BLOCKCHAIN

# Welcome at SfeirSchool
# Blockchain 200


DÉBUTANT
CONFIRMÉ
EXPERT
School

# Training usages

## When can we go on break?

# Agenda

1. LEDGER
   - ❑ Introduction
   - ❑ Improvements

2. DISTRIBUTION
   - ❑ Introduction
   - ❑ Collaboration
   - ❑ Double spending
   - ❑ States & Transitions
   - ❑ Identification
   - ❑ Security

# Agenda

## 3. OPEN DISTRIBUTION

- Synchronisation (Review)
- Self-regulating system

## 4. USE CASES

- Fund management

# LEDGER

- Introduction
- Improvements

# 1. Ledger: Introduction

## What is a ledger ?

# Example: “Supervising sales”

**Ledger**

## IDENTITY

| | |
|---|---|
| *Name :* | Mary KAGHAN |
| *Job :* | Baker |
| *Company :* | Au Bon Pain |
| *Employees's Num. :* | < 3 persons |

## CONTEXT

Mary's company is a little family firm which is not structured to track sales.

## NEED

Mary needs to know the volume of sales, the sold product quantity, and partial sales performance per day.

# Example: “Supervising sales”

**Ledger**

***How to effectively monitor sales?***

# Example: “Supervising sales”

**Ledger**

**BRAINSTORMING**

# Example: “Supervising sales”

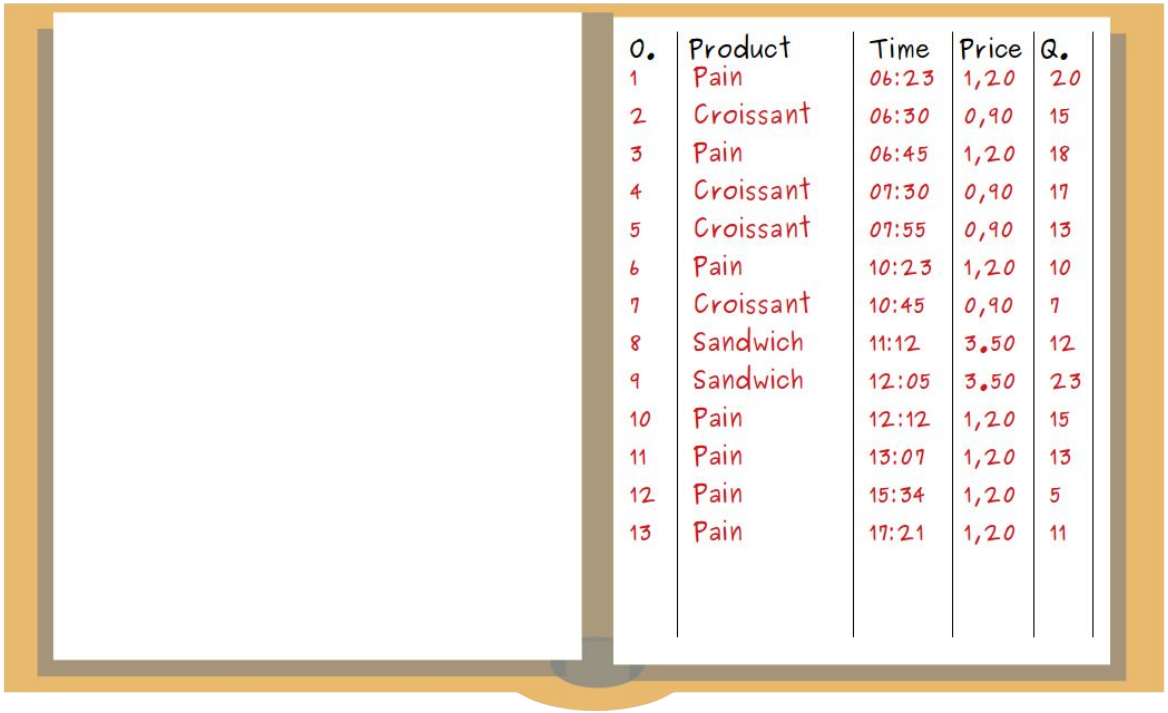
## Ledger

- Intuitive solution : “**Ledger**”

| | |
|---|---|
| Simple solution | ✓ |
| Keep order | ✓ |
| Elastic data storage | ✓ |
| Forgery Proof | ✓ |

# Example: “Supervising sales”

## Ledger



| O. | Product | Time | Price | Q. |
|---|---|---|---|---|
| 1 | Pain | 06:23 | 1,20 | 20 |
| 2 | Croissant | 06:30 | 0,90 | 15 |
| 3 | Pain | 06:45 | 1,20 | 18 |
| 4 | Croissant | 07:30 | 0,90 | 17 |
| 5 | Croissant | 07:55 | 0,90 | 13 |
| 6 | Pain | 10:23 | 1,20 | 10 |
| 7 | Croissant | 10:45 | 0,90 | 7 |
| 8 | Sandwich | 11:12 | 3.50 | 12 |
| 9 | Sandwich | 12:05 | 3.50 | 23 |
| 10 | Pain | 12:12 | 1,20 | 15 |
| 11 | Pain | 13:07 | 1,20 | 13 |
| 12 | Pain | 15:34 | 1,20 | 5 |
| 13 | Pain | 17:21 | 1,20 | 11 |

# Ledger implementation

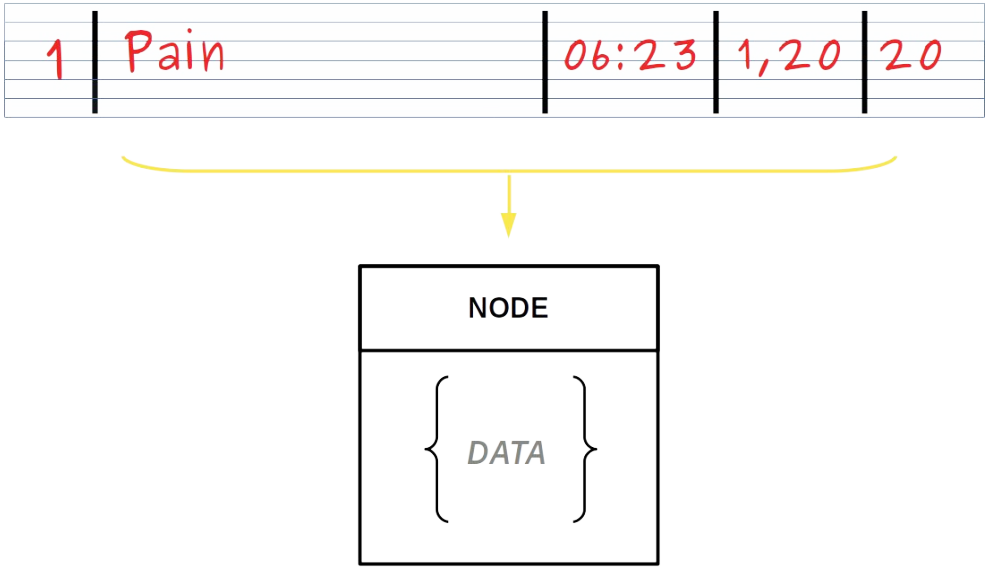
**Ledger**

## How to implement a ledger ?

# Ledger implementation

## Ledger

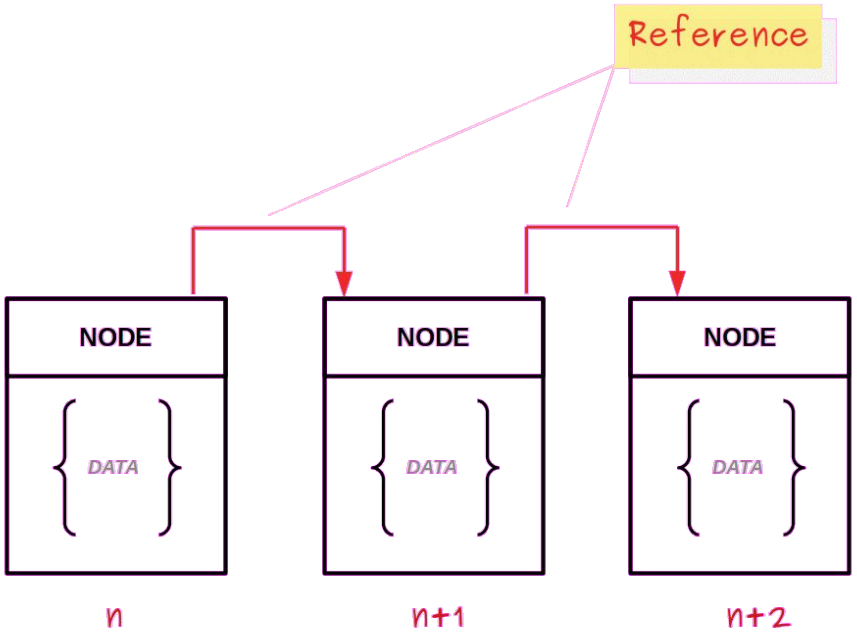
**Rule 1**: One node represents a register line



# Ledger implementation

## Ledger

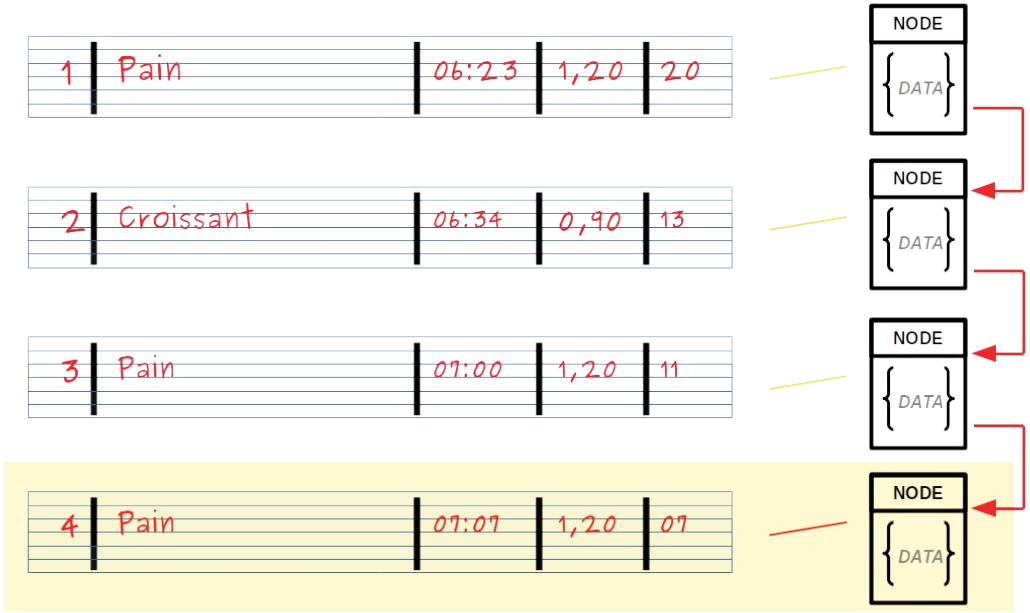
**Rule 2**: Each node must be linked to the rest (In order)



# Ledger implementation

**Ledger**

**Rule 3**: The last inserted node is the most recent



# Ledger: Exercices

## Statement

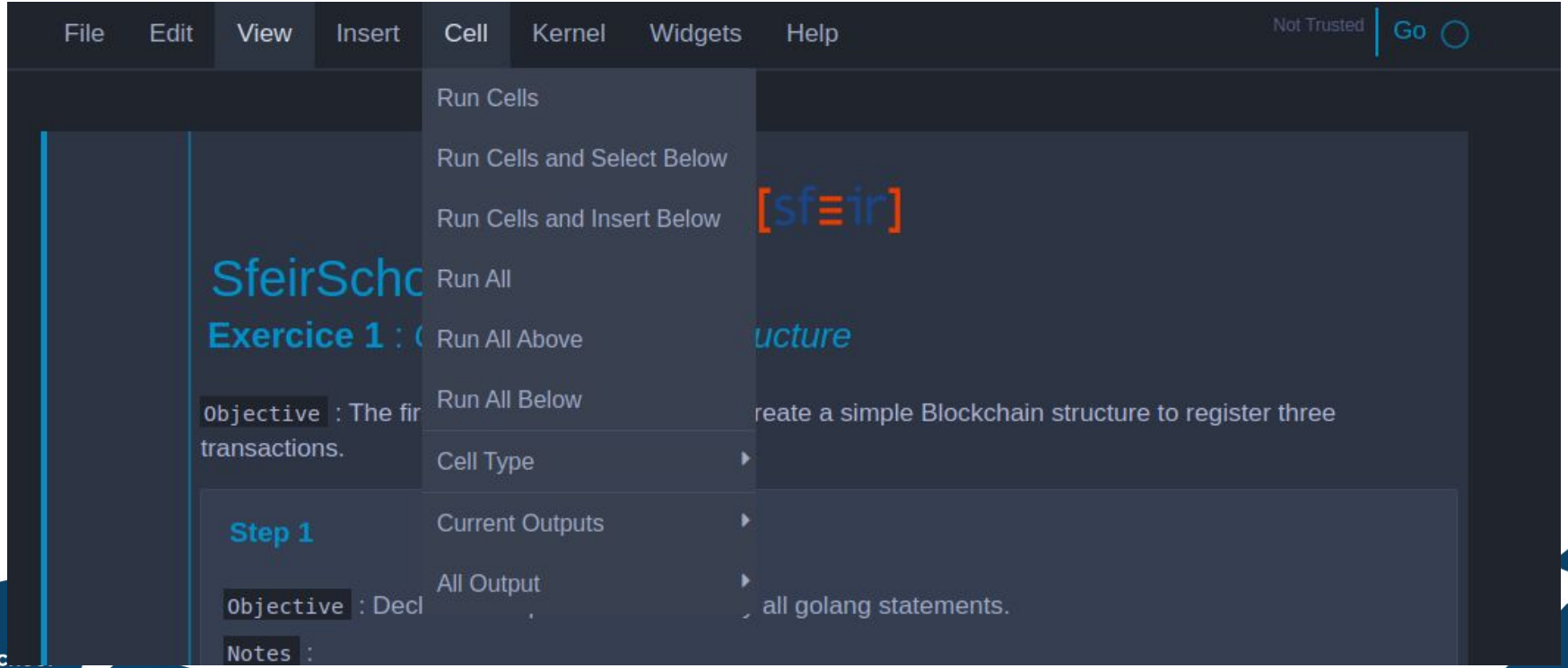
```
# git clone https://github.com/ech54/sfeir-schools.git

# cd 01_introduction_bc

# docker-compose up --remove-orphan
```

# Ledger: Exercices

## Statement



# Ledger: Exercices - 1

## Statement

“Create a ledger”

# Ledger implementation

**Ledger**

**Is it safe ?**

# Ledger: Exercices - 2

## Statement

### “Unique Identifier”

1. **Based on last solution find a better solution to build a unique identifier**
2. ***(Owner signature)***

***NOTE:*** *Think about cryptographic …*

# *Ledger: Sum-up*

- Properties:

  History, Order, Forgery-Proof

- Implementation:

  Chain of blocks (nodes)

- Solution limits:

  In-memory context, mono thread,

  self-ownership on your data

# CONTEXT

**Who is the data master ?**

- *I'm the Master of Data*

**What is ledger context ?**

- *Private*

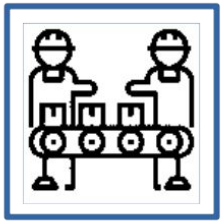
# 1. Ledger: Improvement

## Ledger in real life ...

# Example: “AM Laboratory …”

**Improvement**

## IDENTITY



| | |
|---|---|
| *Name :* | John WHITEKER |
| *Job :* | Quality Control Ingeneer |
| *Company :* | AM Laboratory |
| *Employees's Num. :* | < 50 persons |

## CONTEXT

John is working for AM Lab firm. He controls car parts from greatest automotive factories. Automotive growth will increase the number of parts to control per day …

## NEED

Firm comity want to invest on custom Ledger. In few months, 50 persons will input the result of their control into custom Ledger.

