# IOTA FOUNDATION

## A ledger for the Internet of Things

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# Who am I?

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# The IOTA Foundation

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Hubs in Berlin, Tel Aviv,
Oslo, Taipei

More than **90 employees**
around the globe

Donations of
**$100M+** to date

> 70k active
community members
> 120k content followers

Ecosystem Development Fund
$13M+ in funding
over $150k awarded to date

**Ecosystem** of more
than **100 entities**

# Key Milestones (Update)

**2013-2015**
*Design principles*

**2015**
*First lines of code*

**2016**
*First PoC with industry (Innogy - Germany's Utility)*

**2017**
*Testnet, MAM, Flash*

**May ´17**
*Listing of the IOTA Token*

**Nov ´17**
*Registration as not for profit*

**Nov ´17**
*Launch of the Data marketplace*

**Dec ´17**
*Bosch VC investment*

**Jan ´18**
*VW CDO supervisory board*

**March ´18**
*Fujitsu supervisory board*

**April ´18**
*Full onboarding of 40+ staff*

**Q2 ´18**

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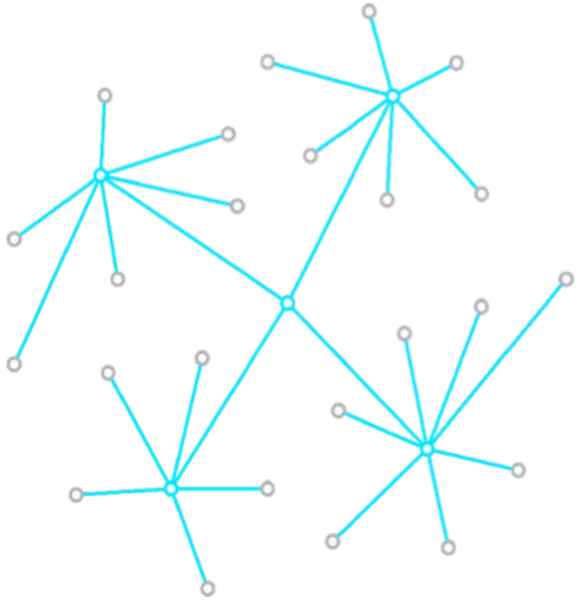
# What DLTs are?

# Network Decentralization

## Centralized

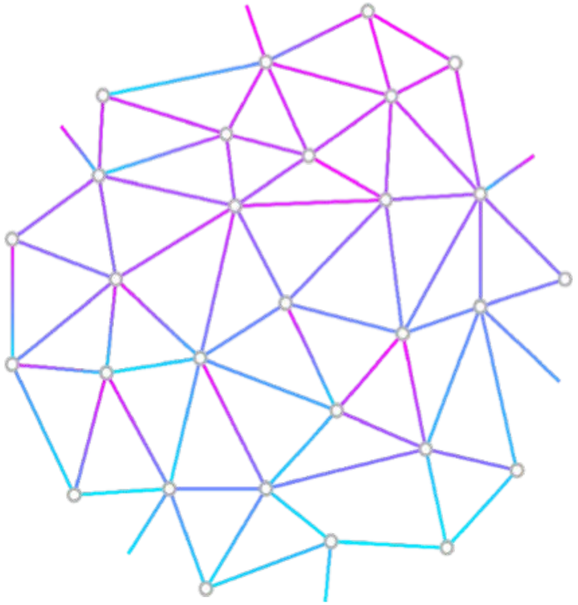
- Single Point of Access to “Truth”
- Single Source of “Truth”
- Single Point of Failure

## Distributed



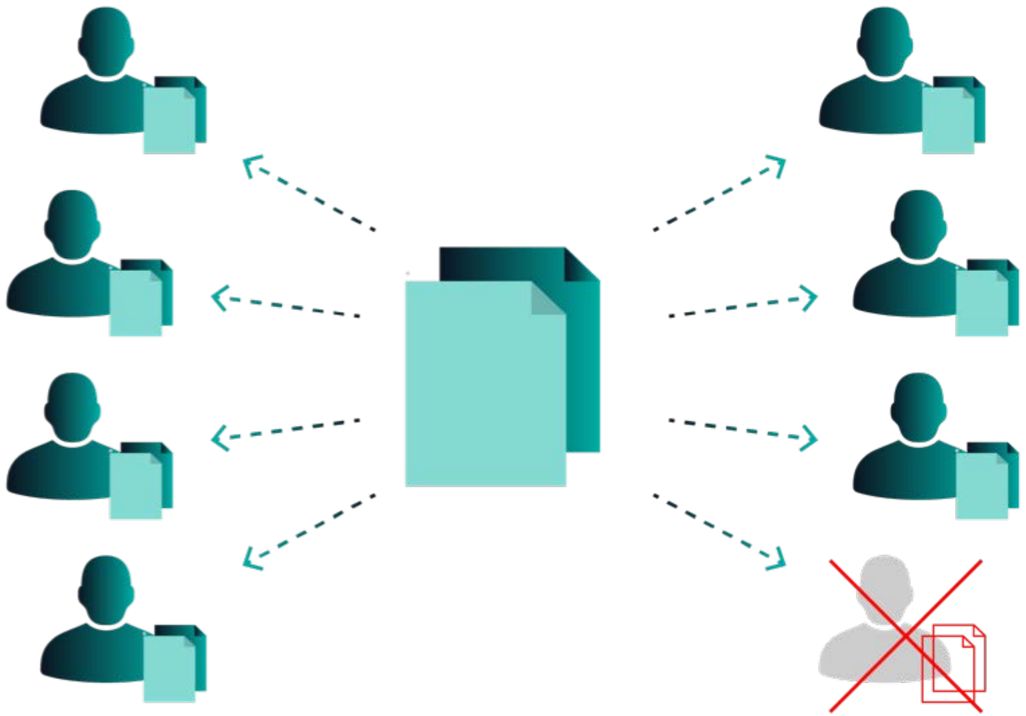
- Multiple Points of Access to “Truth”
- Single Source of “Truth”
- Single Point of Failure

## Decentralized



- Multiple Points of Access to “Truth”
- Democratized Source of “Truth”
- No Single Point of Failure

# Core Innovation



Data is **replicated** in a distributed network. Through **consensus**, the network comes to an agreement which data to store.

Through this, Blockchain's are a:

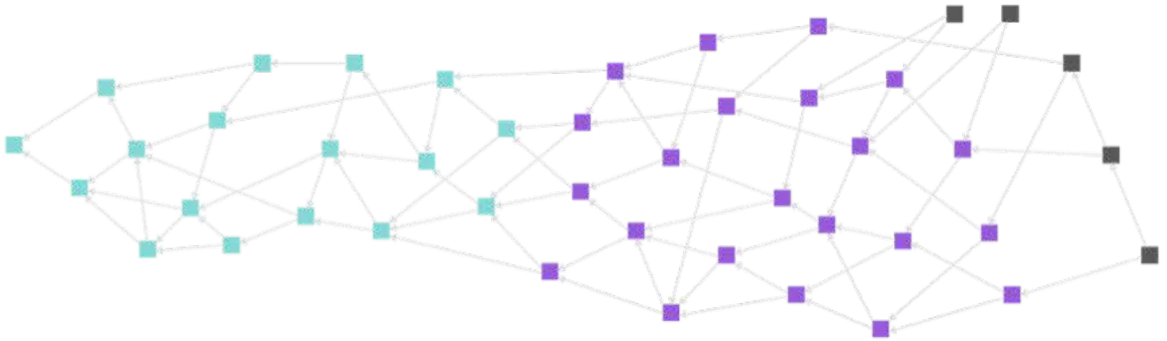
- Single Source of Truth
- Immutable and verifiable record of data

# Trustless solution to Double Spends

Ledgers without a trusted authority where you have consensus on user accounts and double spend resolution

# Distributed Ledger Technologies

Blockchain



Tangle
(DAG - Directed Acyclic Graph)

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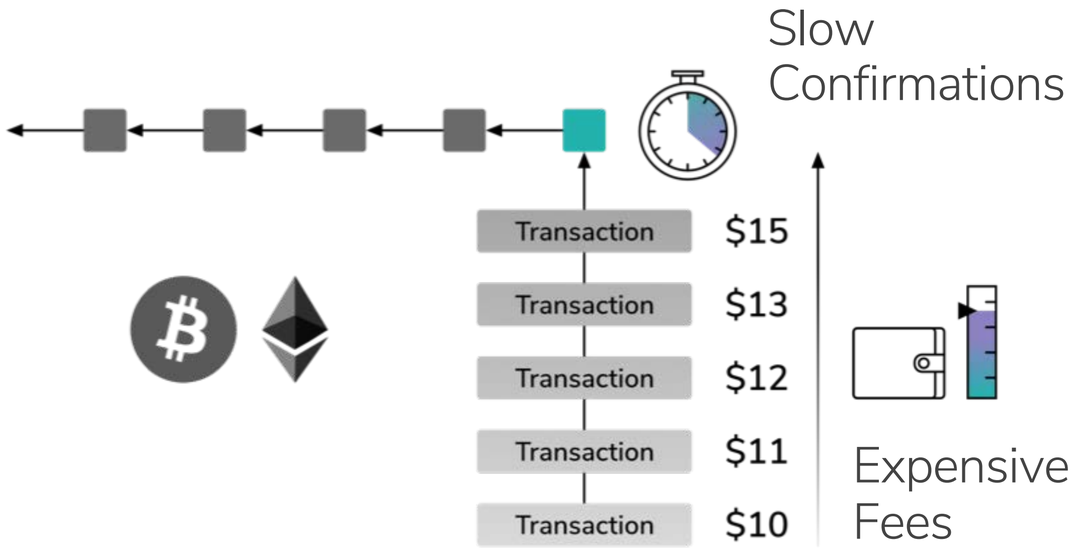
# Why IOTA?

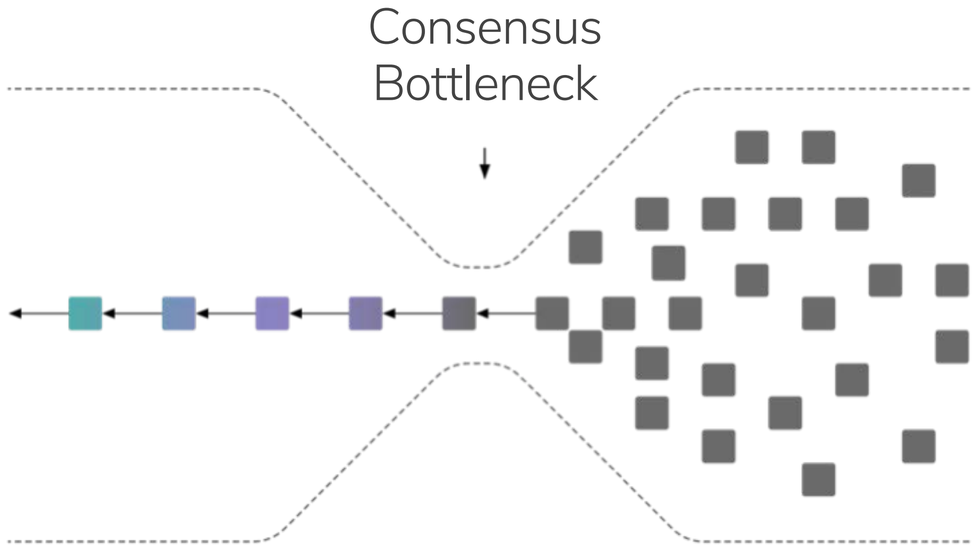
In 2015, the IOTA Founders saw the limits of Blockchain scalability fast approaching.

