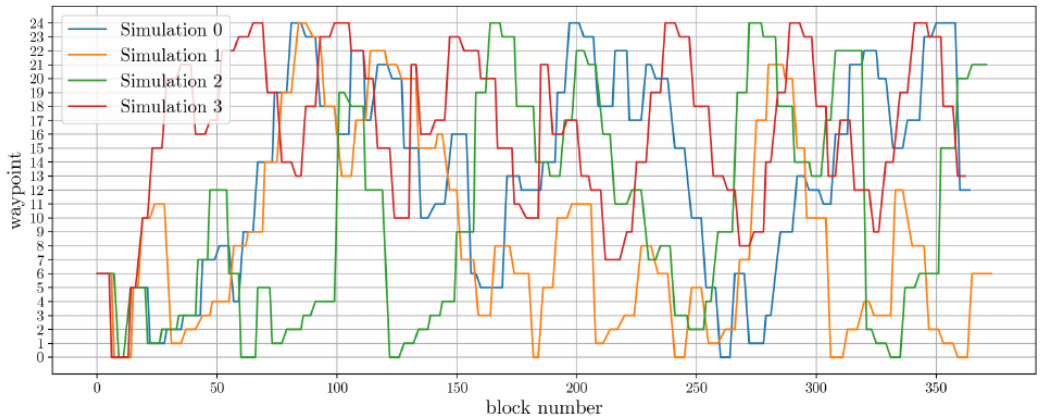
- First evaluation on simulation
- Implementation and demonstration

Simulations

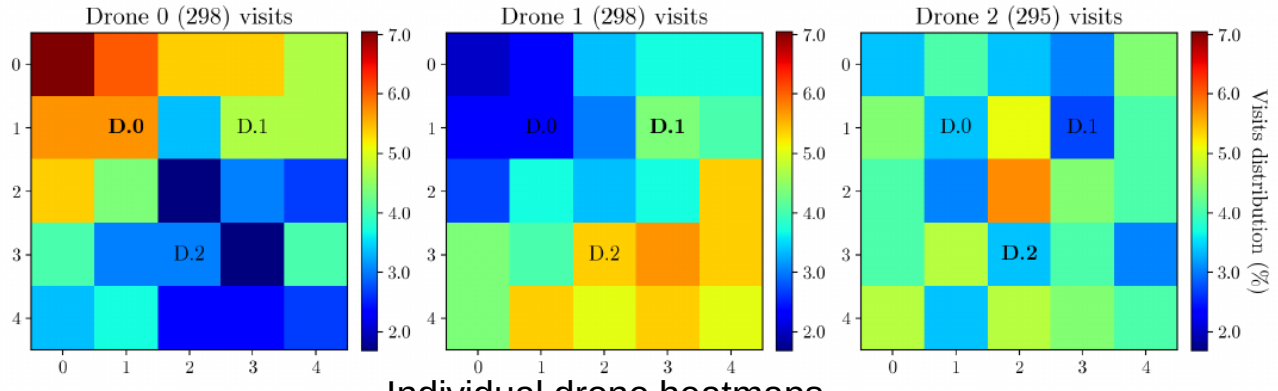
- Management in python
- Besu clients and smart contracts written in Solidity
- Objectives : Validate the algorithms and tune the parameters



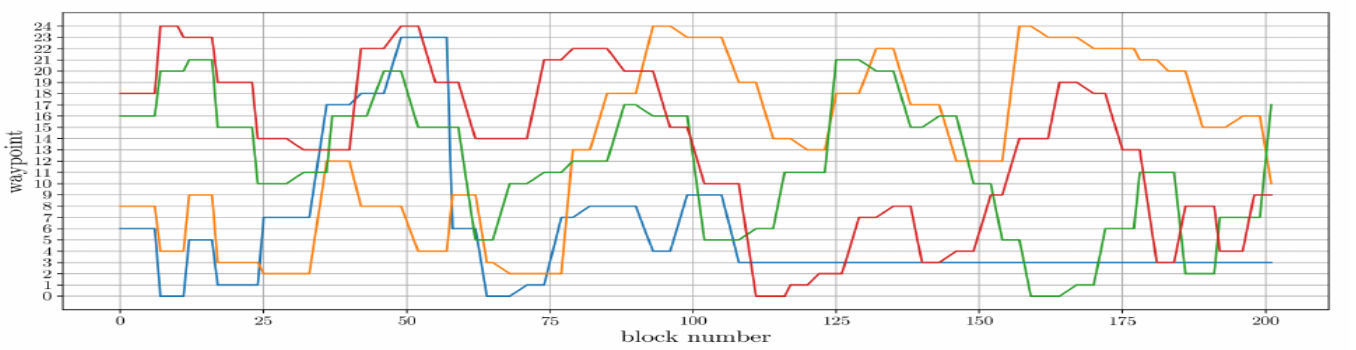




Simulations (2)