# Example: “AM Laboratory …”

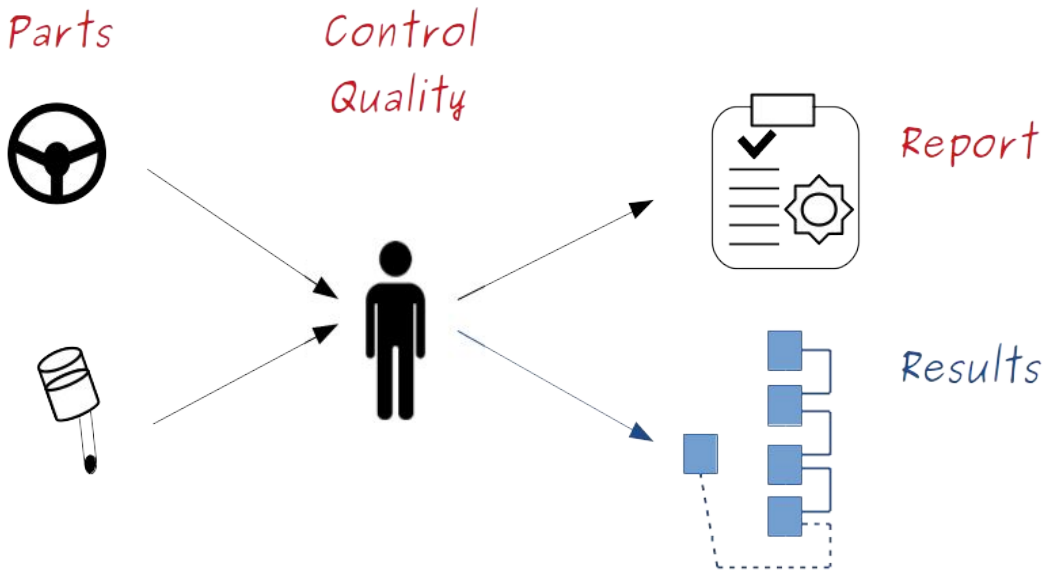
**Improvement**

## How to use a Ledger in John’s context ?

# Example: “AM Laboratory …”

**Improvement**

- Expected solution description:



# Example: “AM Laboratory …”

**Improvement**

## Can we reuse our first proposal implementation in the John context?

# Example: “AM Laboratory …”

**Improvement**

BRAINSTORMING

# Example: “AM Laboratory …”

**Improvement**

## Should we review the first Ledger model ?

# Review Model ?

**Improvement**

- Ledger will contain **quality report result** :
  - Unique tx identifier
  - Last tx identifier
  - Creation date
  - Parts reference
  - Control status [Ok / Nok]
  - Controller reference

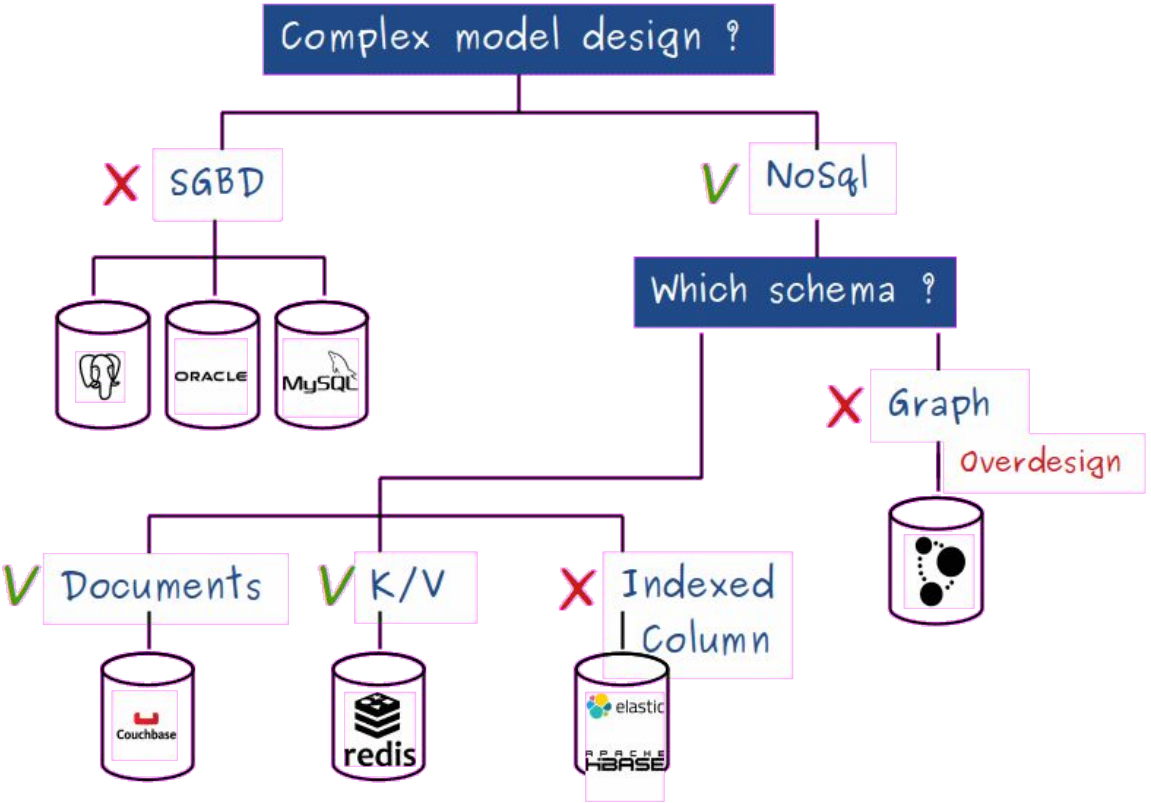
# Storage Target ?

**Improvement**

## Which storage could we used to store Ledger ?

# Storage Target ?

**Improvement**



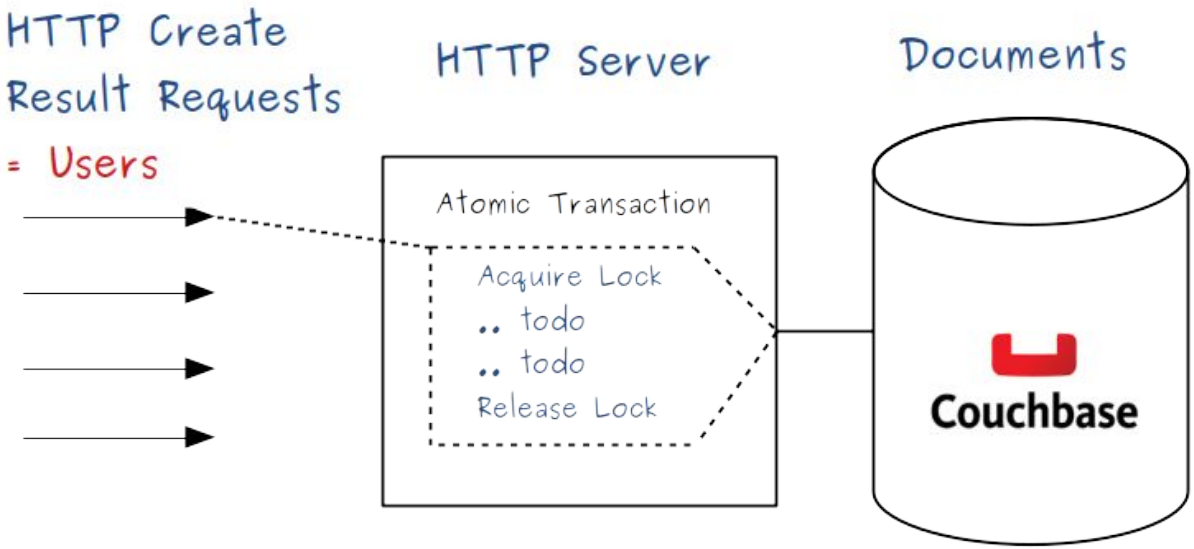
# Number of users ...

**Improvement**

## How to handle multiple users ?

# Number of users ...

**Improvement**




PESSIMISTIC LOCK MODEL

# Number of users ...

**Improvement**

## Which is the limit of solution?

# Number of users ...

**Improvement**

- Lock model has a cost on **performance**
- Lock **synchronizes** all requests

# Performance

## Improvement

How to improve solution performance ?

# Example: “Supervising sales”

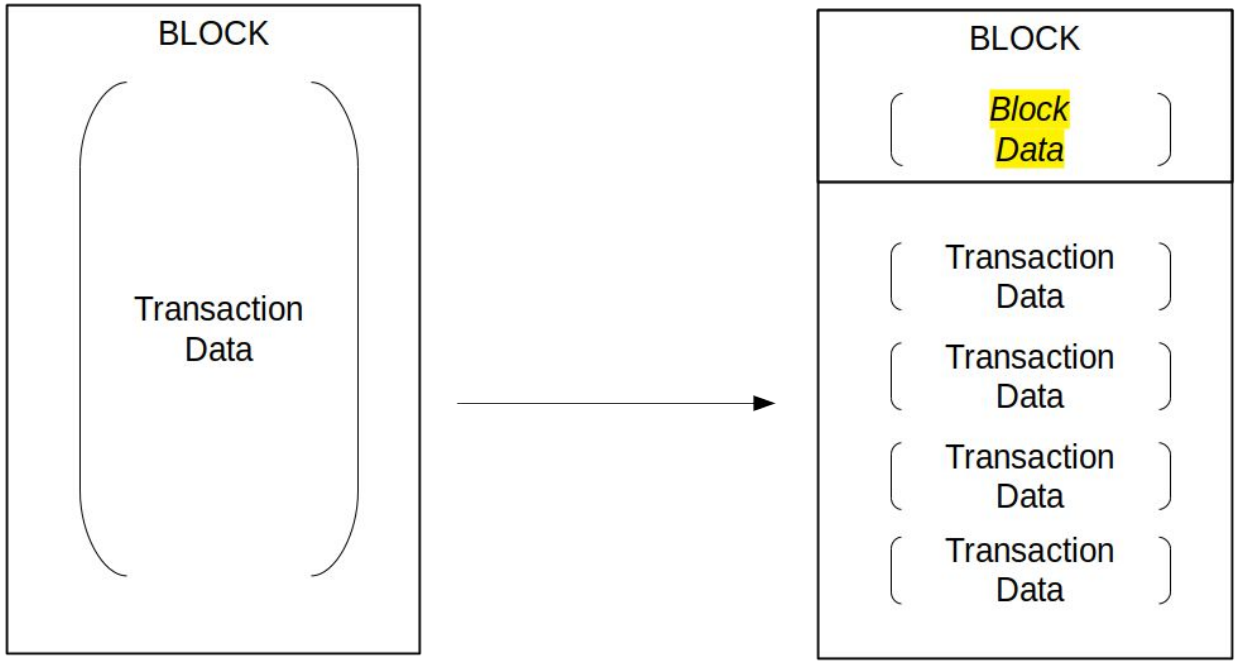
**Ledger**

- Intuitive solution : “**Multiplex n transactions per Block**”

| | |
|---|---|
| Simple solution | ✓ |
| Commit n transactions in storage | ✓ |

# Performance

## Improvement



# Performance

**Improvement**

- Block data header:
  - Unique identifier, Last block identifier, timestamp
- Block data body:
  - **n Transactions**
  - Transaction identifier and data

# Performance

**Improvement**

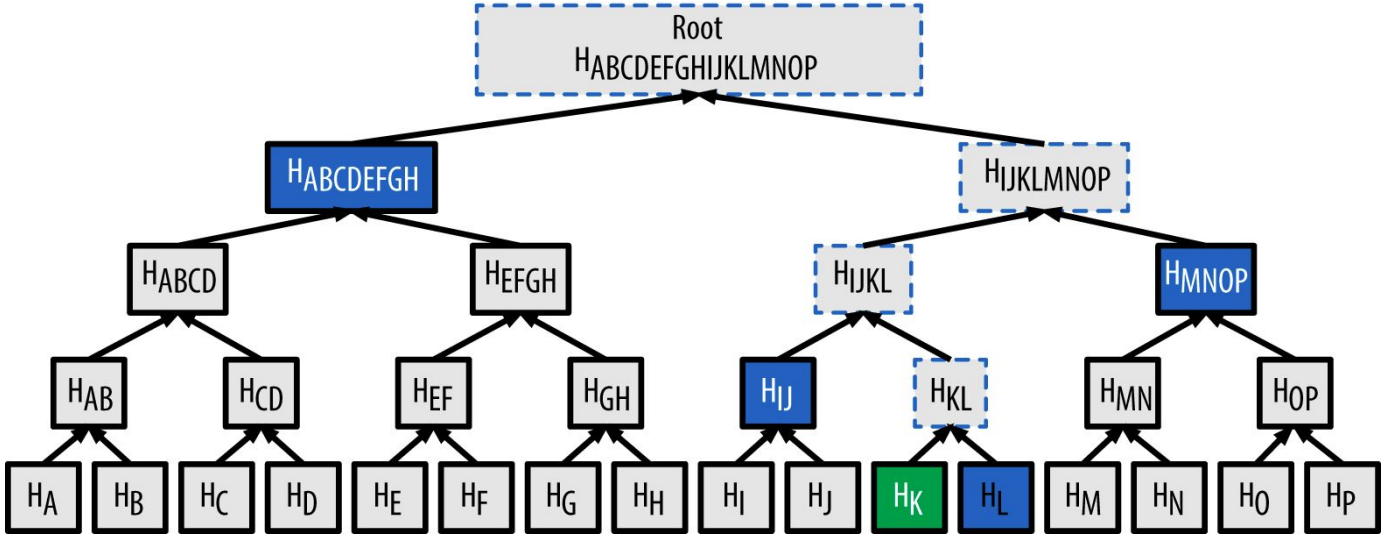
## Issues

- How to keep order ?
- How to keep forgery-proof property?