One of the founders, Dr. Popov, proposed a novel architecture that had better scaling properties. This set out a new way to handle the inherent speed limitations of the blockchain.

This novel architecture is called the Tangle.

# What they saw was a classic bottleneck



# Blockchain was designed for small scale

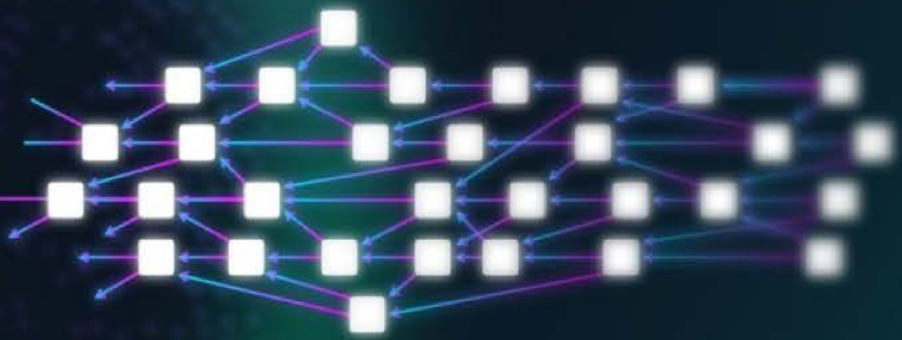
Blockchains have a built in scalability limitation: you cannot send blocks too quickly.

- In Bitcoin, blocks are 1 megabyte in size and arrive every 10 minutes.
- This implies a maximum global capacity of about 7 transactions per second.

This cannot be fixed by simply increasing the size or frequency of block: **if blocks are too big or frequent, we will have many forks.**

- Blockchains can’t reconcile forks easily
- Instead the next block chooses which block is orphaned.

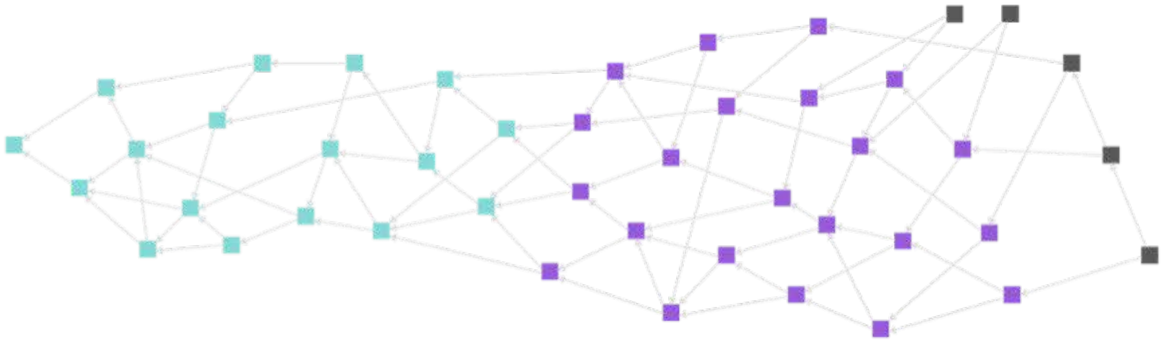
# BEYOND THE BLOCKCHAIN



IOTA

# Blockchain Vs Tangle graph structure

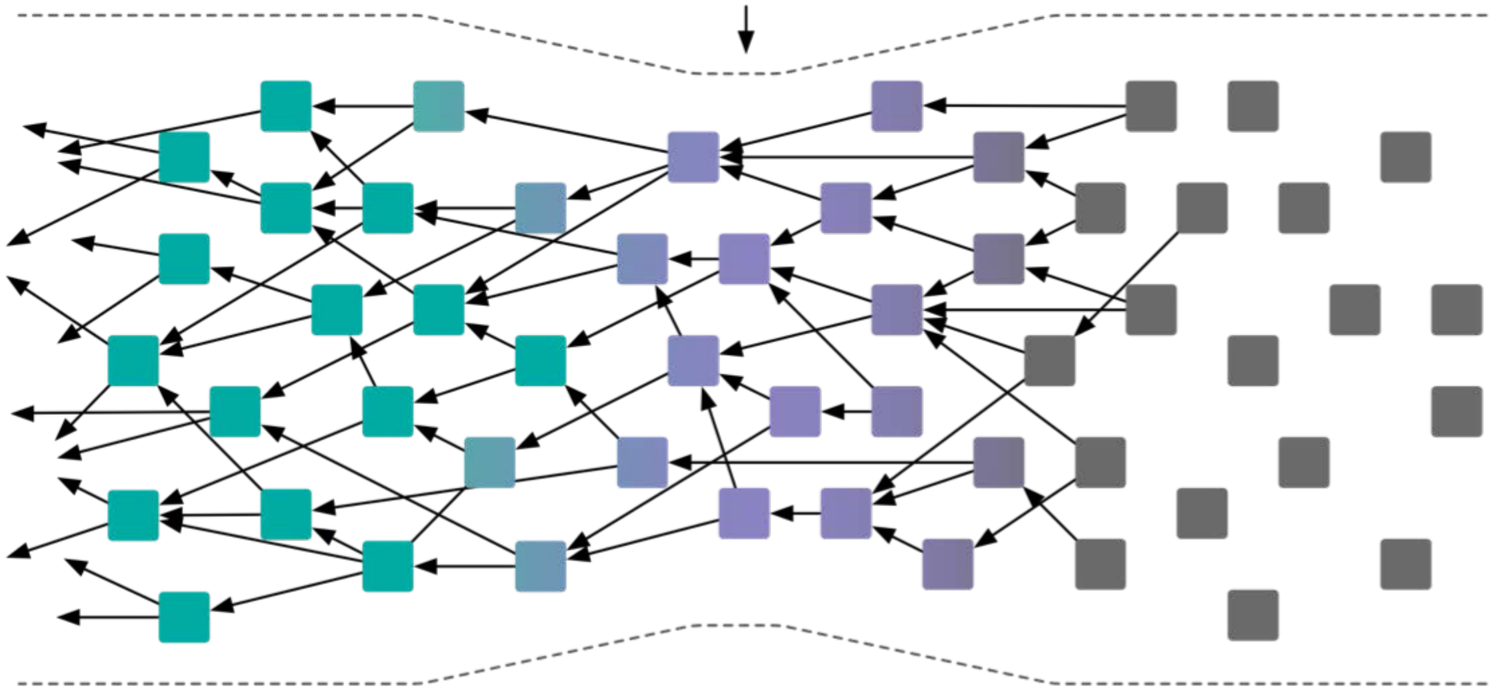
Blockchain



Tangle
(DAG - Directed Acyclic Graph)