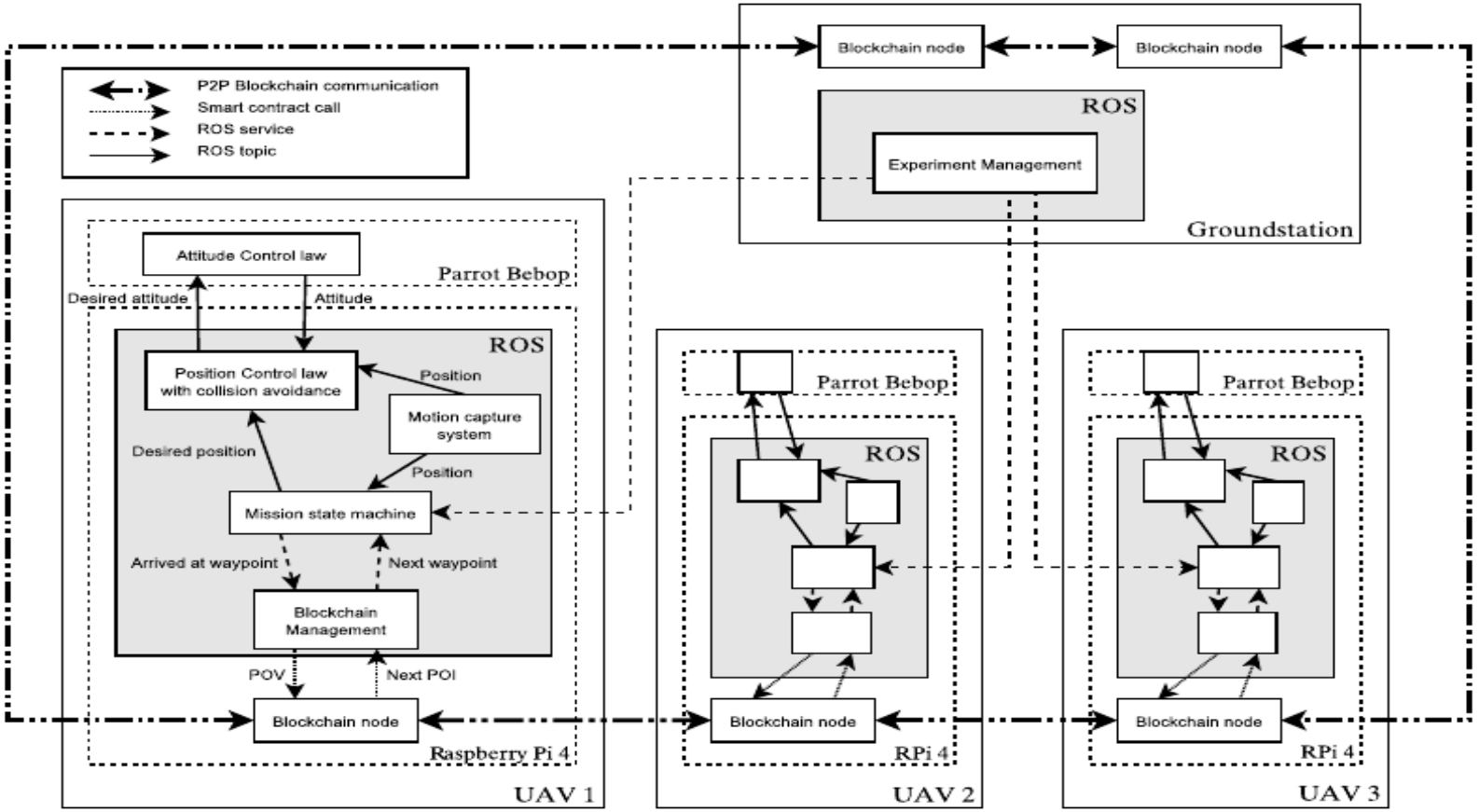


Individual drone heatmaps

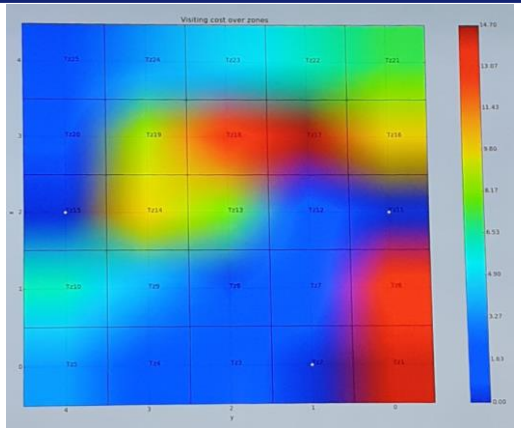


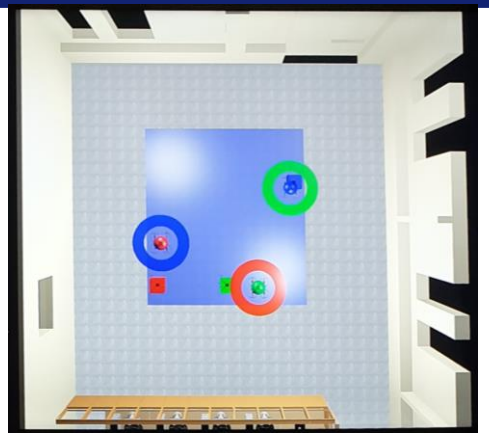
Failing condition path illustration

Implementation

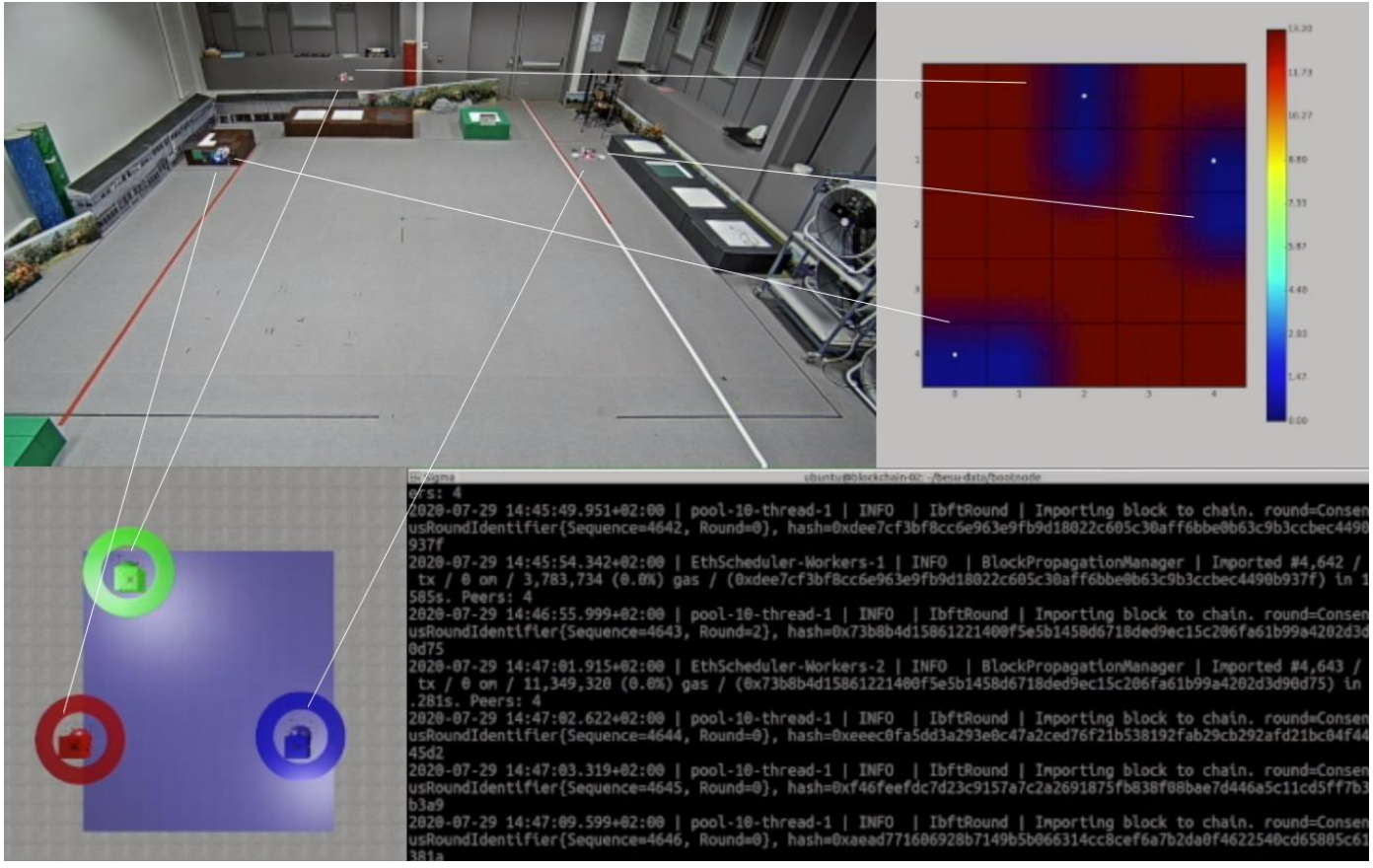


Platform





Demonstration



Conclusions and future work

- Definition of a surveillance system based on autonomous drones embedding a blockchain - Managed by smart contracts
- Validated by simulations and implementations on real drones
- Publications :
  - Santos de Campos, M. G. and Ponzoni Carvalho Chanel, C. and Chauffaut, C. and Lacan, J..Towards a Blockchain-Based Multi-UAV Surveillance System, (2021) Frontiers in Robotics and AI, 8. ISSN 2296-9144
  - A Mission-Level Resilient Blockchain-based Robotic System, to be (re-) submitted
- Future work :
  - Extensions to other drone missions : package delivery, …
  - Extensions to small satellite swarms
  - 2 PhD starting october 2021 on IA and cryptography for embedded blockchains

Questions ?