# Performance

**Improvement**

- Solution : “**Merkle tree**”



# Performance

**Improvement**

- “**Merkle tree**” principles
  - Each transaction is hashed
  - Each hash and transaction is stored on K/V storage
  - Both hashes are hashes step by step until the root hash

# Performance

**Improvement**

- “**Merkle tree**” properties
  - Order can’t be modified
  - Quick search in using the transaction hash
  - Alteration is not possible

# Performance: Exercices - 3

**Statement**

**“Review the block implementation to handle multiple transaction”**

1. Think about K/V storage for transactions
2. Think about hashing for key generation
3. Hash twice key together until create a root key

# *Ledger improvements: Sum-up*

- Persistence:
  - Document NoSql solutions (Key / Values)
- Transaction load:
  - Pessimistic system limitless
  - Multiplex transactions per block (Merkle tree)

# CONTEXT

**Who is the data master ?**

- *I'm the Master of Data*

**What is ledger context ?**

- *Private*

# DISTRIBUTION

- Introduction
- Collaboration
- Double spending
- States & Transitions
- Identification
- Security

# 2. Distribution: Introduction

## Why distribute a ledger ?

# Example: “Outsourced accounting”

**Distribution**

## IDENTITY

| | |
|---|---|
| *Name :* | Mike MATH |
| *Job :* | Business accountant |
| *Company :* | « See my shoes » |
| *Employees's Num. :* | < 200 persons |

## CONTEXT

Mike is working for « See my shoes » company. His job is essential to provide driving tools for his job. Accounting is outsourced, Mike used Ledger to return all accounting evidences to an external recipient.

## NEED

Mike's need is to improve the exchange between his service and this recipient …

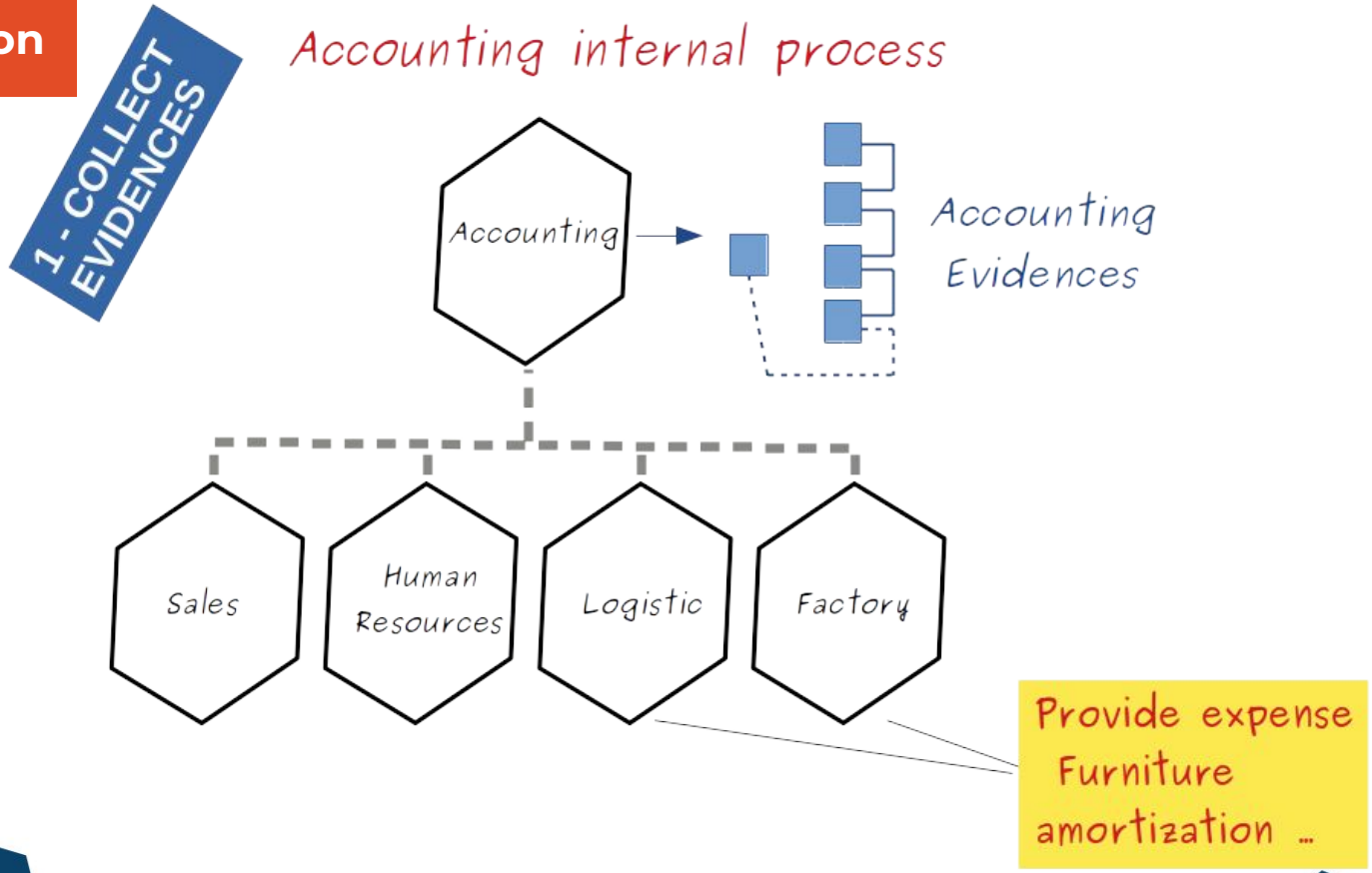
# Example: “Outsourced accounting”

**Distribution**

## How to use accounting Ledger ?

# Example: “Outsourced accounting”

**Distribution**



# Example: “Outsourced accounting”

**Distribution**

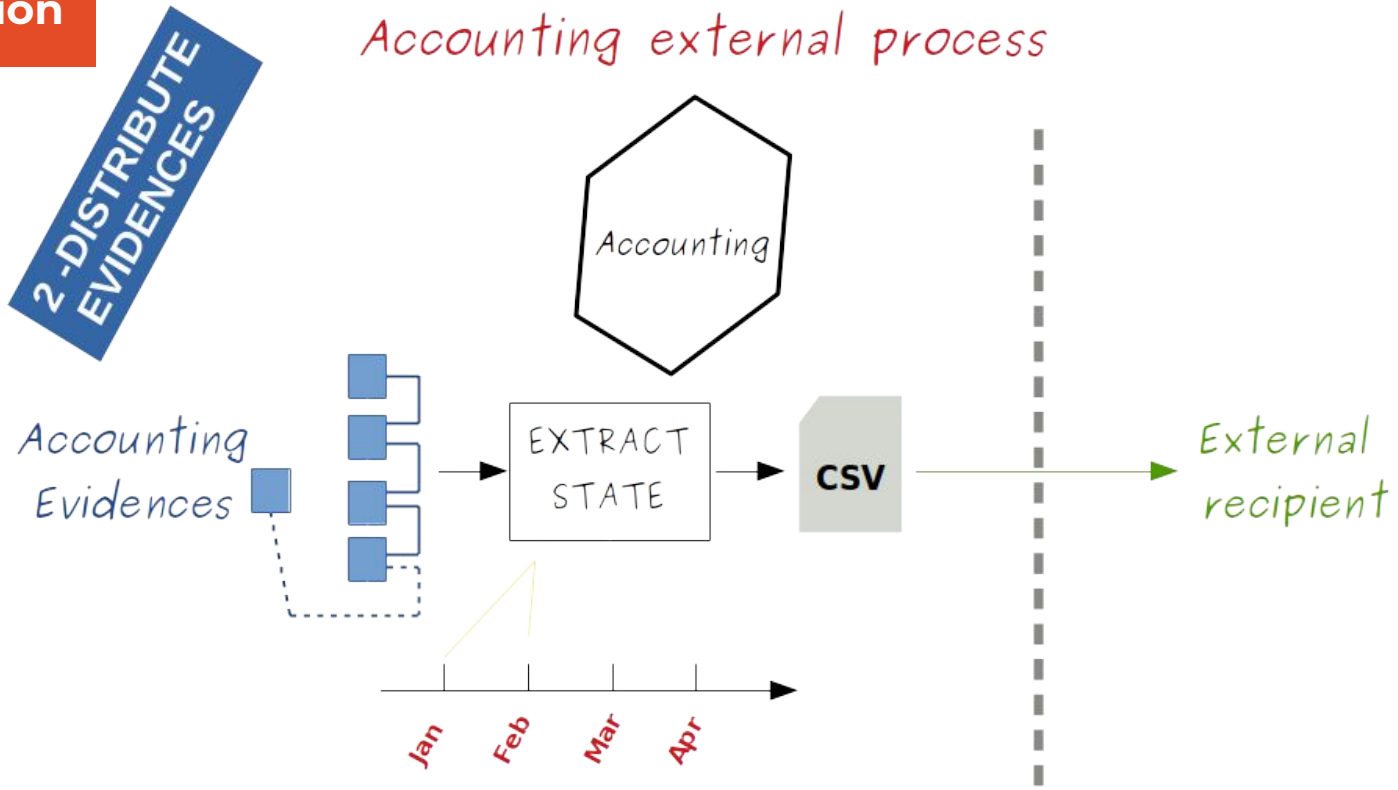
BRAINSTORMING

## Solution ?

# CSV file

# Example: “Outsourced accounting”

**Distribution**



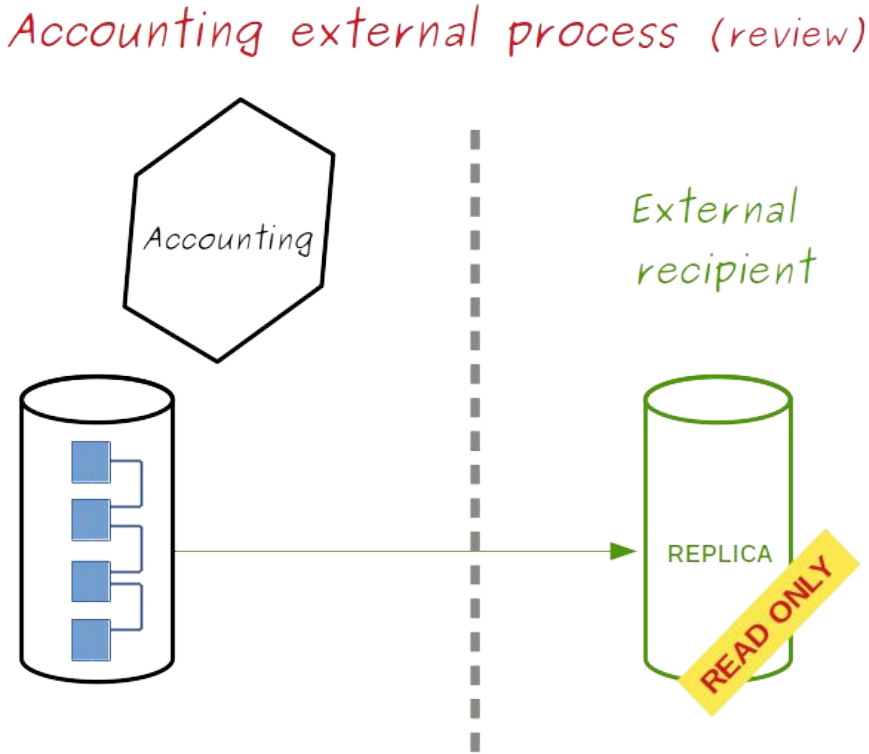
# 2. Distribution

## Introduction

**How can we improve distribution of our Ledger copy ?**

# 2. Distribution

**Replication**



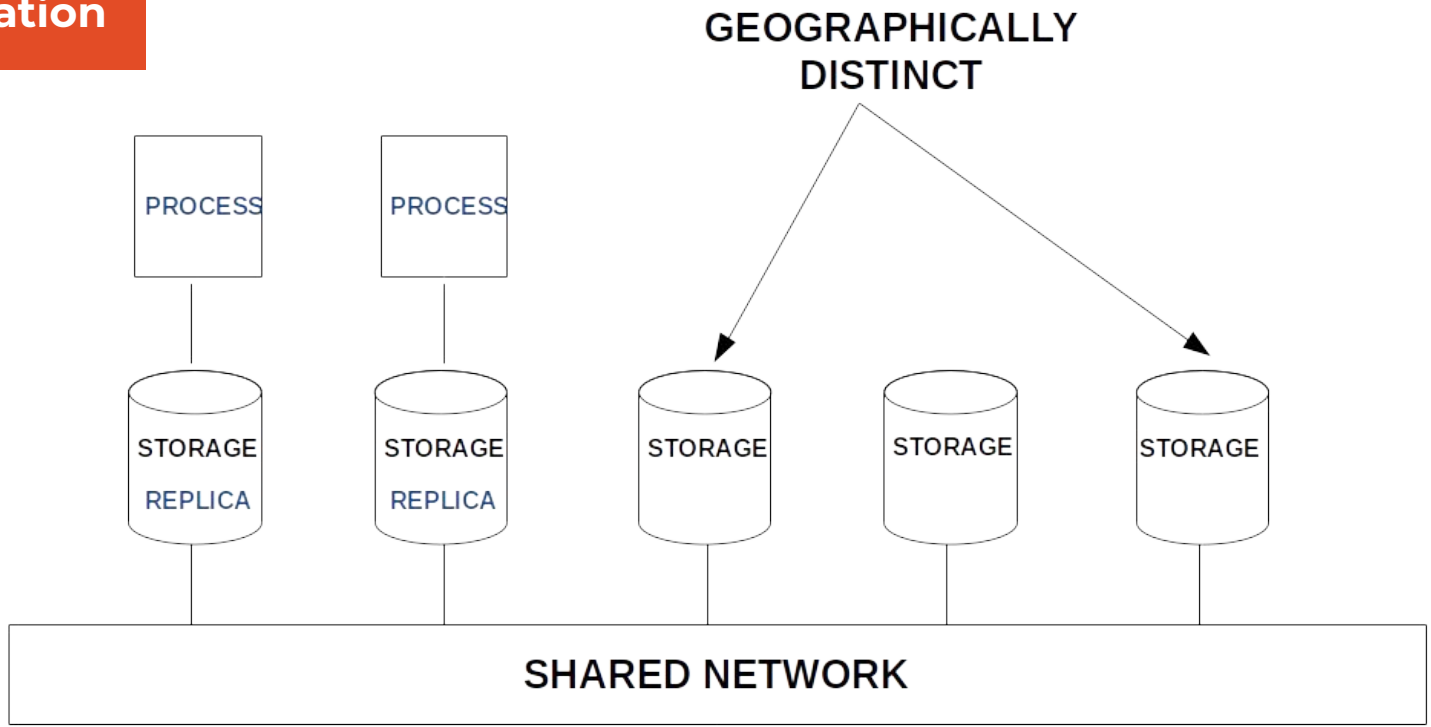
# 2. Distribution

## Replication

- Standard “**Replication**” mechanism
  - First step to implement a distributed system or **distributed service**
  - Systems are geographically distincts
  - Network or channel is shared

# 2. Distribution

## Replication



# 2. Distribution

## Replication

**Why replication is interesting ?**

# 2. Distribution

**Replication**

- “**Transparency**”
  - Hide the fact that **process** and **resource** are physically distributed across multiple computers
- “**Performance**”
  - Solution for **performance degradation issues**
  - Better availability (Load Balancing)

# 2. Distribution

## Replication

How is it working ?