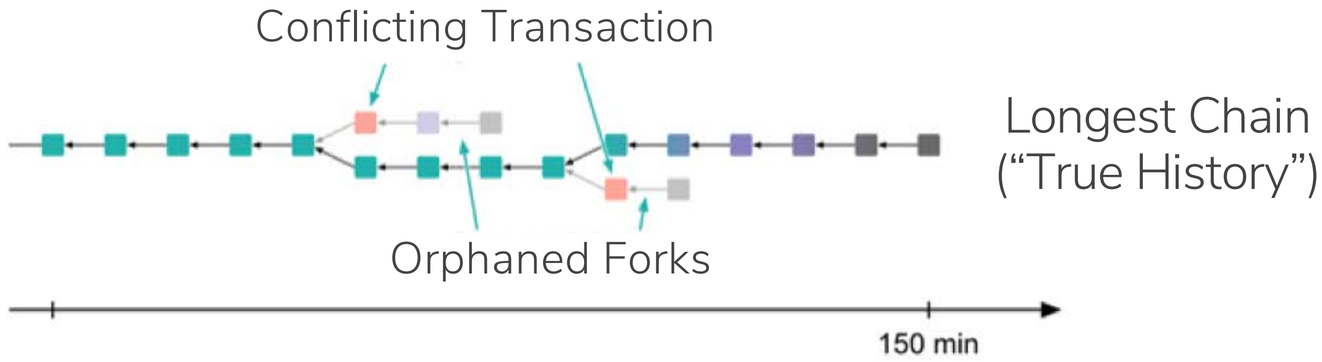
# The Tangle

More activity
=
More validation



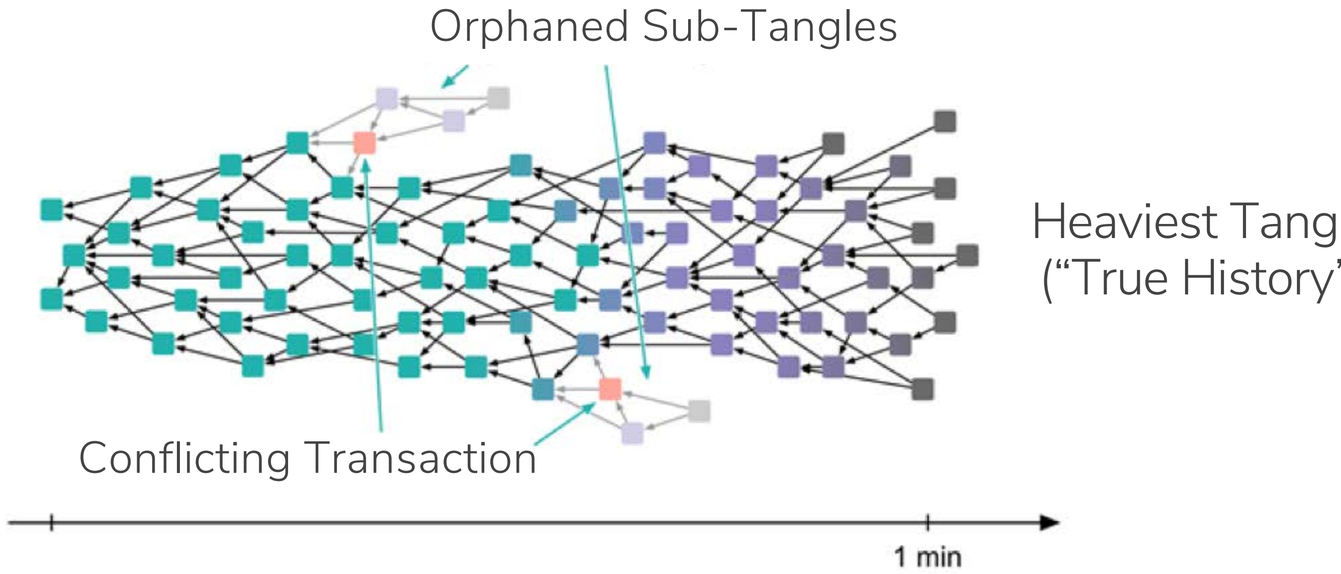
# Consensus in IOTA vs. Blockchain

Blockchain



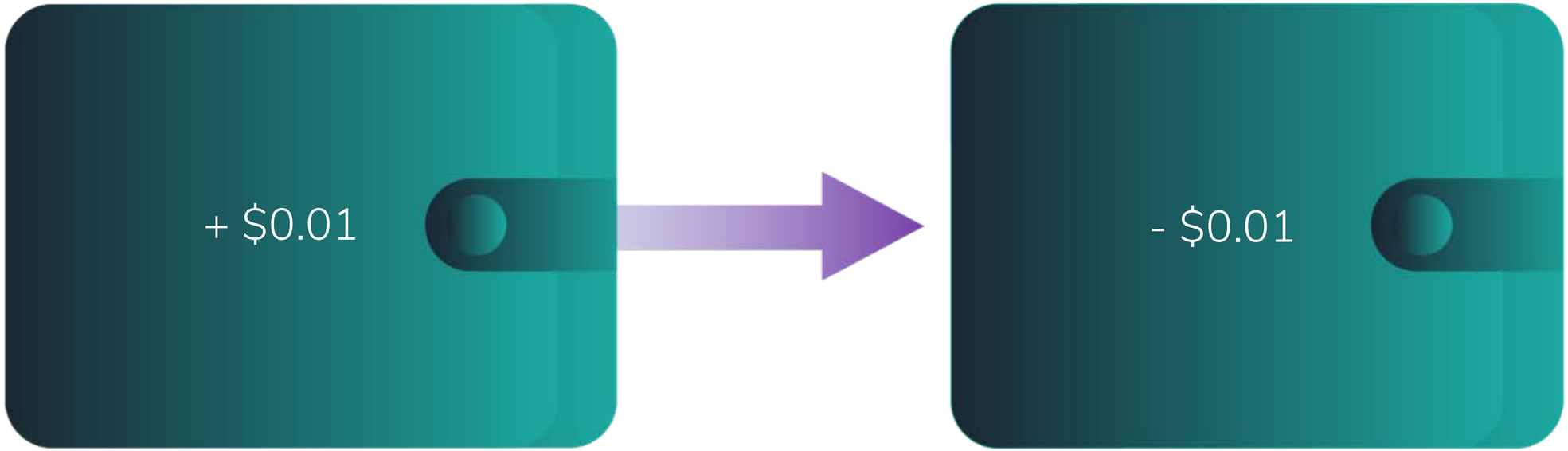

Longest Chain
(“True History”)

IOTA Tangle



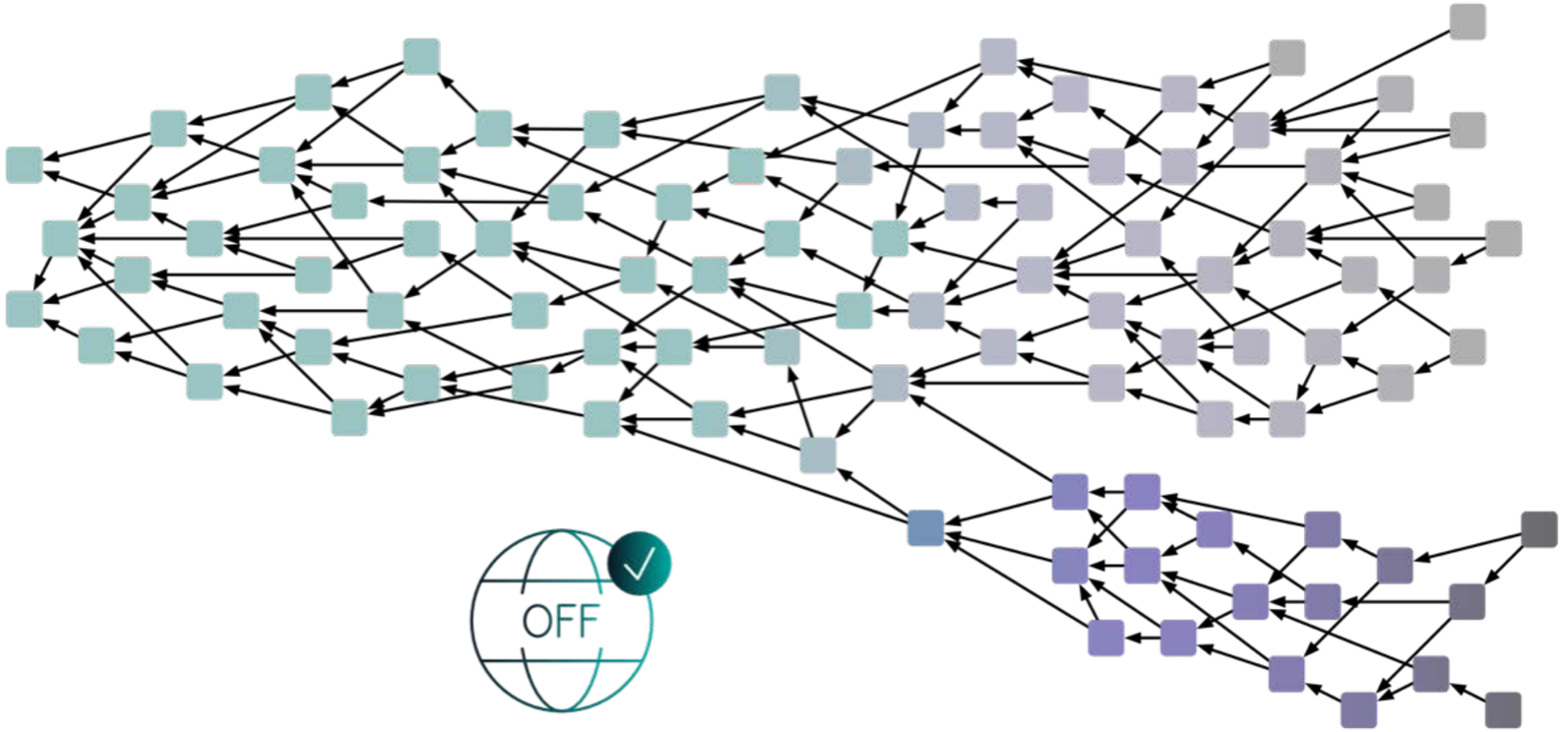

Heaviest Tangle
(“True History”)