# 2. Distribution

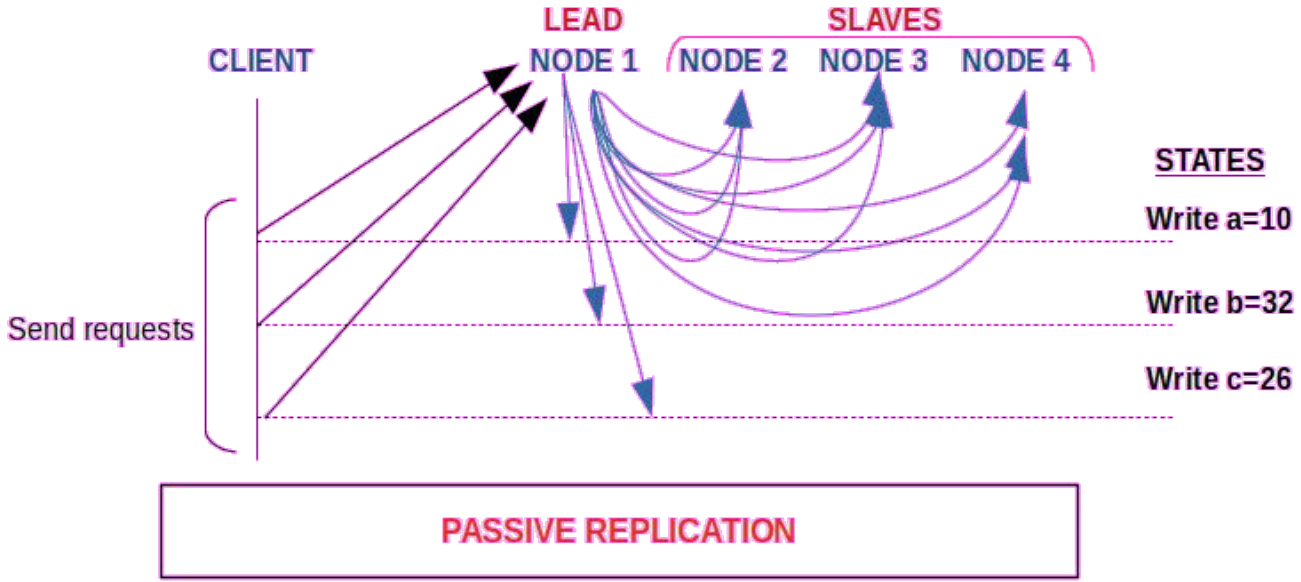
**Replication**

- First mode: “**Passive**” (or primary backup)
  - 1 replica execute all operations issue by a client
  - Periodically replica push states to other replica
  - Other replicas apply update

# 2. Distribution

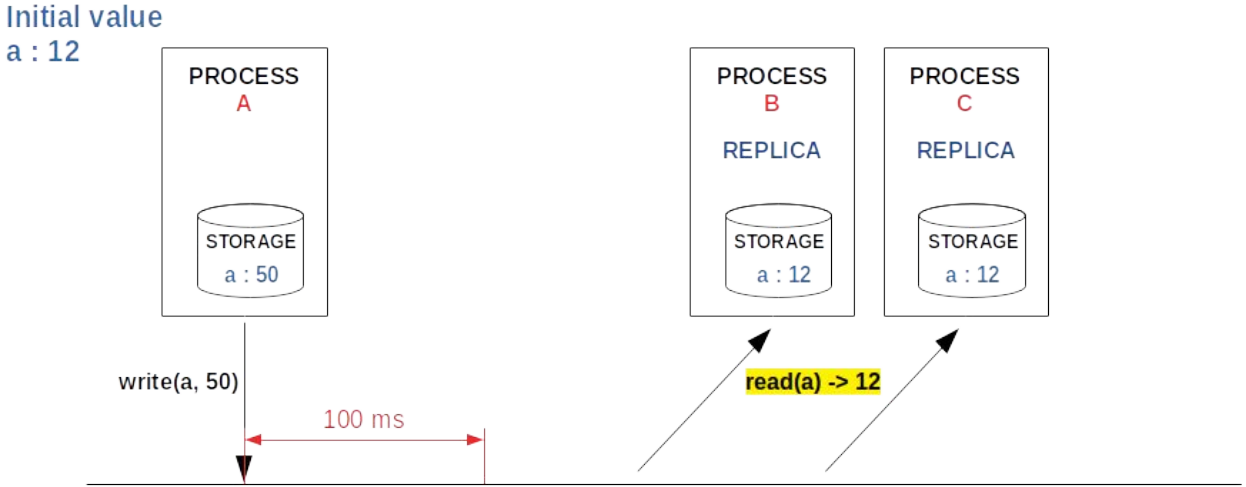
## Replication

- Example



# 2. Distribution

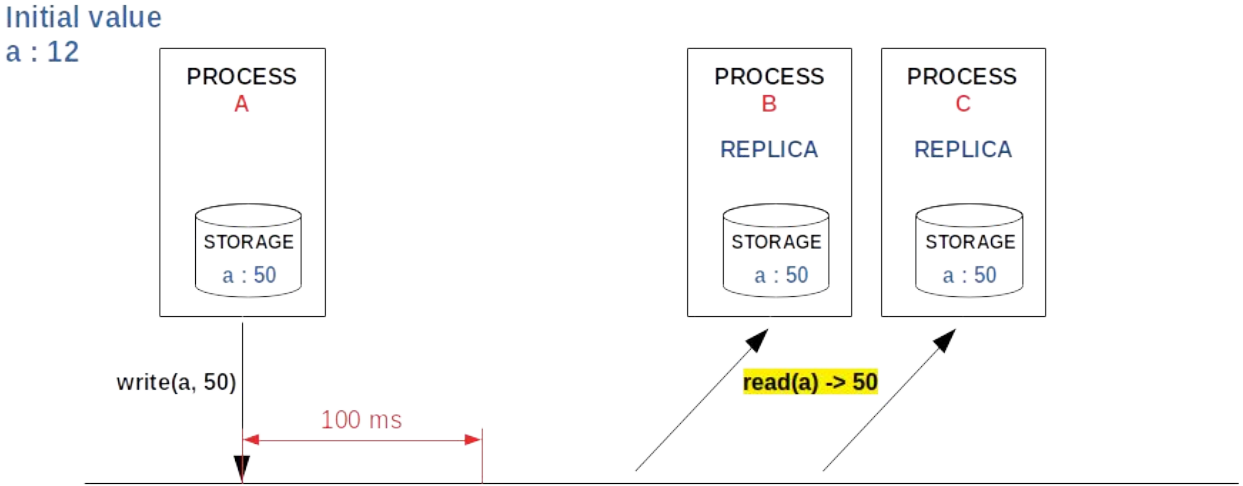
## Replication




**INCONSISTENT REPLICATION**

# 2. Distribution

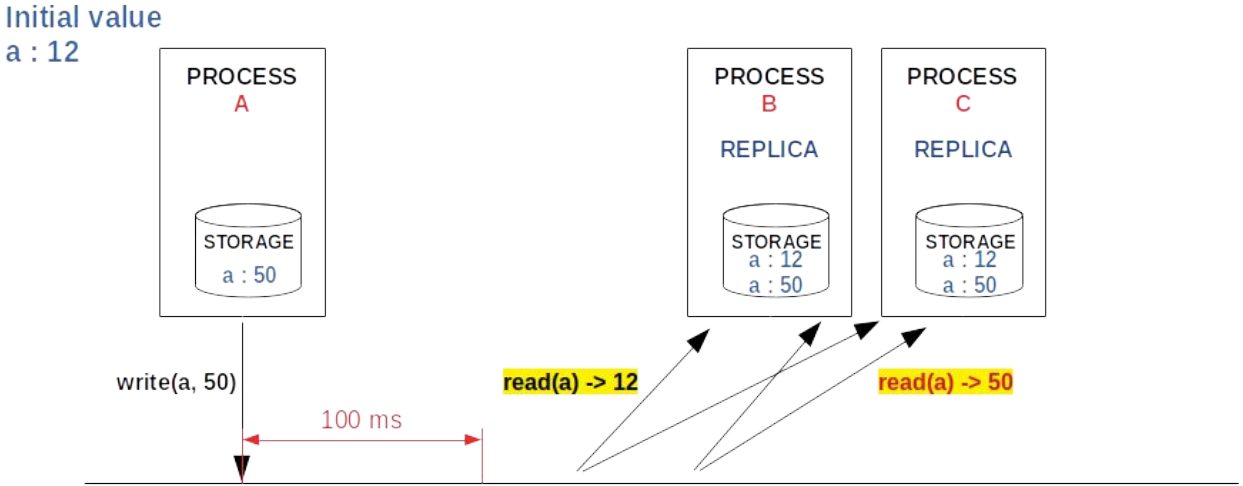
## Replication




**WRONG REPLICATION**

# 2. Distribution

## Replication




**WEAK REPLICATION**

# 2. Distribution

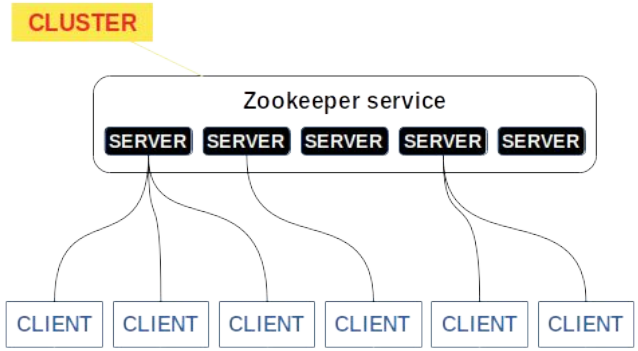
## Replication

**Example of distributed service**

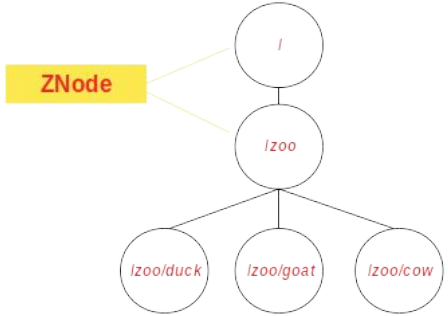
**with “**Zookeeper Apache**”**

# 2. Distribution

## Replication



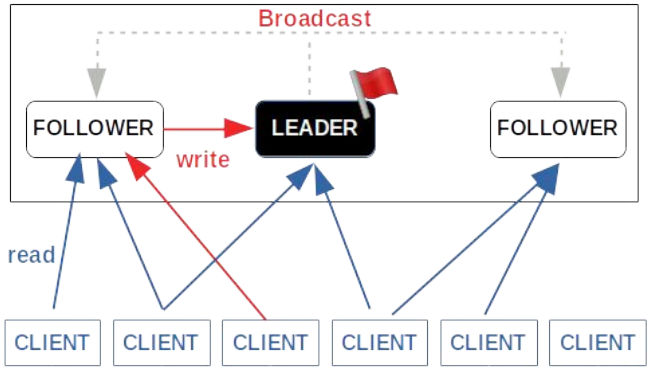

ZK ARCHITECTURE




DATA MODEL

| Operation | Description |
|---|---|
| create | New node in specified path |
| delete | Remove node from a path |
| exists | Check for a path if a node is existing |
| getChildren | Get all children from a node |
| getData | Get data linked to a node |
| setData | Save data into node fields |
| sync | Synchonize client view from Zk |

ZK OPERATIONS




PASSIVE REPLICATION

# 2. Distribution

**Replication "passive"**

- "**Leader election**"
  - Each replica looks for active leader
  - Replica informs new replica that a Leader is existing
  - Each replicat synchronizes his states with Leader
- "**Quorum**" constitutes a majority of replicas
  - Minimum of replicas to store a new state
- "**Atomic broadcast**"

# 2. Distribution

**Replication “passive”**

- “**Consistency**” issues
  - Modifying a copy makes that copy different from the others
- “**Replica**” or follower
  - Look and Inform for existing leader
  - Synchronize his states with Leader orders
  - Participate to Leader election

# 2. Distribution

## Replication Failures

**What are the issues in case of failure ?**

# *Distribution “introduction”: Sum-up*

- 1 Data Master :

  Only one participant writes, and others participants consume data

  Private context

- Replication :

  Communication way

  Transparency

  Consistency, Fault tolerance

# CONTEXT

**Who is the data master ?**

- *I'm the Master of Data*

**What is ledger context ?**

- *Private, and Ledger is distributed by myself*

# 2. Distribution

## Sharing business

# 2. Distribution

**Collaboration**

## Who is data master ?

# 2. Distribution

**Collaboration**

## IDENTITY

| | |
|---|---|
| *Name :* | John Smith |
| *Job :* | Software Engineer |
| *Company :* | Rick Star Game |
| *Employees's Num. :* | < 200 persons |

## CONTEXT

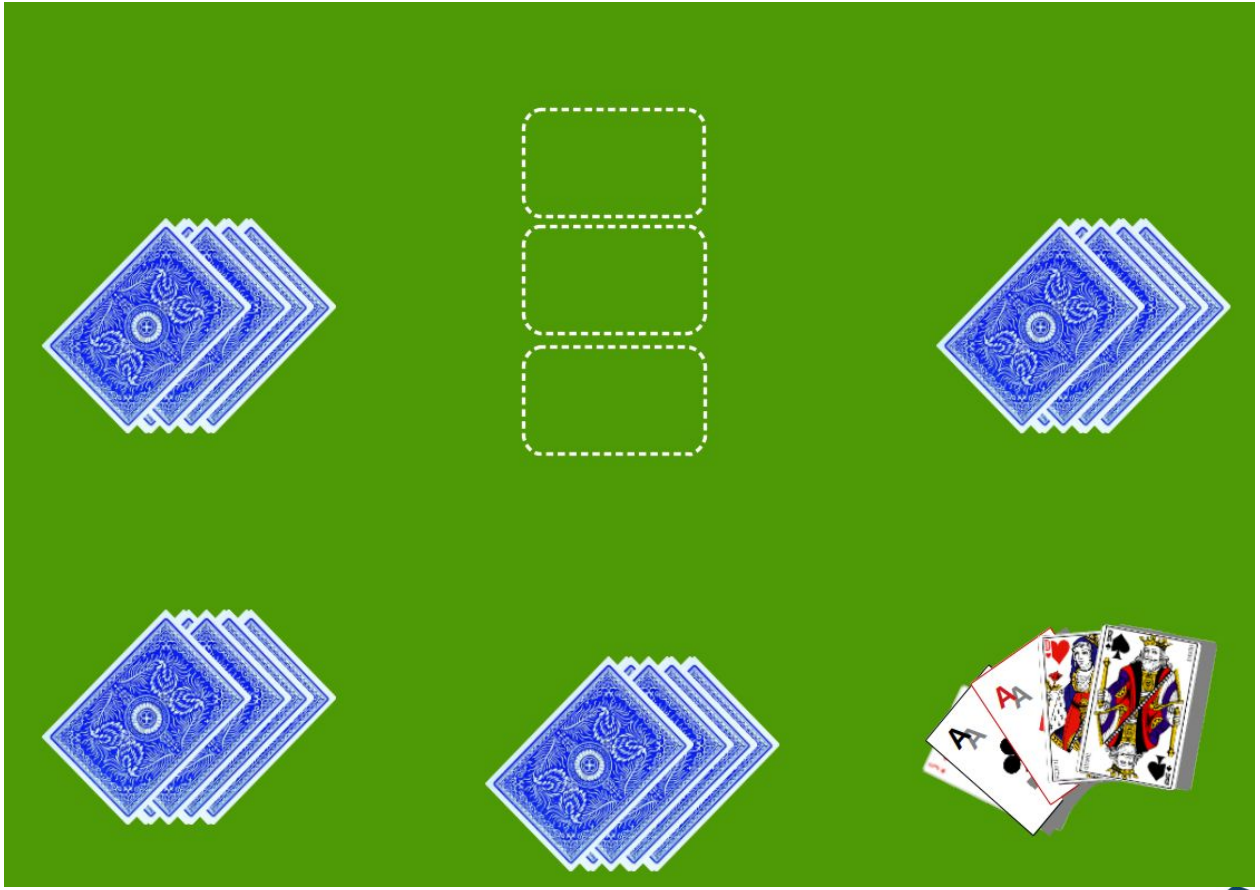
John's company is a game software editor, which decided to develop a poker game online for multi-players.

## NEED

Each player client will be an autonomous ledger, the need is to synchronize the state of each client.

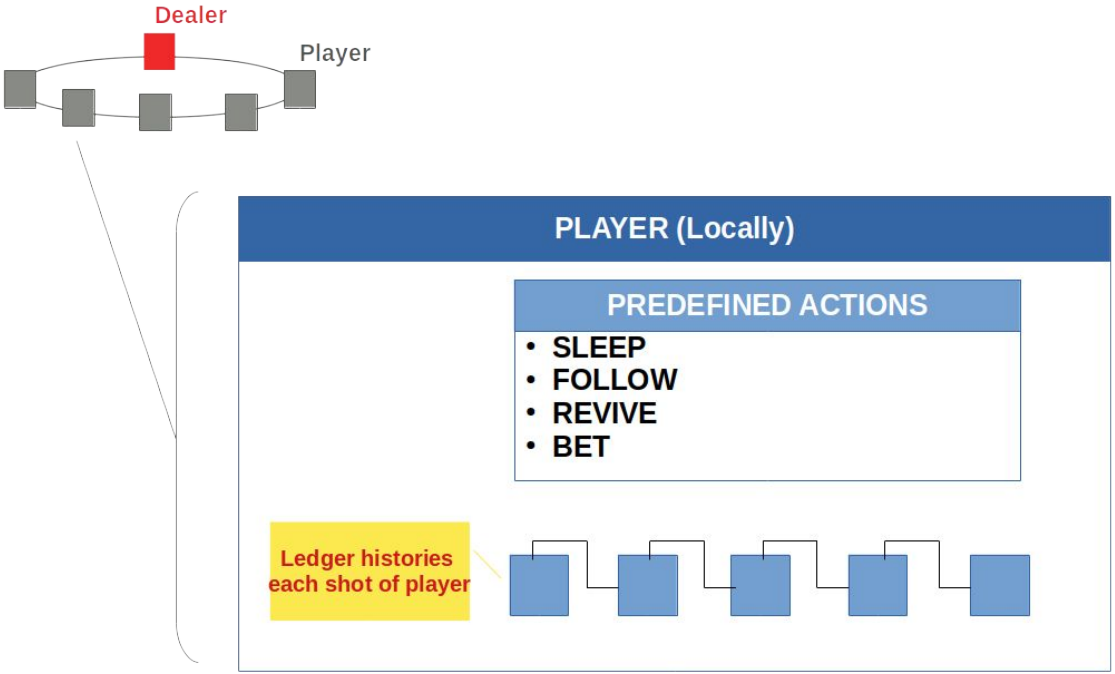
# 2. Distribution

**Collaboration**



# 2. Distribution

## Collaboration



# 2. Distribution

**Collaboration**

# 2. Distribution

**Collaboration**

## How to synchronize each player ledger ?

# 2. Distribution

**Replication “active”**

- Second mode: “**Active**” (or SMR)
- All commands are sent to <u>all replicas</u>
- Replica need to
  - Share same INITIAL STATE
  - Execute deterministic operations
  - Coordination
  - Replica number or Quorum

# 2. Distribution

**CONSENSUS**

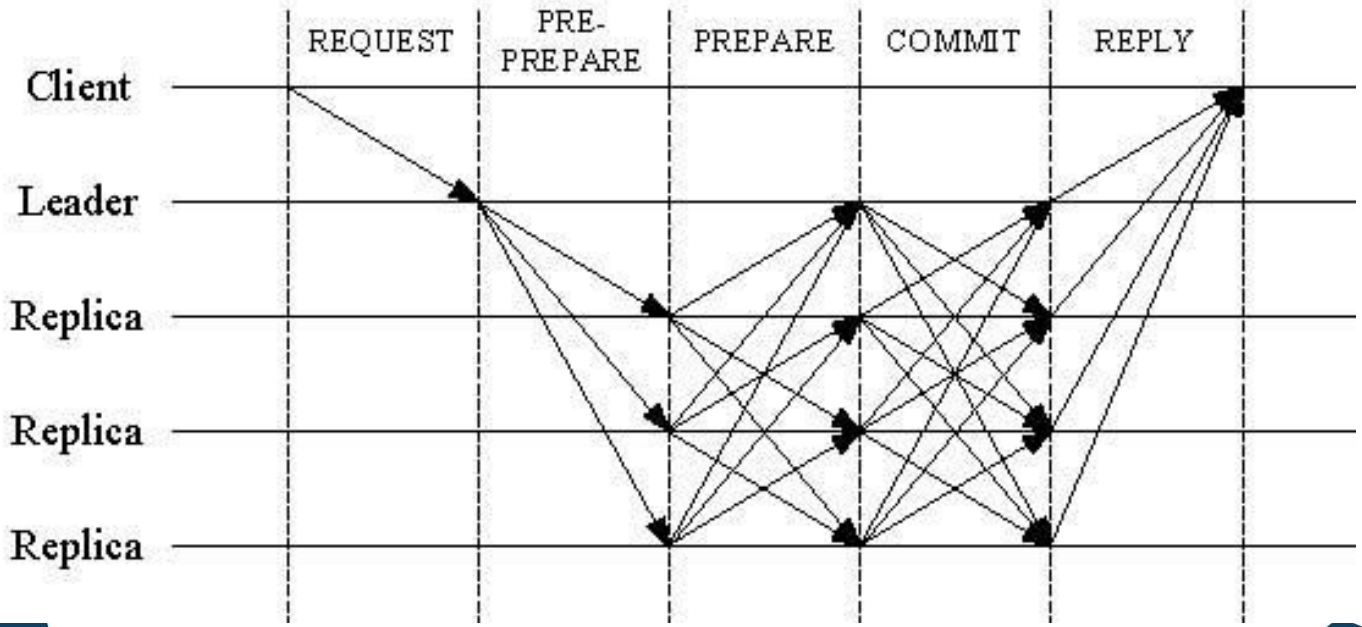
**Example of coordination**: “Practical Byzantine Fault Tolerance”

1. **REQUEST:** A client send a request to the Leader
2. **PRE-PREPARE:** Leader delivers the request to other replica
3. **PREPARE:** Each replica “simulates” with local state the request and broadcast results
4. **COMMIT:** A voting allows to accept the request
5. **REPLY:** The accepted result is replied to client

# 2. Distribution

**CONSENSUS**

**Example of coordination**: “Practical Byzantine Fault Tolerance”



# *Distribution “collaboration”: Sum-up*

- n data master :

  Each participant can read/write

  Private context

- Replication :

  Consensus algorithm is depending of usage context

  Predefined actions (Game Theory)

  ex: PBFT handles failures, request coordination (decentralized algorithm)

# *Distribution “collaboration”: Sum-up*

- “**ORDER-EXECUTE**” architecture style

  ORDER transactions

  BROADCAST (propagate transactions to other peers)

  EXECUTE transaction sequentially and locally

# *Distribution “collaboration”: Sum-up*

- “**ORDER**”

  Based on CONSENSUS (BFT, PoW, Pos)

- “**BROADCAST**”

  Based on ACTIVE replication

- “**EXECUTE**”

  Handled by a SMR (State Machine Replication)

# CONTEXT

**Who is the data master ?**

- *Several Master of Data*

**What is ledger context ?**

- *Private, and Ledger is distributed by a network*

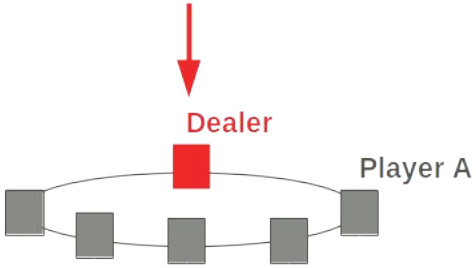
# 2. Distribution

**Oups ...**

**Dealer has paid twice same player !**

# 2. Distribution

**Double spending**




TRANSACTIONS

Dealer → Player A

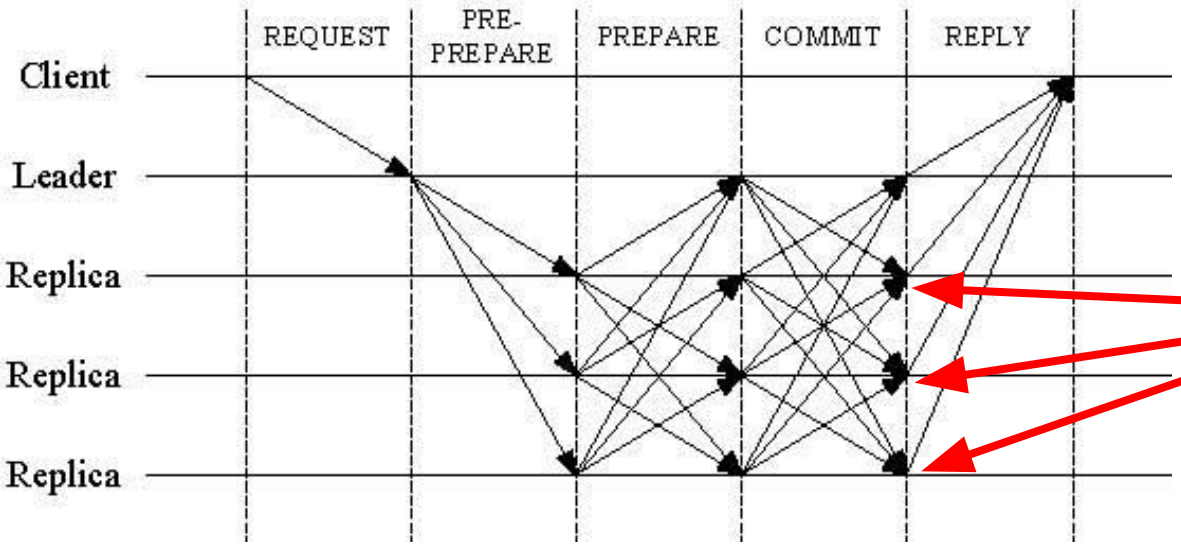
Dealer → Player A

LEDGER

| | | | | |
|---|---|---|---|---|
| 8 | PAY | 20:05 | D>A | 6 |
| 9 | PAY | 20:06 | D>A | 6 |

# 2. Distribution

**Double spending**

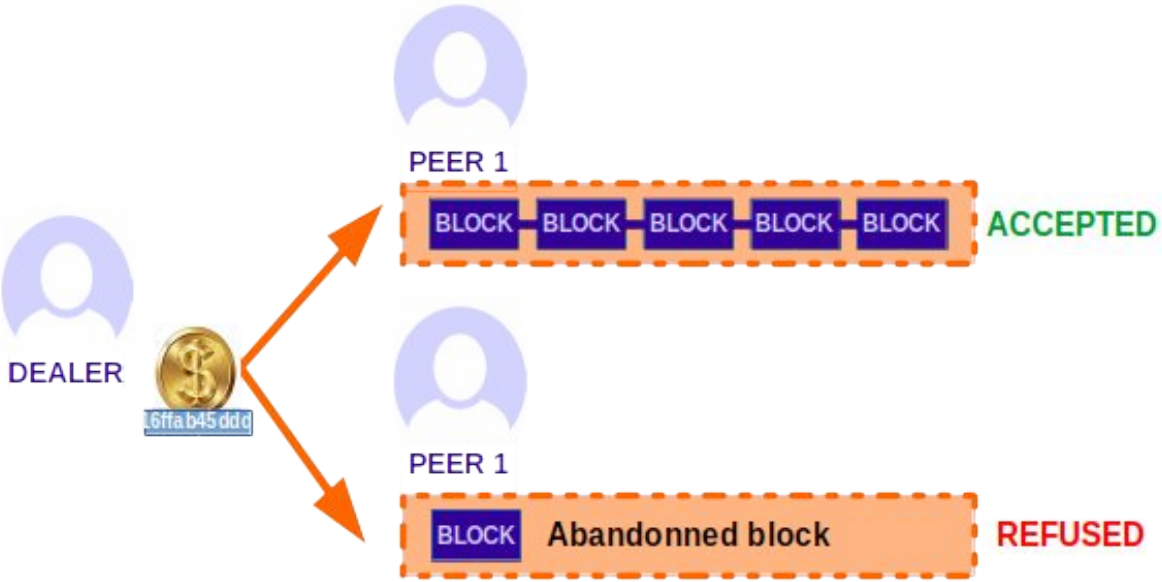



***Wait confirmation from other "replica" !!!***

# 2. Distribution

**Double spending**

Historic of transaction allows to solve the double spending issue



# *Distribution “double spending”: Sum-up*

- Voting:

  Replica inserts transaction in its local ledger based on “n” replica confirmations

- Data Safe:

  Oldest accepted blocks are safe

# CONTEXT

**Who is the data master ?**

- *Several Master of Data*

**What is ledger context ?**

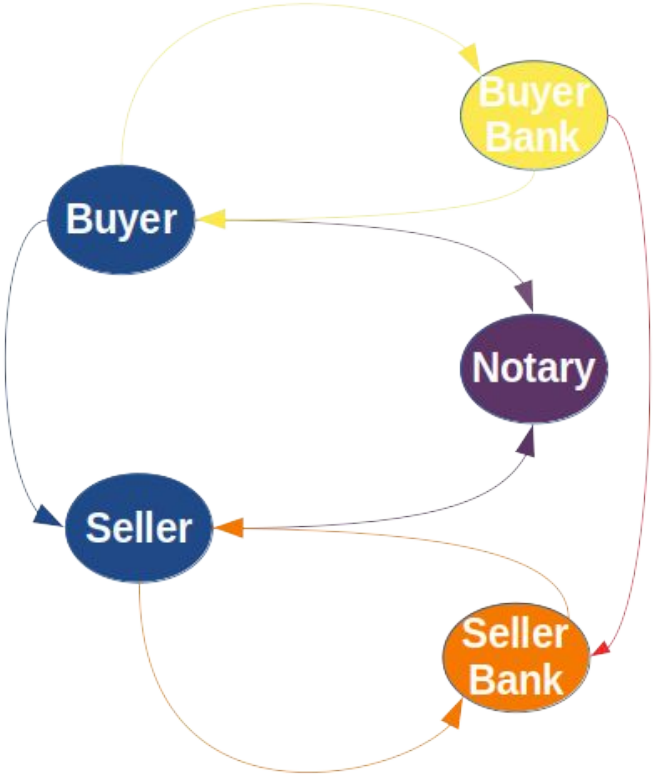
- *Private, and Ledger is distributed by a network*

# 2. Distribution

a distributed state machine ...