# No Miners = No Fees




IOTA makes fee-less micro-transactions possible

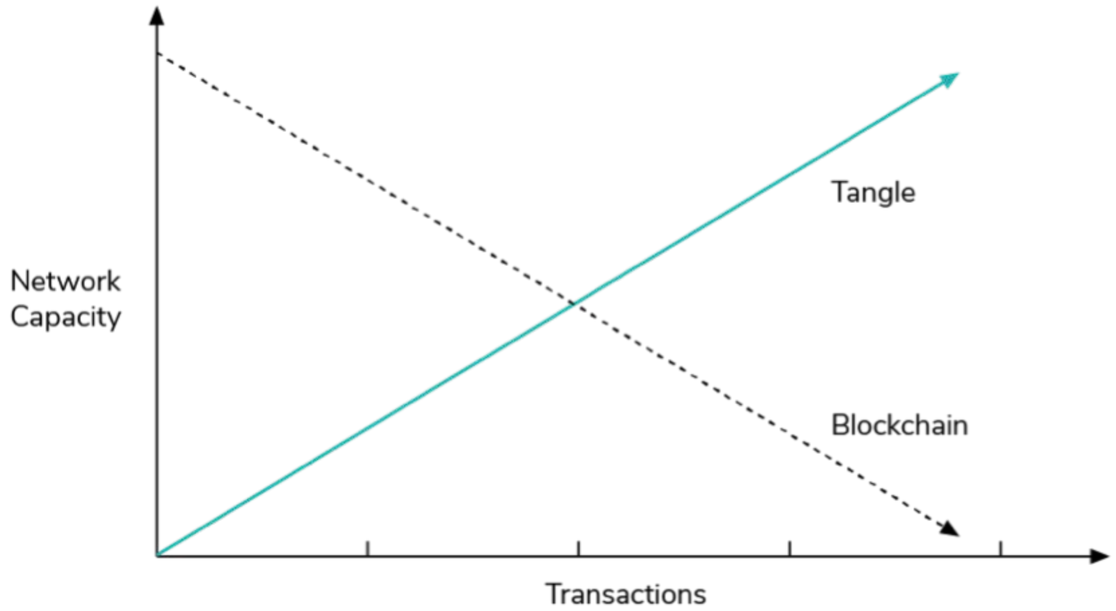
# Offline Transactions




Main Tangle

Offline Tangle Cluster

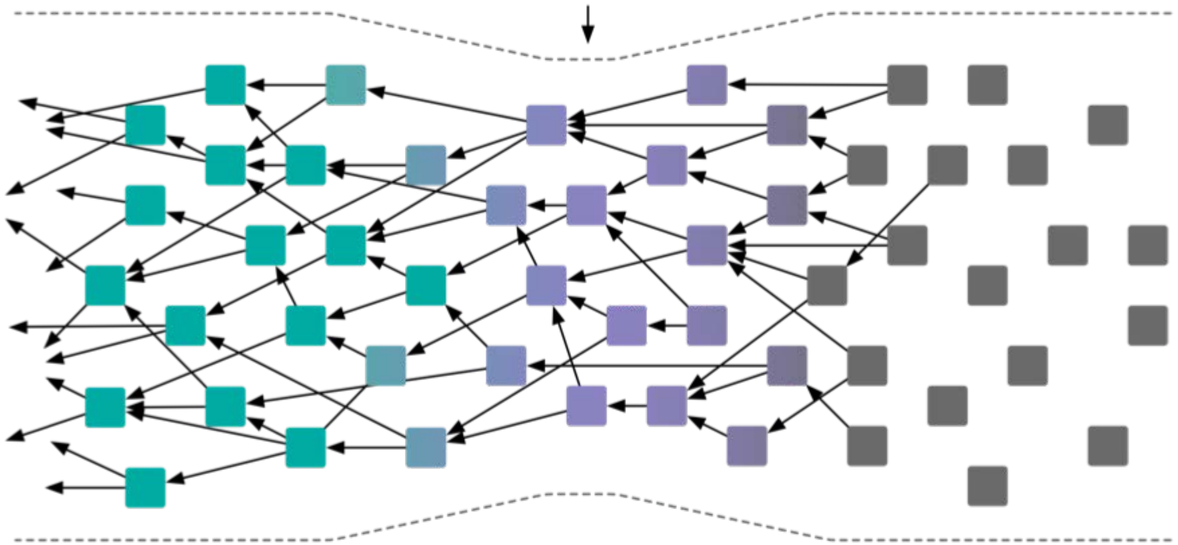
# A Technology for the Era of Trust



- No Transaction Fees
- Secure and Decentralized
- Scalable
- Interoperable

# Deep dive into ‘The Tangle’

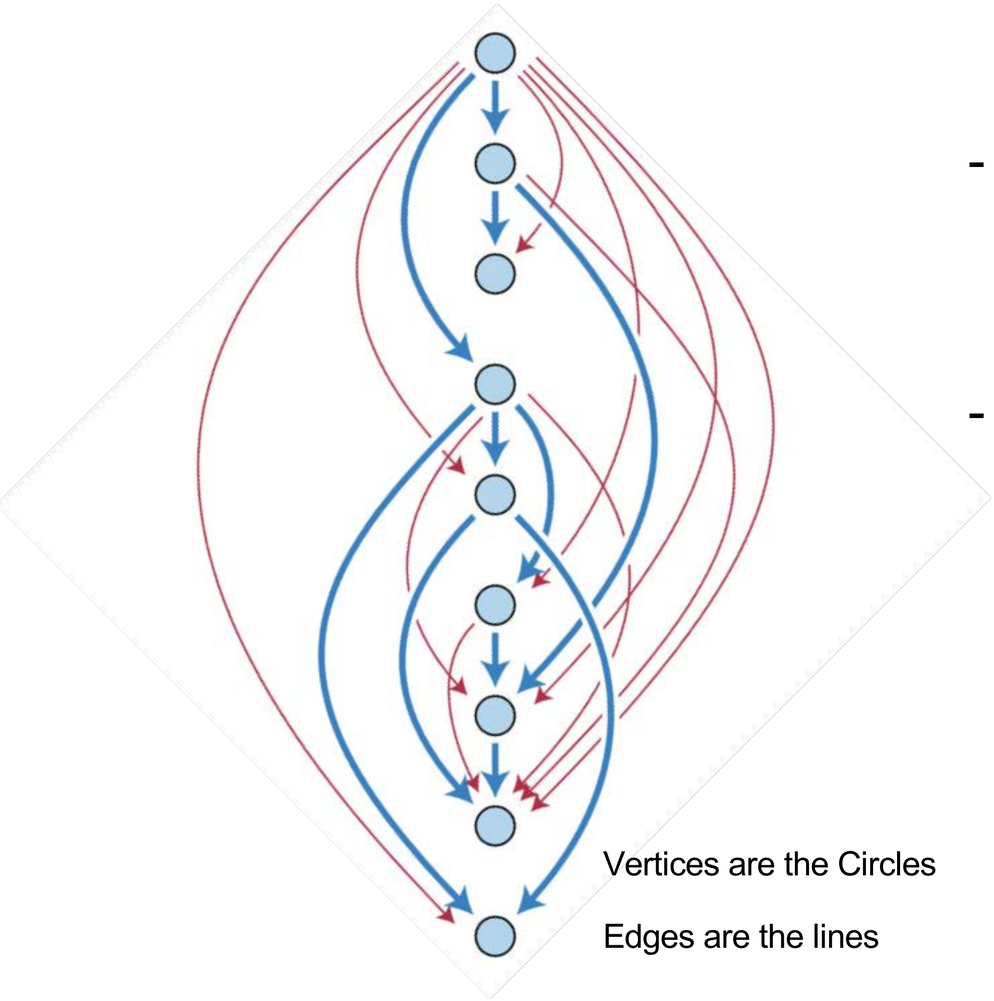
# The Tangle



*... The main feature of this novel cryptocurrency is the tangle, a directed acyclic graph (DAG) for storing transactions. The tangle naturally succeeds the blockchain as its next evolutionary step, and offers features that are required to establish a machine-to-machine micropayment system...*

The Tangle, 2015 - Prof. Serguei Popov

# What is a Directed Acyclic Graph

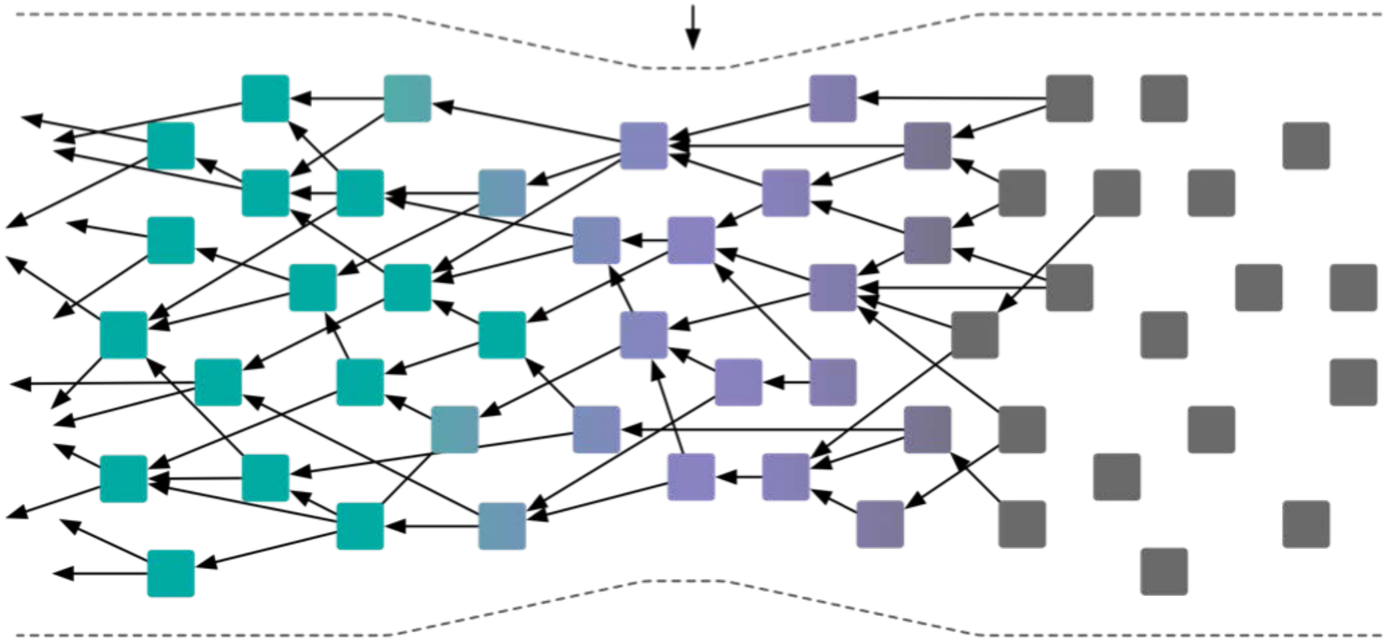


Vertices are the Circles

Edges are the lines

- A **DAG** is a finite **directed graph** with **no directed cycles**
  - Directed: *Vertices* connected by *edges*: edges have a direction
  - No Cycles: *Vertices* unable to be connected in a closed chain
- Topological ordered
  - *Vertices* organised such that every *edge* is directed from earlier to later in the sequence

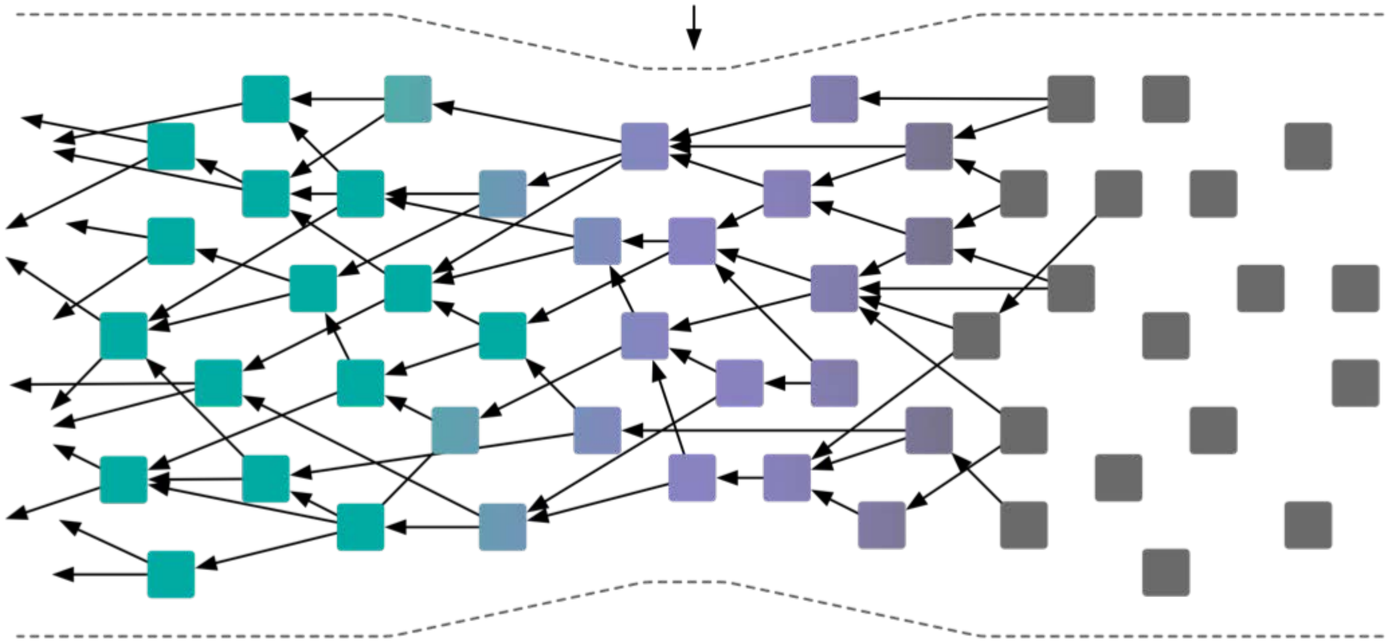
# IOTA’s DAG Structure



Each **Vertex** represents a transaction (Squares)

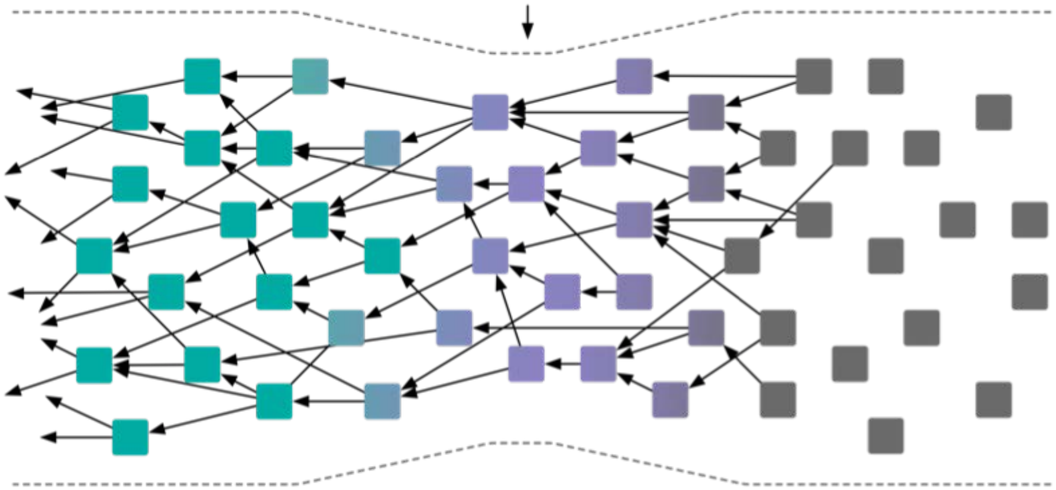
Each **Edge** represents an approval (Lines)

# Transaction States



High Confidence  Low Confidence  Tip (unreferenced)

# Adding a Transaction to the Tangle



Tip (unreferenced) ←

- To add a Transaction to the network your TX **must** reference **two** Tips (unreferenced vertices).