# 2. Distribution

**States Transition**



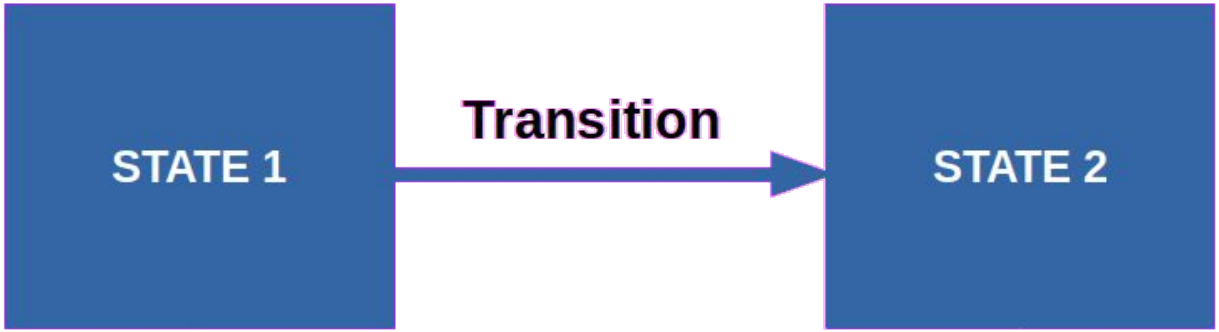
# 2. Distribution

**States Transition**

## What’s a state machine ?

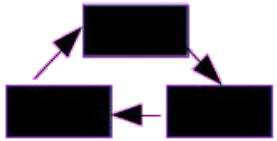
# 2. Distribution

**States Transition**

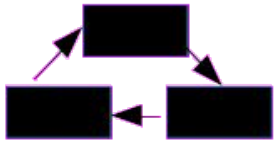


# 2. Distribution

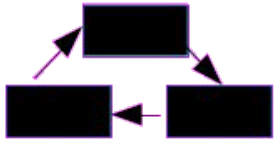
**States Transition**



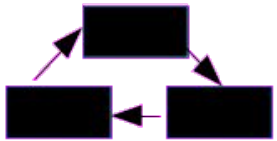
Buyer - Seller



Buyer – Buyer’s Bank



Buyer – Seller – Notary



Seller’s Bank – Seller

# 2. Distribution

**States Transition**

## Ledger, is it a state machine ?

# 2. Distribution

**States Transition**

- Blockchain is a State Machine
- **STATES** are based on **transactions history**
- Some DLT offers extension to change state machine : **SMART CONTRACT**

# *Distribution “States-Transitions”: Sum-up*

- States:

  Deduced based on all ledger transactions

- Transitions:

  Blockchain State machine

  Behavior can be customized = SMART CONTRACT

# CONTEXT

**Who is the data master ?**

- *Several Master of Data*

**What is ledger context ?**

- *Private, and Ledger is distributed by a network*

# 2. Distribution

**I’m not the owner of this transaction !!!**

# 2. Distribution

**Identification**

## How to manage non-repudiation ?

# 2. Distribution

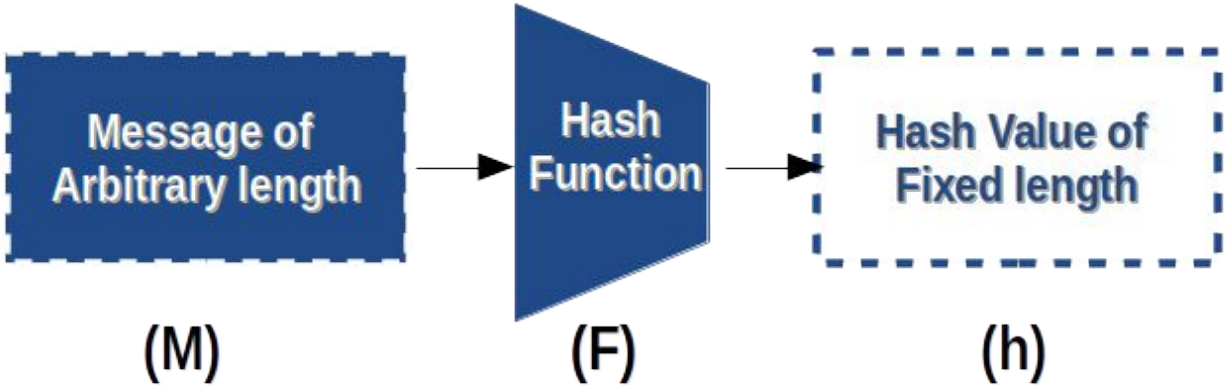
## Transaction

- **FLOW** between several participants
- Transaction is **DIGITALLY SIGNED** by the sender
- Transaction « transports » **DATA**

# 2. Distribution

CRYPTOGRAPHY

*HASHING*



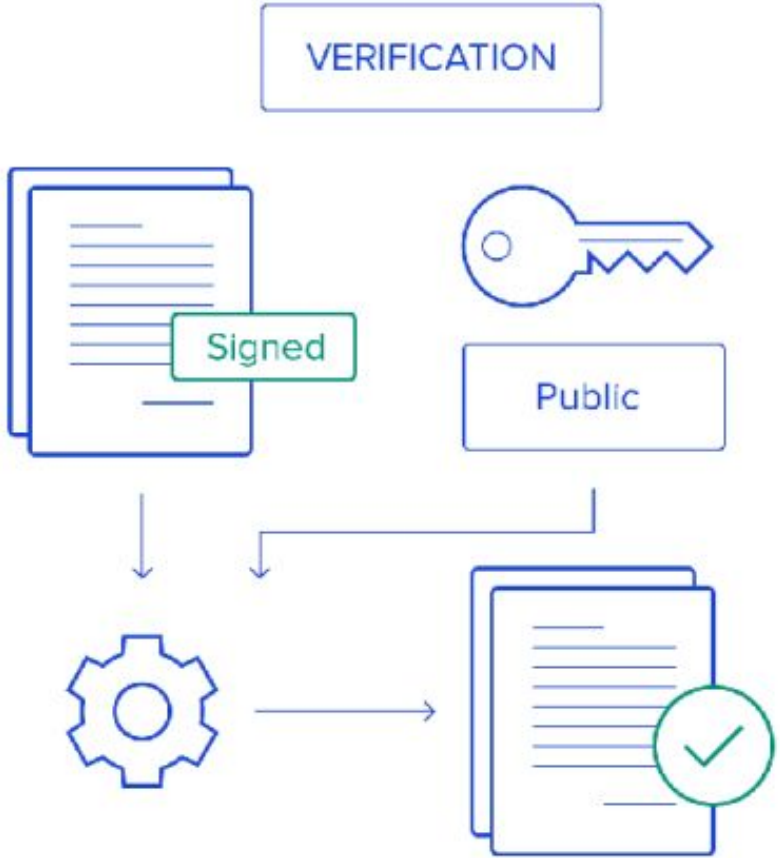
# 2. Distribution

**CRYPTOGRAPHY**


***NON REPUDIATION***
***&***
***AUTHENTIFICATION***

# 2. Distribution

**CRYPTOGRAPHY**




***CHECK SIGNATURE***

# *Distribution “identification”: Sum-up*

- Identification:
  - 1 Certificat per participant
  - Transaction with a Digital signature
- Non Repudiation:
  - Transaction can’t be revoked by a owner

# CONTEXT

**Who is the data master ?**

- *Several Master of Data*

**What is ledger context ?**

- *Private, and Ledger is distributed by a network*

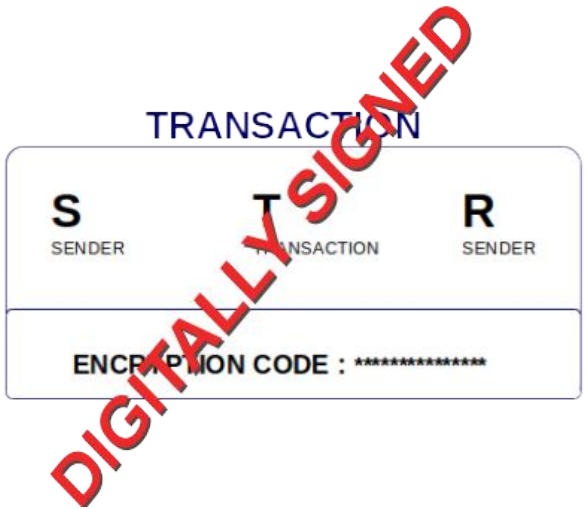
# 2. Distribution

## Ledger security

# 2. Distribution

**SECURITY**

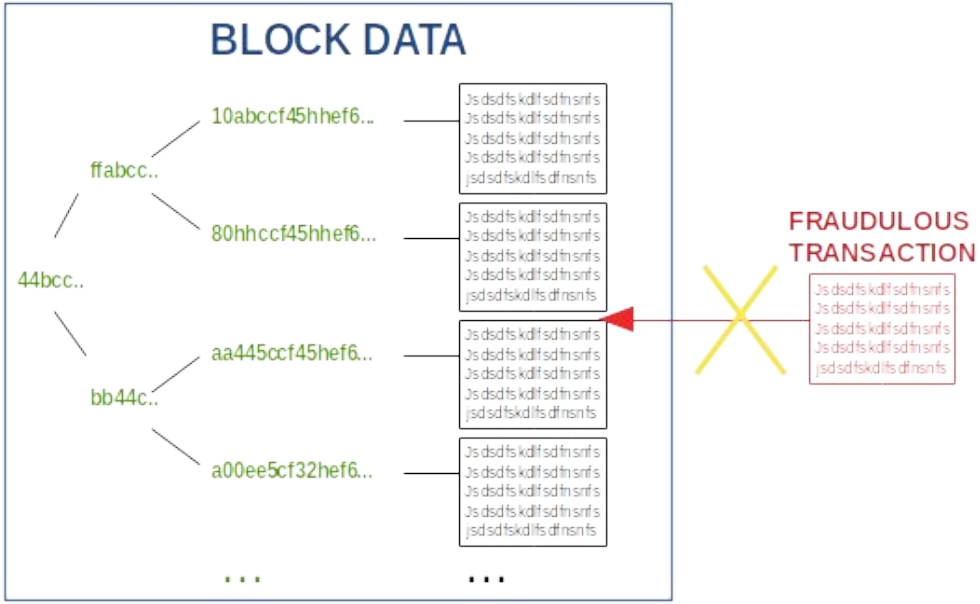
- Against **FORGERY**
- **NON REPUDIATION** of a transaction



# 2. Distribution

**SECURITY**

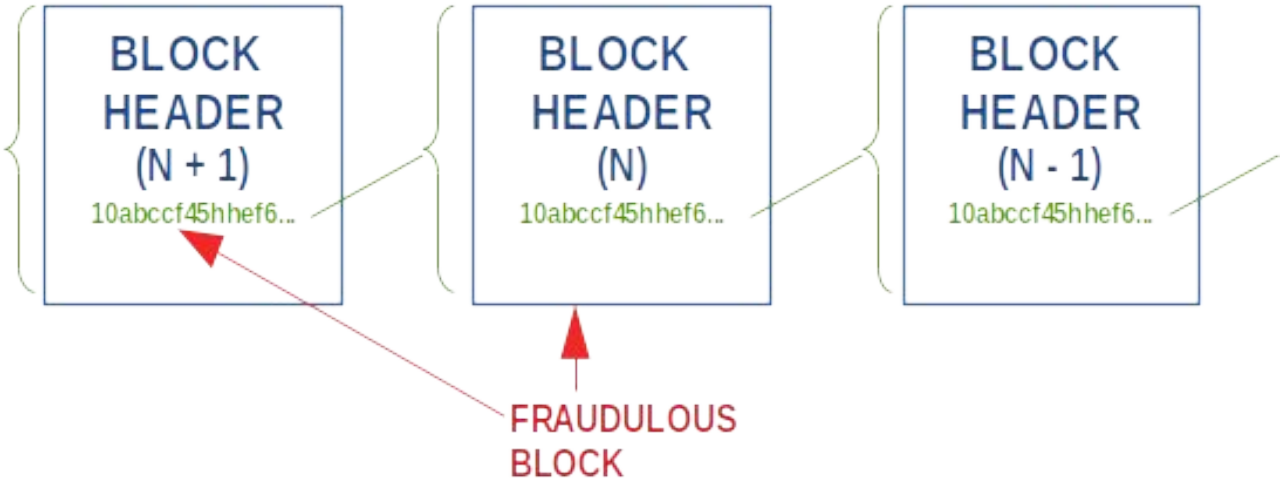
- Can’t insert **FRAUDULENT TRANSACTIONS**
- At **Block level**