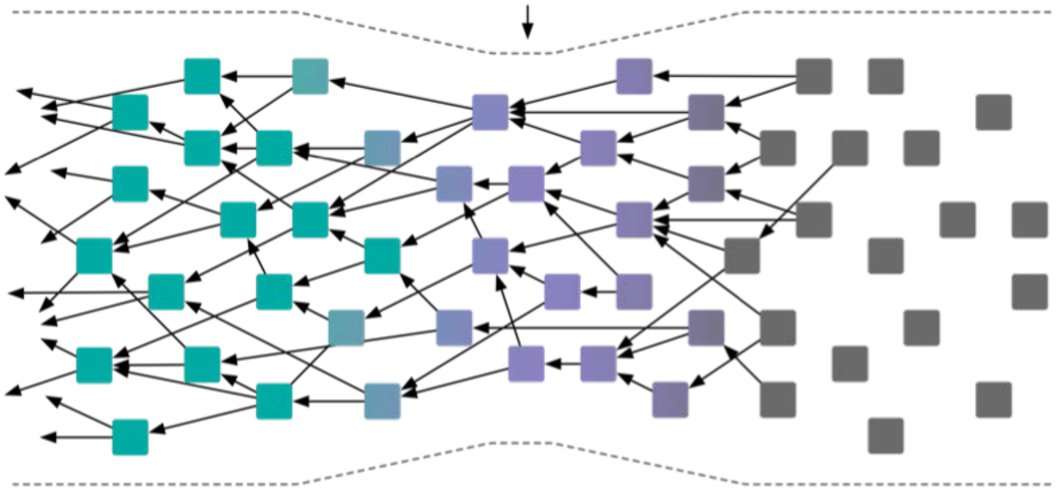
- When you reference a TX (vertice) you are directly & indirectly approving all TX's back to the latest epoch

- Reference a TX that breaks consensus, namely transaction resulting in a negative balance or conflicts with another TX, will cause you Tip not to be referenced.

Rules

- Vertices have exactly **two** Edges
- Edges **can** reference already referenced Vertices

# Picking Tips to Approve



Tip (unreferenced)

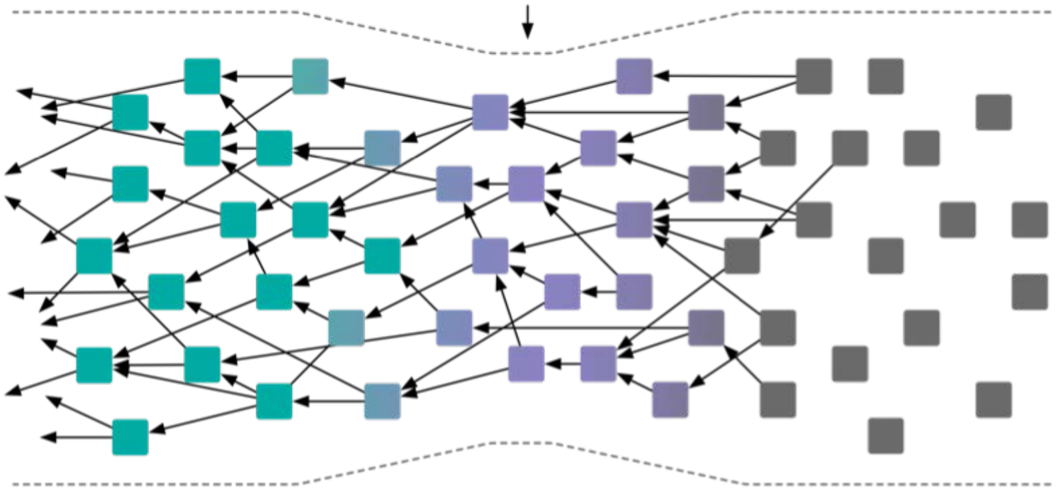
Tip selection in The Tangle is done by performing a Weighted Random Walk (WRW) from the genesis finishing at the Tips.

- The WRW is performed **twice**, to get the two required tips.

The WRW is **biased** towards transactions with more **cumulative weight**, or more **transactions referencing** them.

- Incentive to approve new TXs rather than old ones.
- WRW causes large branches (sub-tangles) to grow and small branches to get abandoned.

# Consensus in The Tangle

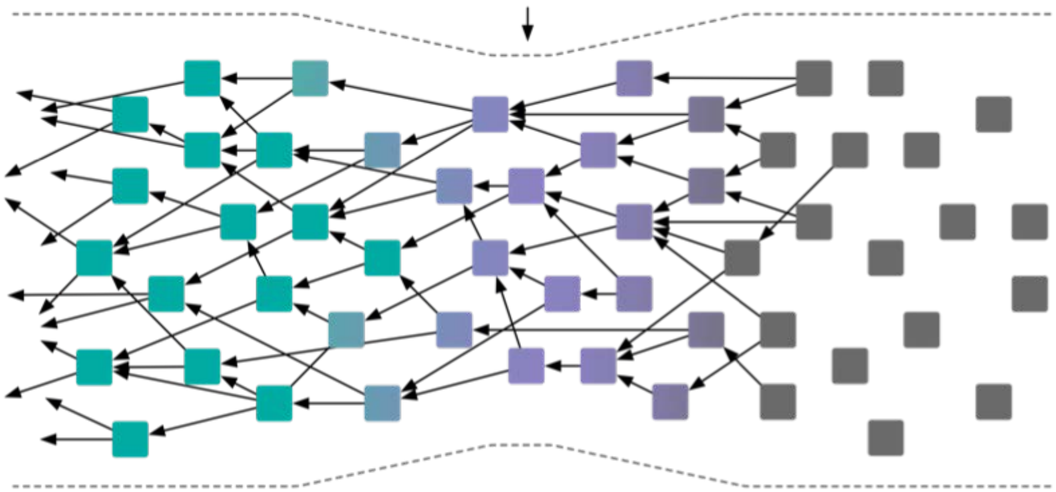


High Confidence ← Low Confidence

- Similar to Bitcoin and other DLTs, a transaction has a **confirmation confidence**, which is an indication of its acceptance level.

- **Confirmation confidence** is derived by sampling the Tangle's Tips. Then the percentage of those Tips which reference a transaction is calculated. If 80% reference that TX then the TX is 80% confirmed.

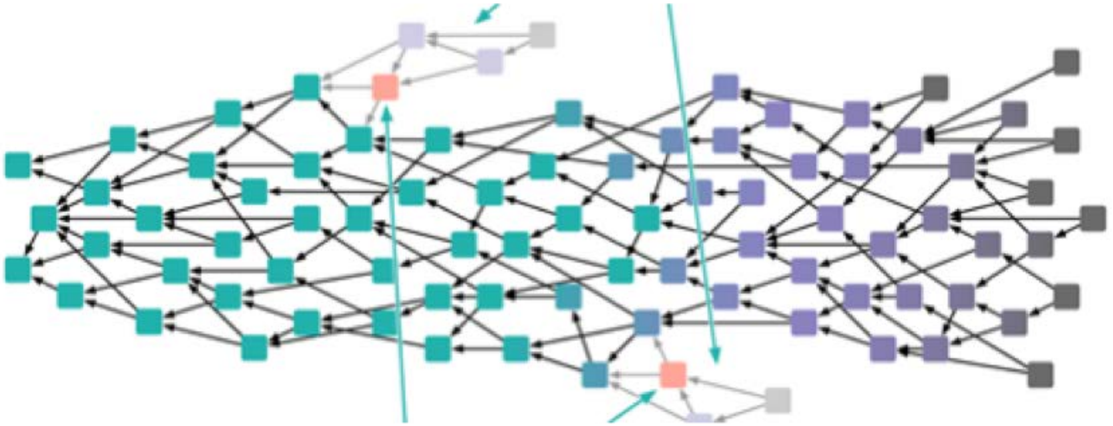
# Incentive to participate



High Confidence ← Low Confidence

- Your aim when adding a transaction to the Tangle is to reach the highest **confirmation confidence**.
- To achieve 100% **confirmation confidence**, the TX should be referenced by all of the Tips of the network.
- To have the best chance of getting referenced, pick the two tips with the **heaviest cumulative weight / references.**
- This will incentivise other TXs using WRW to reference the TX.

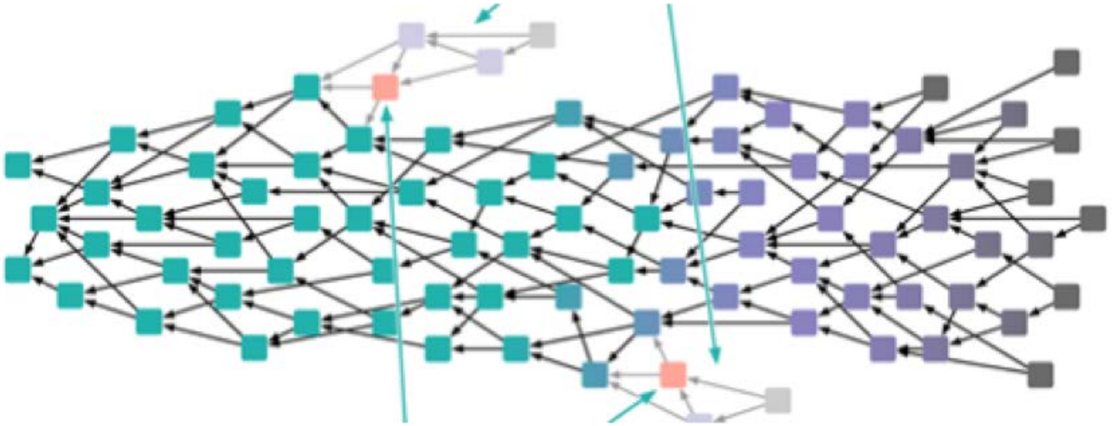
# Unique Outcomes



- **Single participant class**
  - No dichotomy between Miners and Users
  - **Users** validate the network which enables them to publish TXs without paying a fee.
    - Note: Validation of the Ledger is not free and requires CPU cycles.

- **Networking as the TPS limit**
  - Removing *'Blocktime'* and *'Blocksize'* in favour of a blockless DAG offers scalability.
    - Blockchains will require soft-forks or 2nd layer solutions to keep up with adoption
  - Scalability towards the limit of the communication medium.

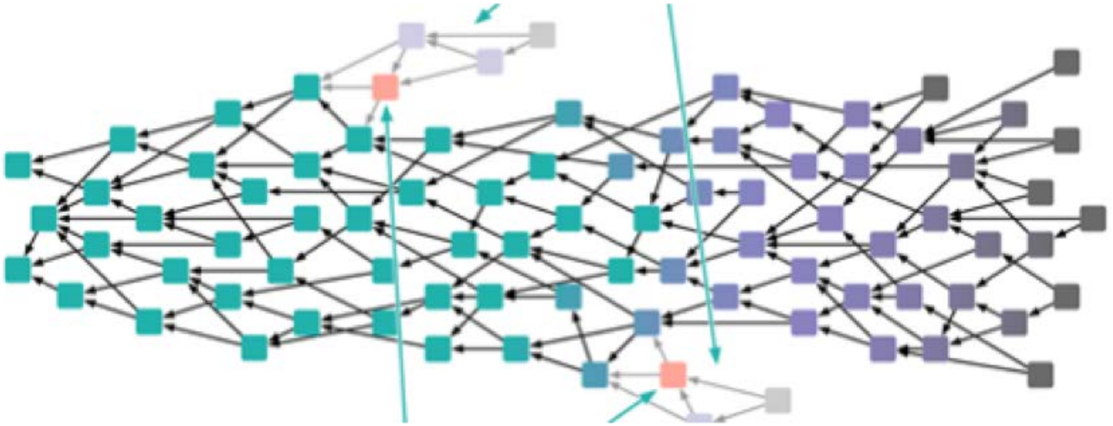
# Unique Outcomes



- **Micro Transaction Economics**
  - With no payable fee, there is no minimum payment size. *1i sent is 1i received.*
  - Provides the access to new business models that traditional infrastructure can’t support.

- **Partition Tolerance**
  - Sub-Tangles can split off & merge later due to the Tangles architecture
  - Considers real-world networking events and maintains functionality through them.

# Unique Challenges

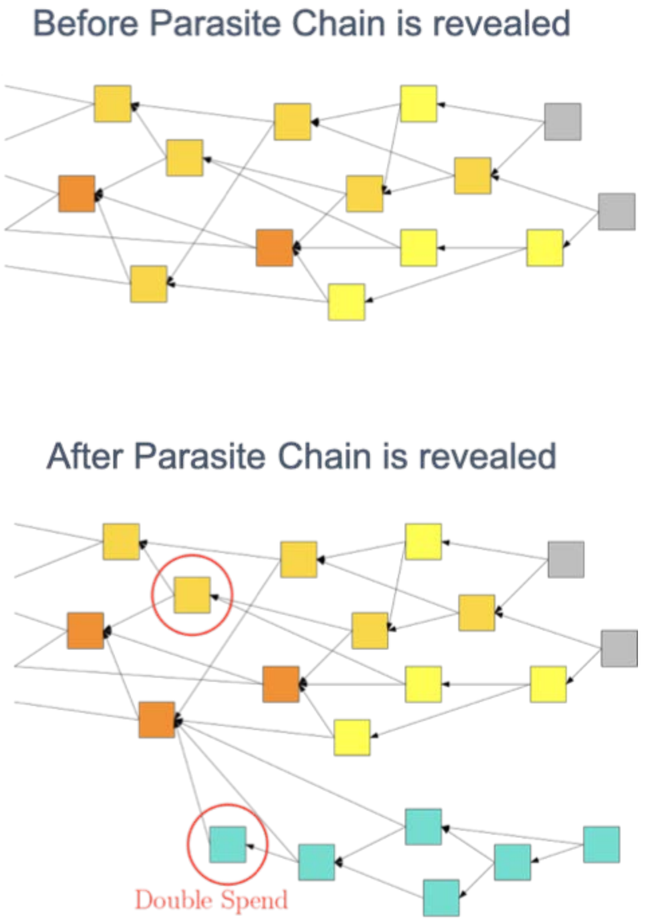


- **Probabilistic Confirmation**
  - Tip selection isn’t deterministic which can lead to unselected TXs. Thus unconfirmed TXs
  - Requires extra Promotion or Reattachment transaction to rectify

- **Open Research Questions**
  - The Tangle is a new concept in the DLT world.
  - There are a few areas of active research relating to throughput, stability and security.

# Parasite Chain Attack

An adversary secretly builds a sub-tangle, which is called **parasite chain (PC)**. At some point the adversary issues a transaction in the main tangle, as well as issuing a conflicting transaction on the still hidden PC, thereby creating a double spend. For a while the attacker continues to issue hidden transactions to the PC, until the transaction in the honest part of the Tangle is accepted. He then reveals the PC and hopes to exploit the tip selection algorithm to make most of the incoming transactions approve the double-spend transaction on the PC, thereby reverting the ledger history.

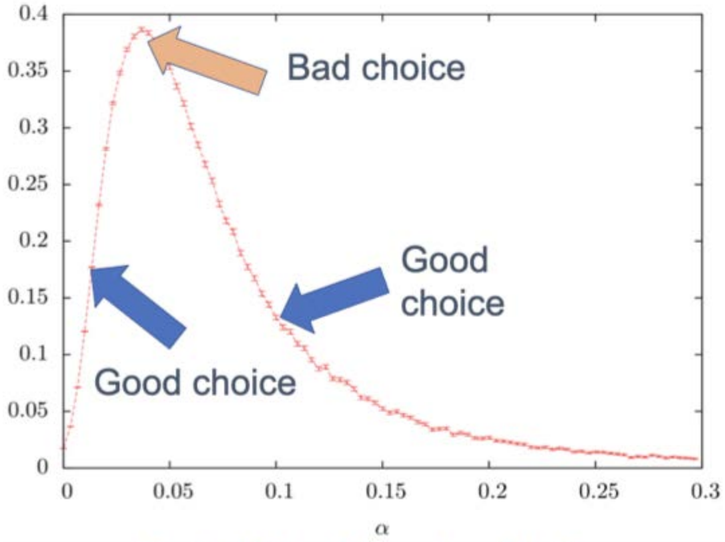


# How to counteract

- ts - suggested waiting time before accepting payment (analogous to Bitcoin 6 blocks rule)

Parameters of random walk:

- α parameter
- Local modifiers (β parameter)
- q - backtrack probability
- Different tip selection mechanisms



Probability of Random Walk ending on Parasite Chain

Problem:

A high value of α increases security, but increases the probability of becoming orphan because random walkers will, with high probability, walk over heaviest txs

# TSA models

**Biased Random Walk**

Pro
- Prevents Lazy tips
- Nash equilibrium

Cons
- Computationally demanding
- Security relies on high participation / honest tx rate
- Growing complexity to prevent attacks

Known attacks:
- Parasite chain
- Splitting
- Multiple Spend

**Uniform Random (URTS)**

Randomly select 2 tips

Pro
- Computationally efficient
- No tx left behind

Cons
- Lazy tips
- Time does not necessarily add to security of tx

Known attacks:
Similar to Biased Random Walk

**Secure and swipe**

1. Trunk tip = Security step (α↑)
   Ensure honest tips get selected
2. Branch tip = Swipe step (α↓,URTS)
   No orphans

Pro
- No tx left behind
- Similar tip number to URTS

Cons
- 2 classes of txs?
  (Security txs and Swipe txs)
- Similar attacks still possible?
- Confirmation time for Swipe txs increase?

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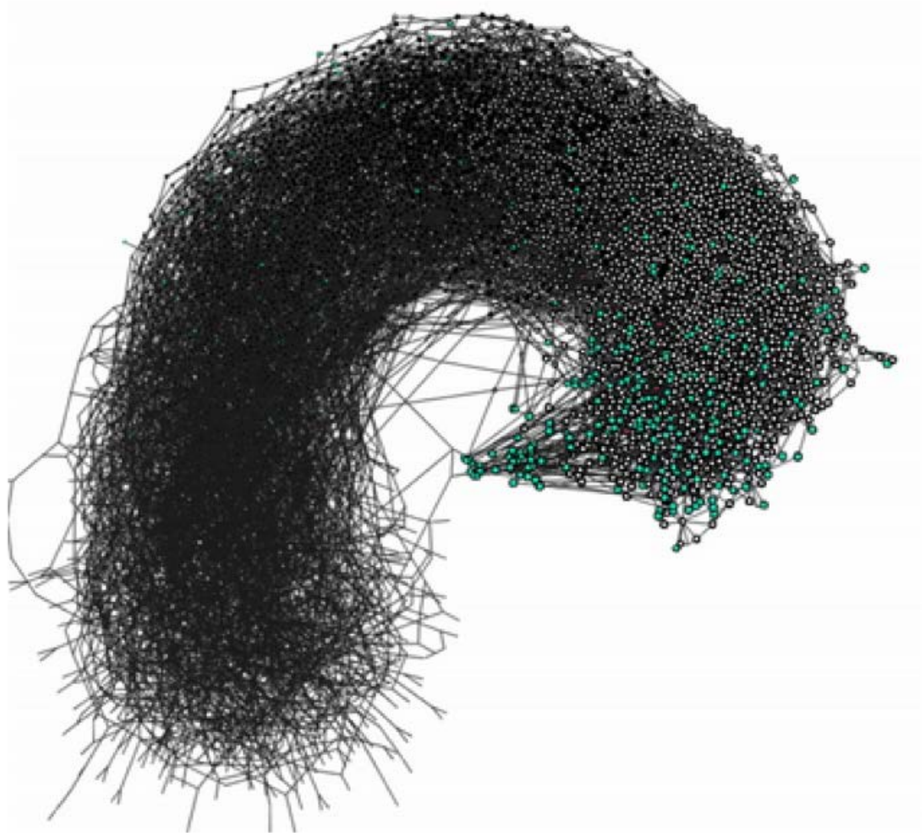
# Tangle Research