# 2. Distribution

**SECURITY**

- At **Ledger level**
  → **The other block pointers must be recomputed**

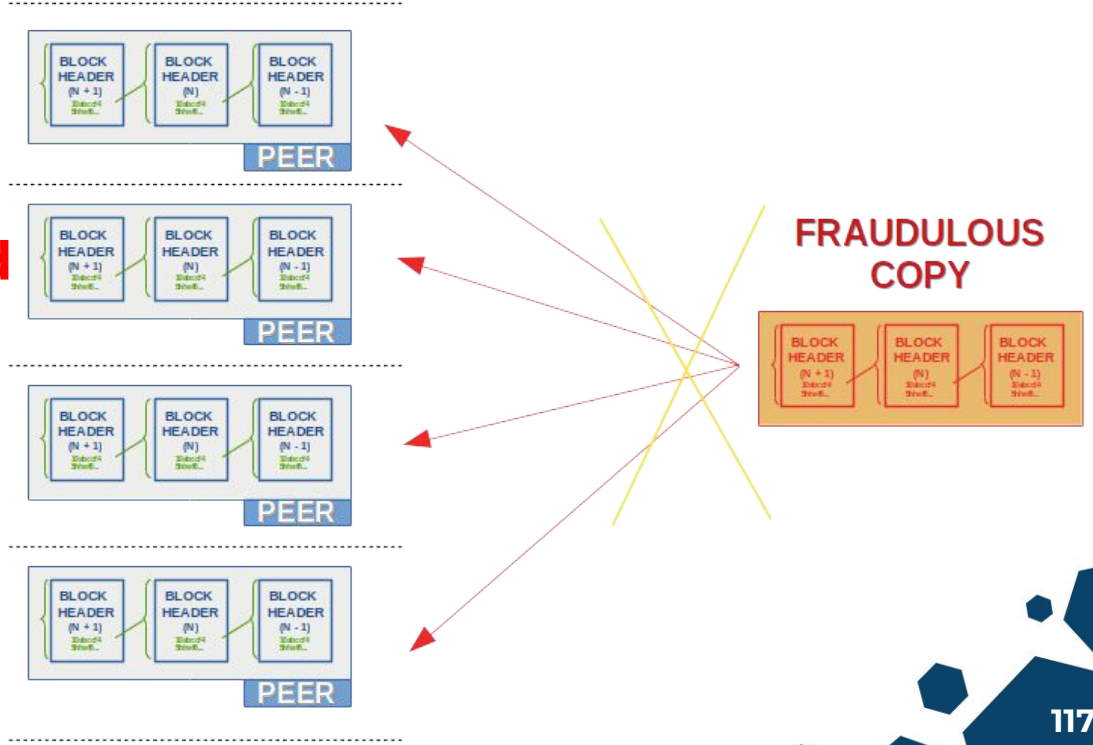


# 2. Distribution

**SECURITY**

At **Distributed Ledger level**

→ **The other peer ledger copies must be recomputed**



# *Distribution “security”: Sum-up*

- Different levels:
  - Transaction
  - Block
  - Ledger

# CONTEXT

**Who is the data master ?**

- *Several Master of Data*

**What is ledger context ?**

- *Private, and Ledger is distributed by a network*

# OPEN DISTRIBUTION

- Synchronisation (Review)
- Self-regulating system

# 3. Open distribution

**Synchronization** [review]

# 3. Open distribution

## Consensus

- *Example :* Proof of work (PoW)
- Consensus objectives

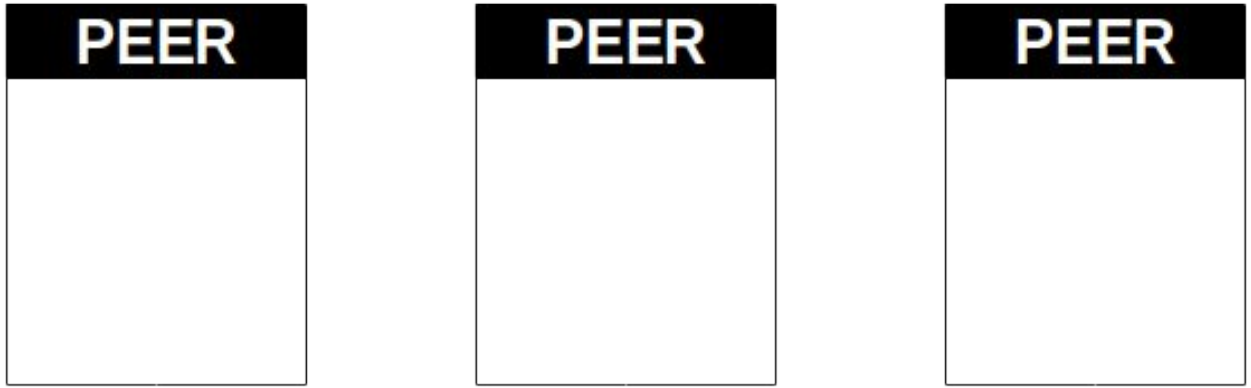
  Coordinate block diffusion (new state)

  Participant can **commit** or **ignore** block

  Temporize the block creation

# 3. Open distribution

**Consensus**




| | | | |
|---|---|---|---|
| Number of participants | {1} | {1, n} | {n-1} |
| Role | PROPOSE NEW BLOCK | MINER | COMMIT BLOCK |

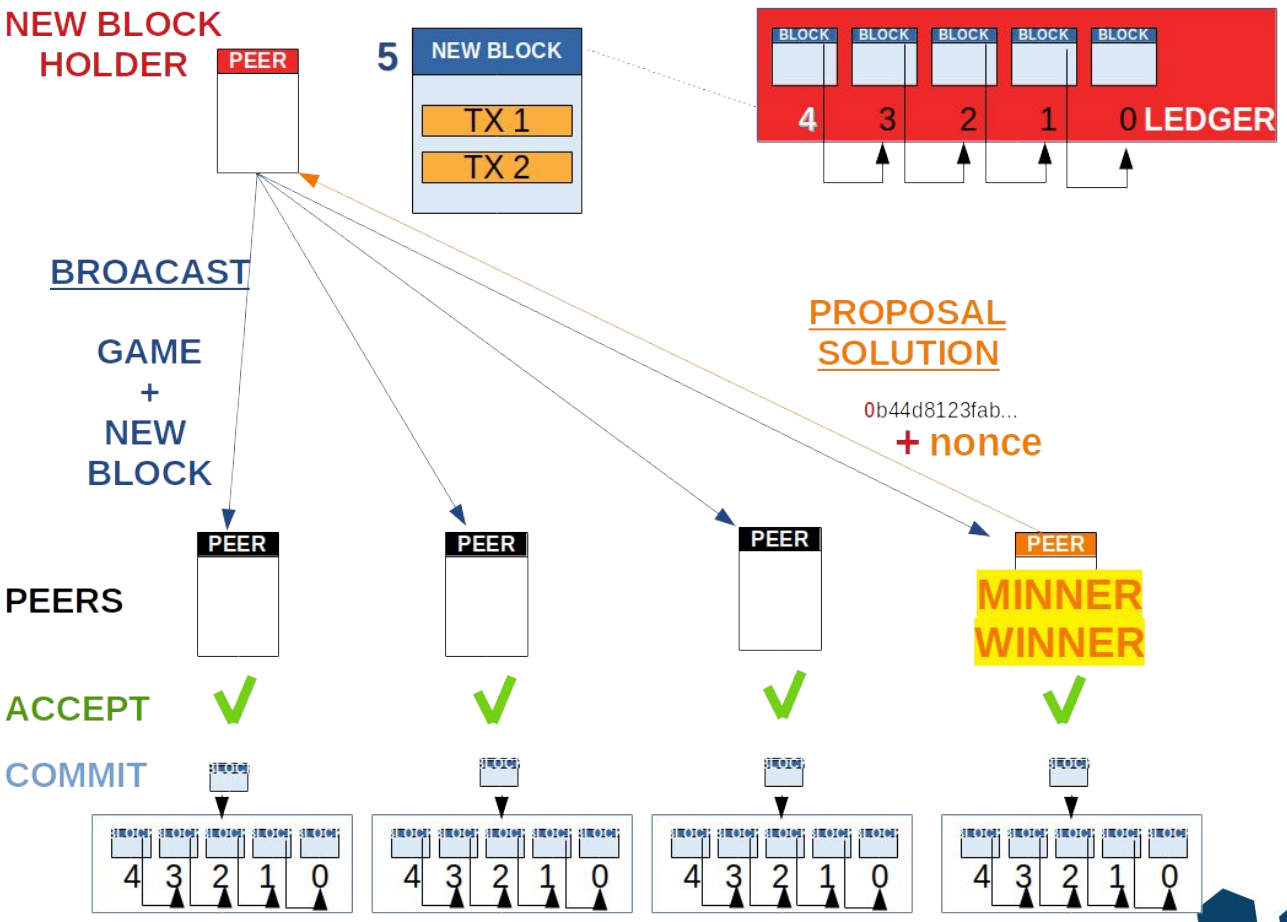
# 3. Open distribution

## Consensus

- PEER roles
  - Propose new blocks
  - Mine blocks
  - Commit blocks

# Consensus

**PoW**



# *Open “consensus”: Sum-up*

- PEER proposes new blocks
  - Link block to last ledger block hash
  - Hash blocks (difficulty)
  - Broadcast blocks and hash
- PEERs mine blocks
  - Solves the hash to find the nonce
  - Diffuse the matching solution
- PEERs accepts blocks
  - Verify solutions and blocks
  - Commits the block to local ledger

# CONTEXT

**Who is the data master ?**

- *Several Master of Data*

**What is ledger context ?**

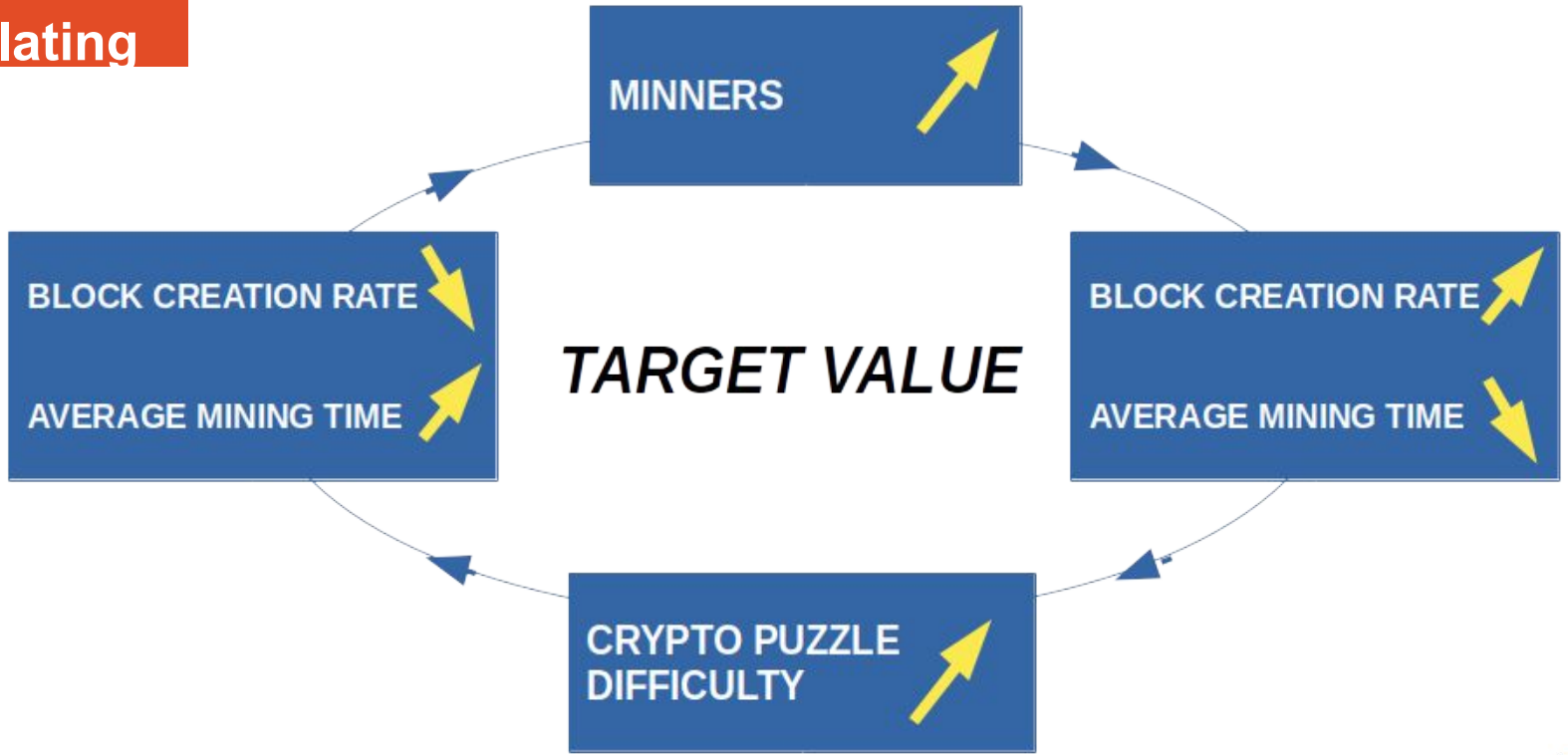
- *Public, and Ledger is distributed by a network*

# 3. Open distribution

## Self regulating system

# 3. Open distribution

**Self regulating**



# CONTEXT

**Who is the data master ?**

- *Several Master of Data*

**What is ledger context ?**

- *Public, and Ledger is distributed by a network*

# 3. Open distribution

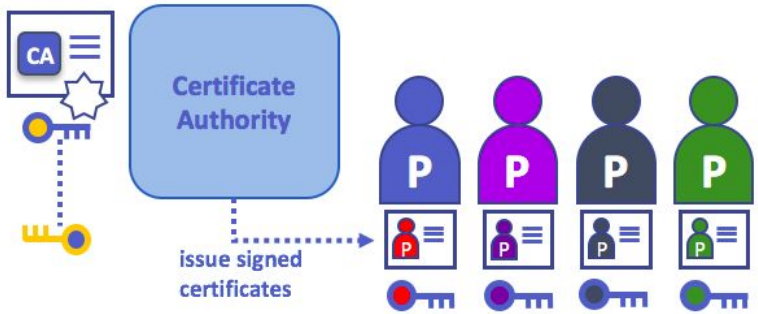
**Identification** [review]

# 3. Open distribution

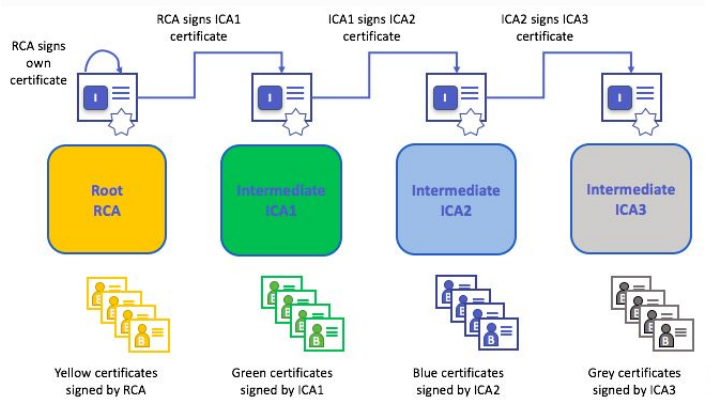
**Identification**

## IDENTITY

CA (certificate authorities)




Chain of trusts



# DLT SOLUTION REVIEWS

# “Solution reviews”

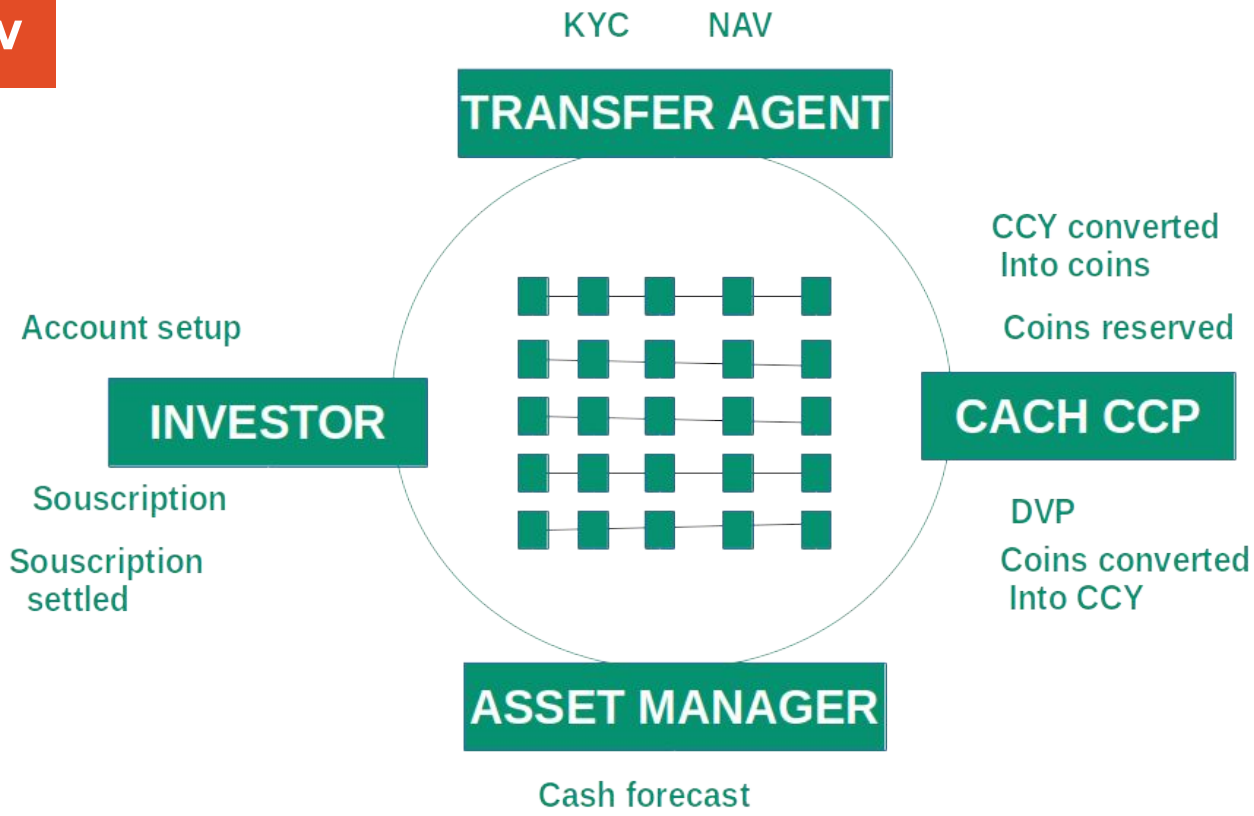
| | | |
|---|---|---|
| STATE MACHINE | SMART CONTRACT | |
| DATA ORGANISATION | TRANSACTION | |
| | BLOCK | |
| | LEDGER | |
| DISTRIBUTION | PASSIVE | |
| | ACTIVE | ACTIVE |
| | SIMPLE CONSENSUS | COMPLEX CONSENSUS |
| CONTEXT | PRIVATE | PUBLIC |
| SECURITY | CERTIFICATE – PRIVATE KEY | |

# USE CASES

- Fund management

# Fund Management “FundsDLT”

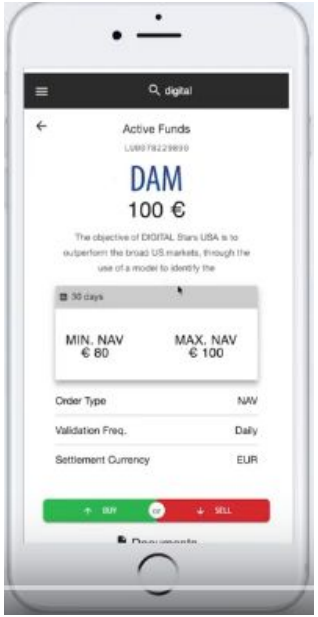
## Overview

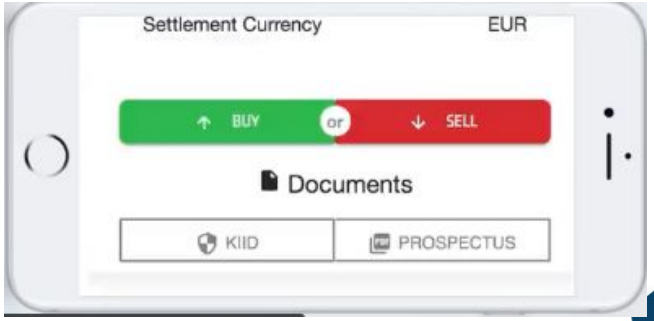


# Fund Management “FundsDLT”

## Overview

- Investor
  - Account setup
  - Souscription

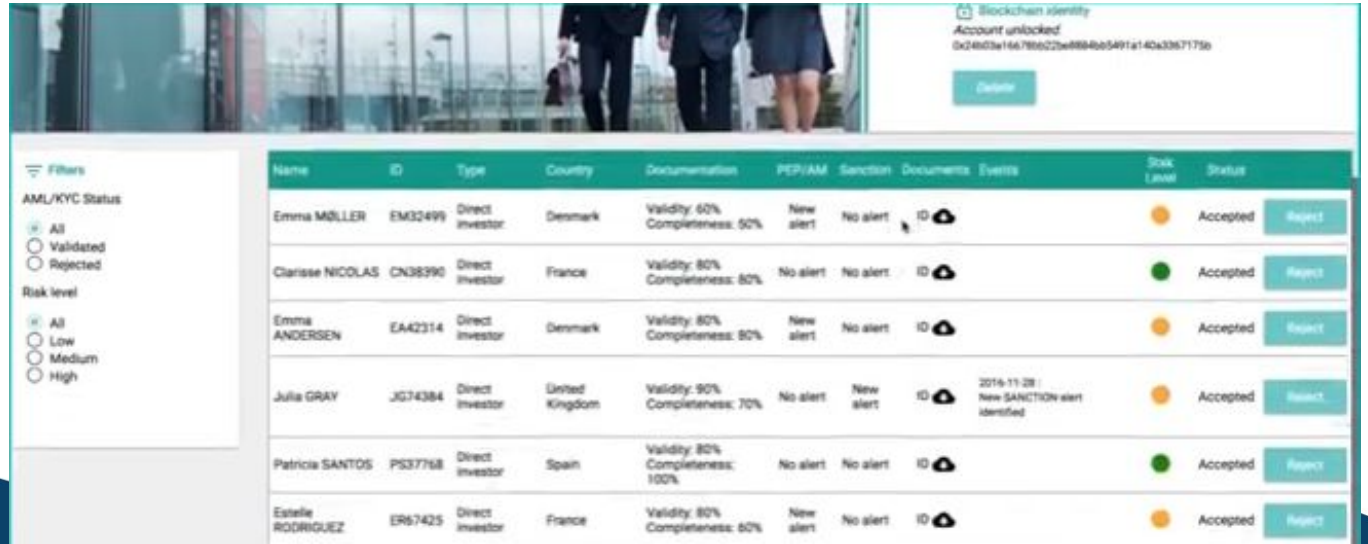


# Fund Management “FundsDLT”

## Overview

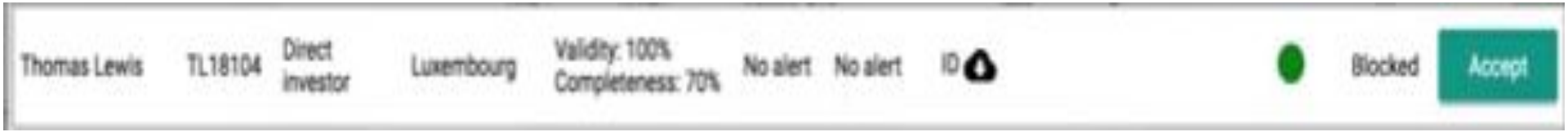
- Transfer agent
  - KYC
  - Nav



# Fund Management “FundsDLT”

## Overview

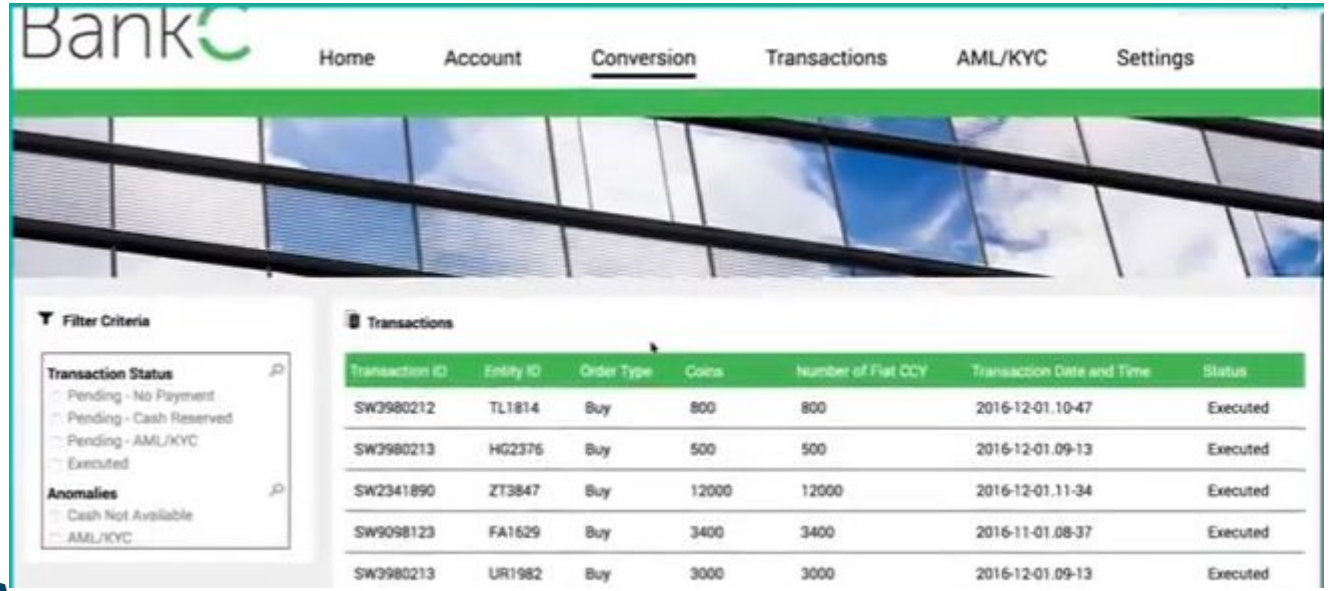
- Transfer agent



# Fund Management “FundsDLT”

## Overview

- CASH CCP



# Fund Management “FundsDLT”

## Overview

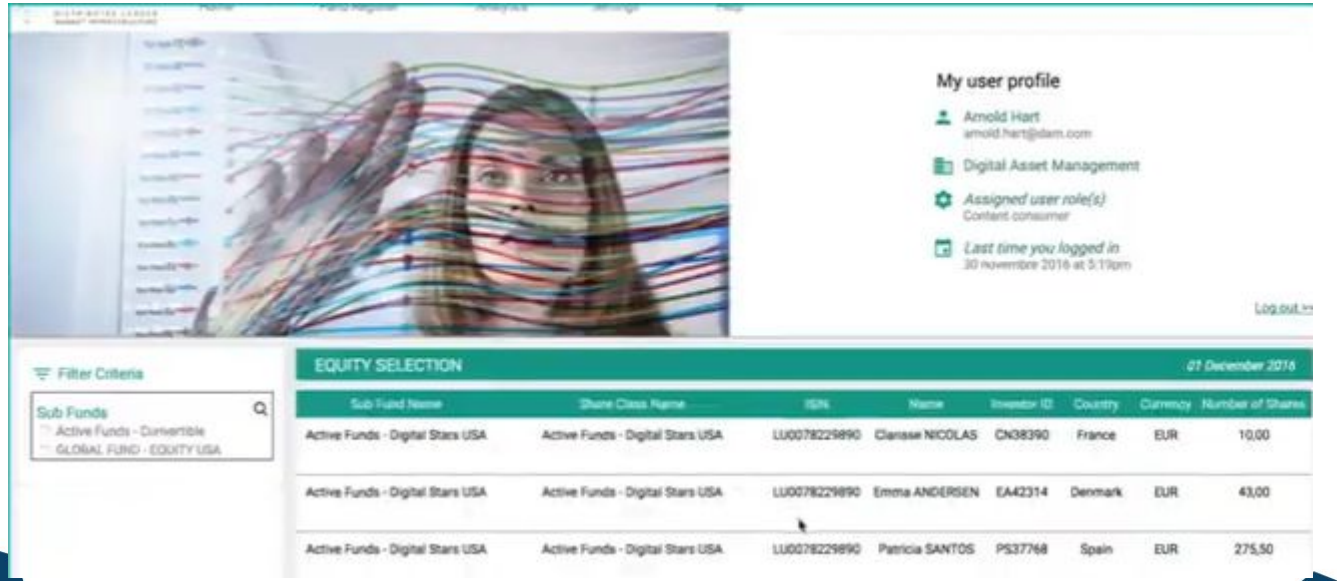
- CASH CCP
  - Reserved Cash (-> Transfert Agent is alerted)
  - Coin conversion

| Transaction ID | Entity ID | Order Type | Coins | Number of Fiat CCY | Transaction Date and Time | Status |
|---|---|---|---|---|---|---|
| SW3980212 | TL1814 | Buy | 800 | 800 | 2016-12-01.10-47 | Executed |

# Fund Management “FundsDLT”

## Overview

- Asset Manager



# Questions ?