# IOTA’s Tangle

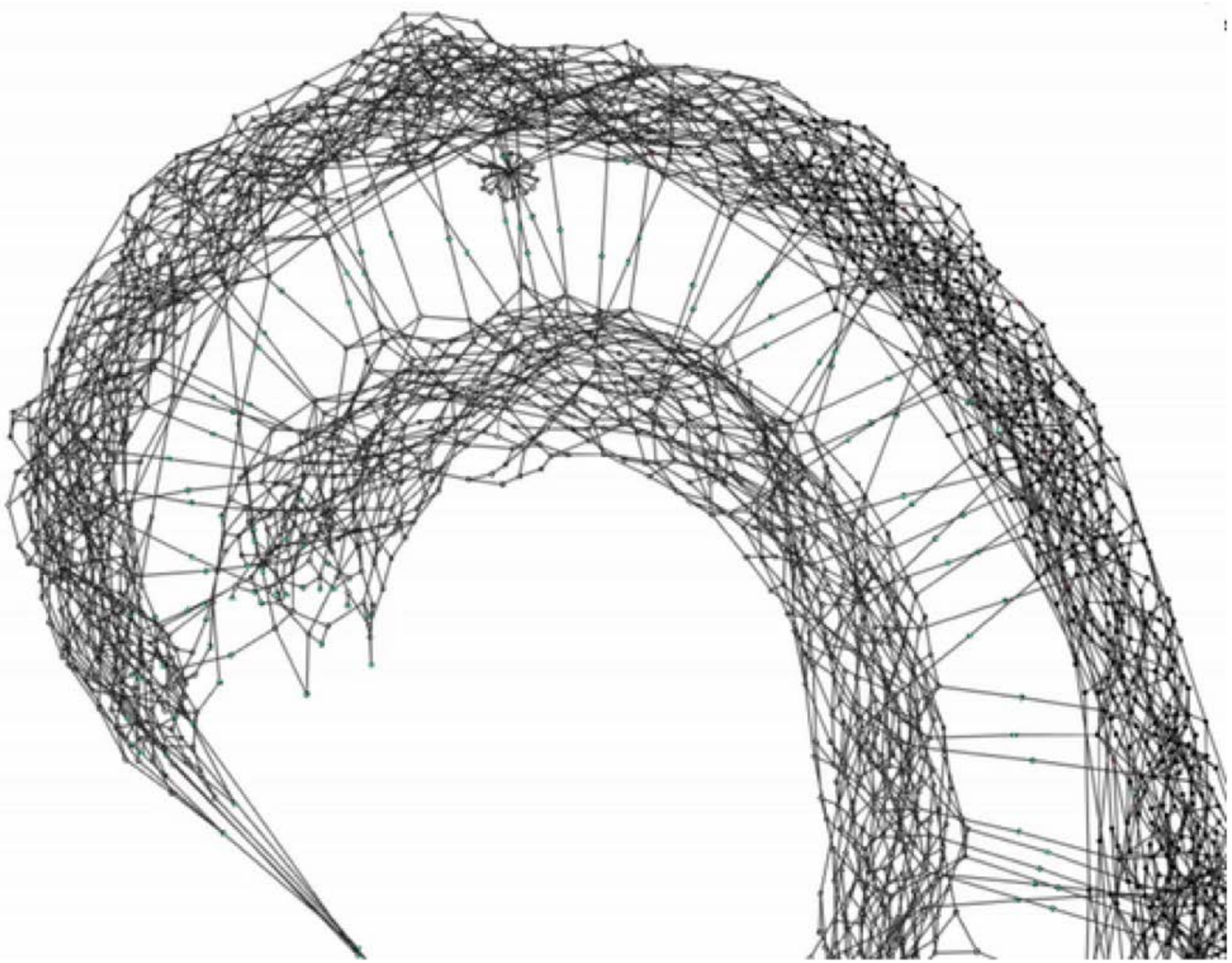


The IOTA Tangle (know as the ‘Mainnet’) has been operational since 2016.

The current Tangle slightly differs from the protocol outlined in ‘The Tangle’ whitepaper due to a need ‘bootstrap’ the network during the initial adoption phase.

We are working towards building a stable tangle that represents the protocol outlined initial whitepaper.

# Attacks on the Tangle



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# The IOTA Network

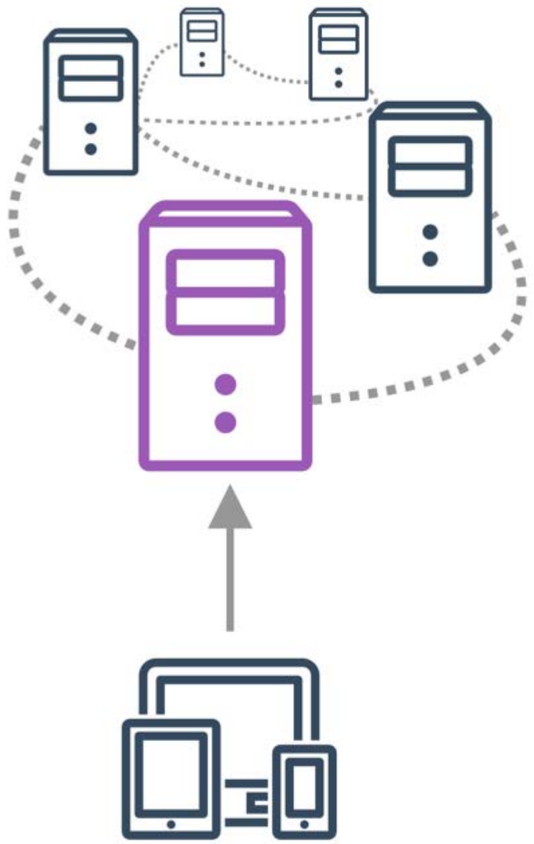
# The Tangle Network

The IOTA Tangle is hosted by a collection of computers known as ‘Nodes’.

Nodes maintain a realtime database of the distributed ledger. Node receive new transactions from clients and share them with their neighbours.

Currently, the majority of the network runs the **IOTA Reference Implementation** (IRI) which is developed by the IOTA Foundation.

# IOTA Reference Implementation

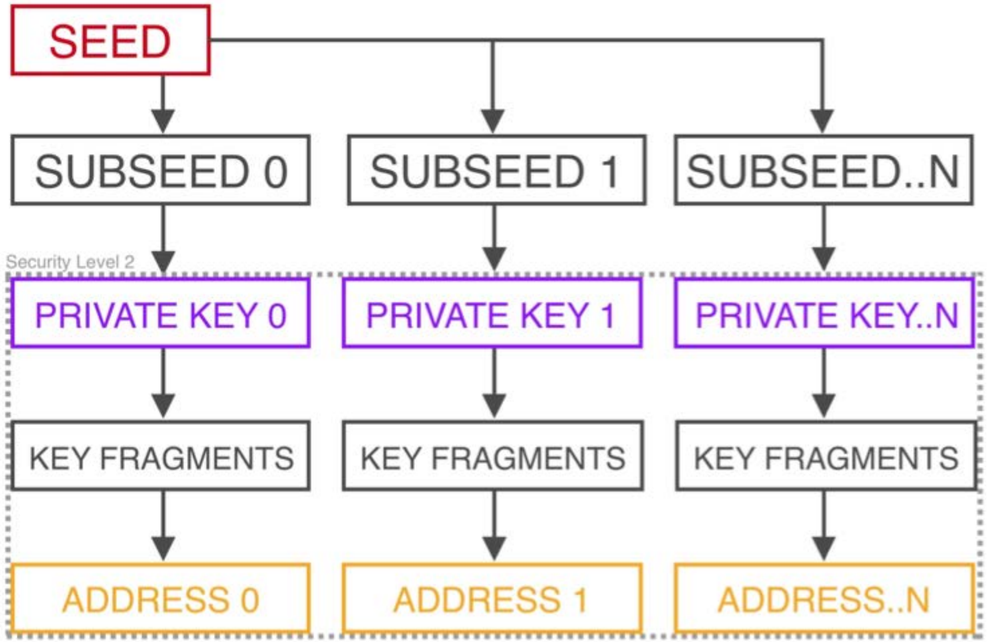


The **IOTA Reference Implementation** (IRI) is the current standard for Node software on the network. It is actively maintained by the IOTA Foundation and has frequent releases.

Its main function is to maintain the ledger state, execute the tip selection algorithm, and propagate information amongst its peers.

There are other implementations of the Node software being produced by third parties which are target at different platforms.

# Seeds, Private Keys & Addresses



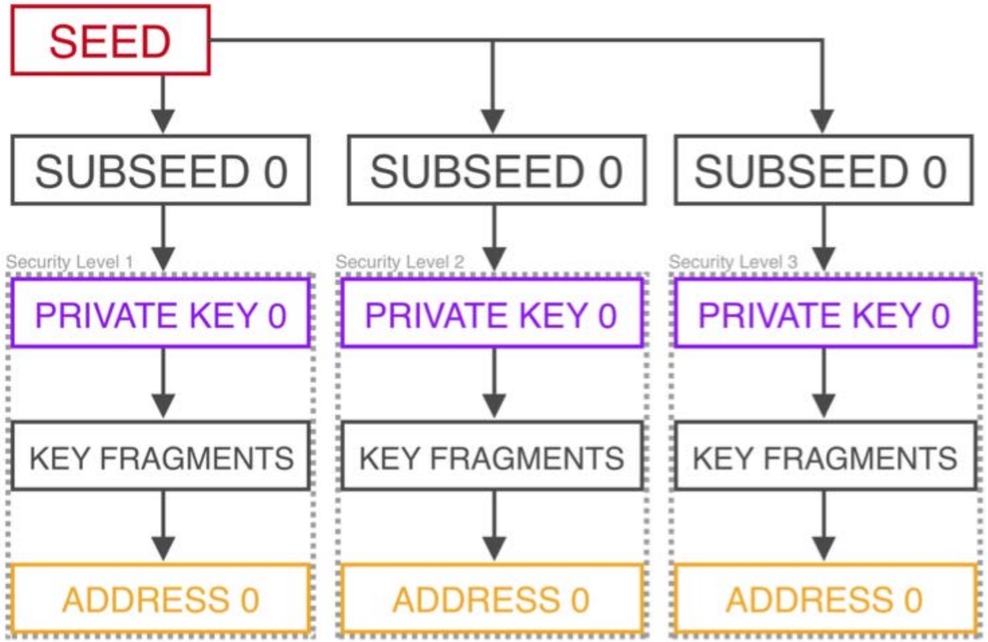

The Seed is starting point for creating an ‘account’ or ‘wallet’. This is the **secret** that controls the addresses that hold tokens.

- It is used derive the secret **Private Keys** and their corresponding public **Addresses**.
- A seed has a practically limitless number of **Addresses**.

A few important notes:

- Knowing a Seed is **Proof of Ownership**. If you can control an address this means you own the tokens at it.
- A Seed is comprised of 81 Trytes.

# Hashing & Security




When generating new Addresses and Private keys it is possible to specify one of **3 Security Levels.** The security level specifies the number of rounds of hashing to derive the **Private Keys**.

- Resulting in 81, 162, 243 trit keys respectively
- More hashing rounds are more difficult to brute force but take longer to generate addresses and sign transactions.

Each security level generates **totally independent** pool of addresses. This enables one Seed to have 3 ‘different’ wallet spaces. However, most applications stick to **Level 2.**

# A note on Trinary

**Trit:**

Analogous to **one bit** in binary,

Trits have **3** states

[1, 0, -1] are three states

**Tryte:**

Analogous to **one byte** in binary

Trytes consist of 3 Trits giving them 27 states

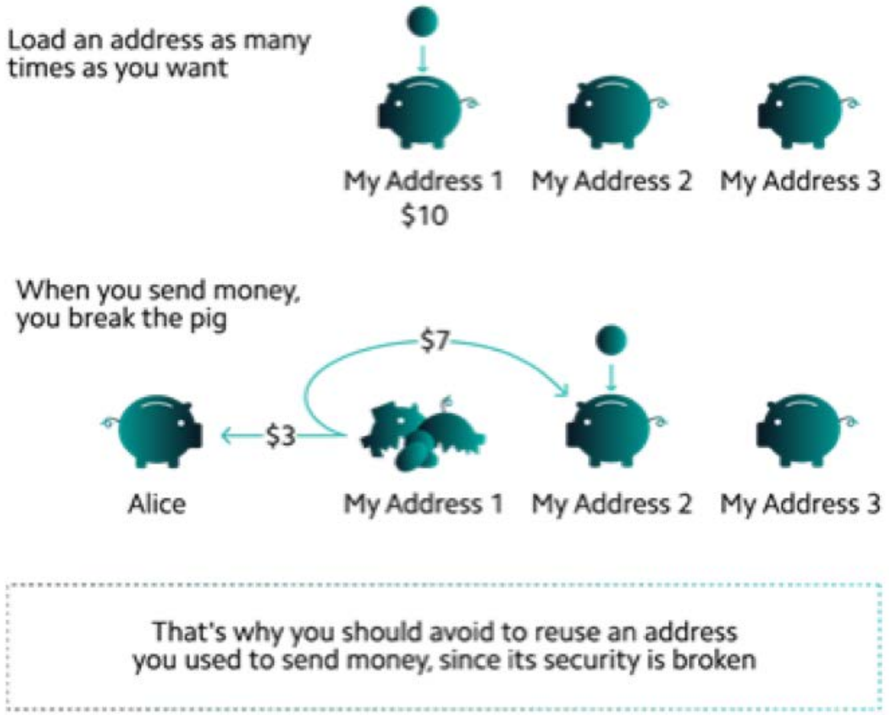
IOTA uses Trinary instead of Binary:

- Transaction and information transmitted through the network is sent in Trinary
- Client libraries allow for the conversion of data to & from Trytes.

Trytes are represented as the characters ‘A-Z + 9’

- Valid Tryte string: **BAKDHA9K**
- Invalid Tryte string: **BAjjsak82D**

# Winternitz OTS

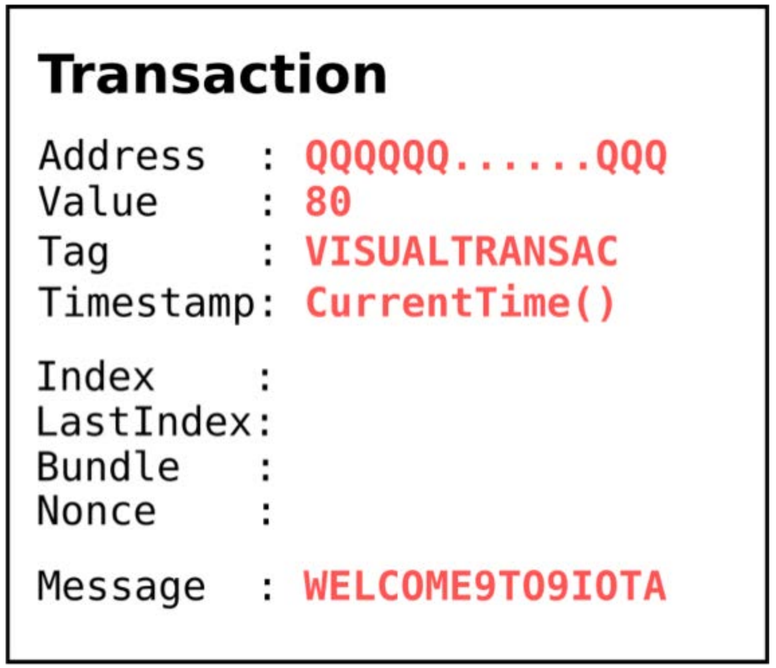



IOTA uses Winternetz One Time Signatures (**OTS**) which is a Hash-based signature scheme. This is used to authorise spending IOTA tokens from an address. This scheme was chosen due to its superior Quantum Resistance over ECC schemes.

As per the name: Signatures can only be used **once**

- Due to its one-time nature, the security of funds in an address decreases rapidly if you sign multiple transactions using the same key.
- IOTA you **never re-use an address** that has been spent from (as one signature has already been shared with the network).

# Transaction Anatomy




In order to send tokens or data on the IOTA ledger you must construct a valid transaction to attach to the Tangle.

**Address:** The relevant address for the operation the transaction is performing.

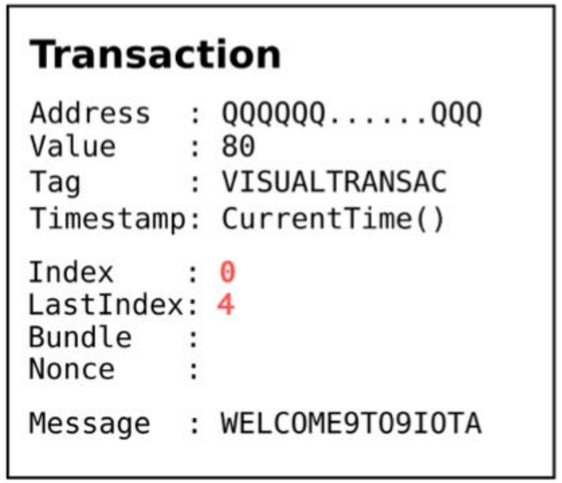
**Value:** Positive/Negative number of tokens to send

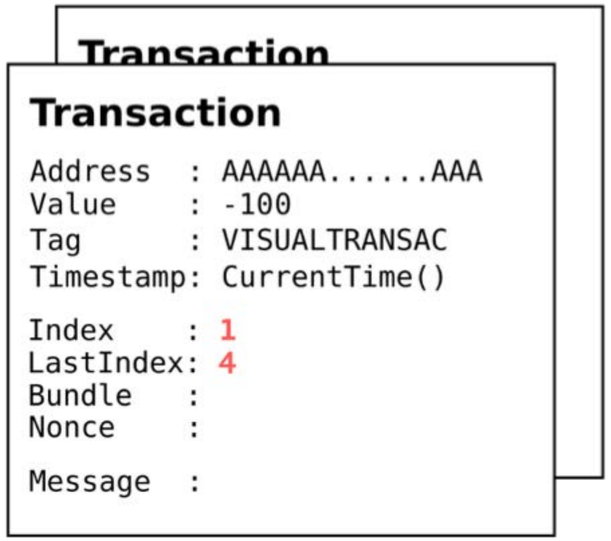
**Message:** 2187 Tryte field that can be filled with information.

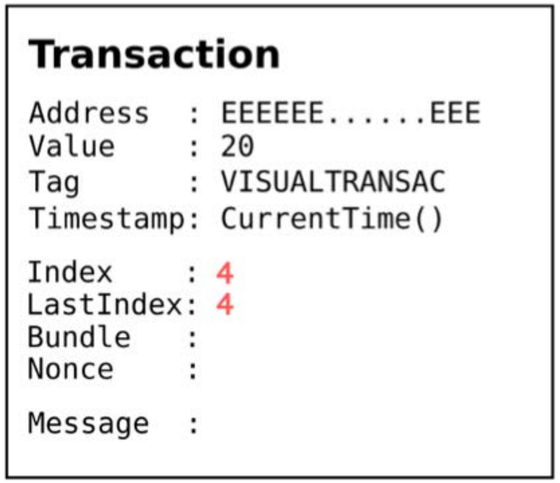
**Tag:** 27 Tryte field that can be used to search for the transaction.

Other fields are computed internally.

# Typical Bundle Construction




## Output

- Address directed to recipient
- Value is positive
- Message field is able to be used
- There can be **multiple outputs**

## Input

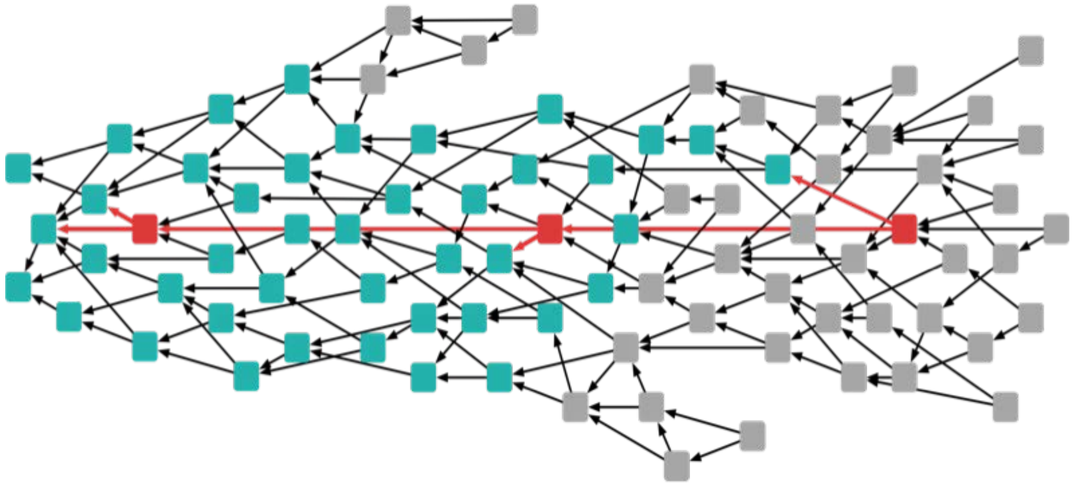
- Address is where the tokens are taken from
- Value is negative and equal to total balance
- Message field is taken up by **Signature**
- There can be **multiple inputs**

**Note: There are two transactions above due to the imaginary address having a security level of 2.**

## Remainder

- Address directed to Seed controlled address
- Value is equal to '**Input - Output**'
- This is usually generated by the client software.
- If no remainder is found, this transaction wont be created.

# Coordinator & Consensus



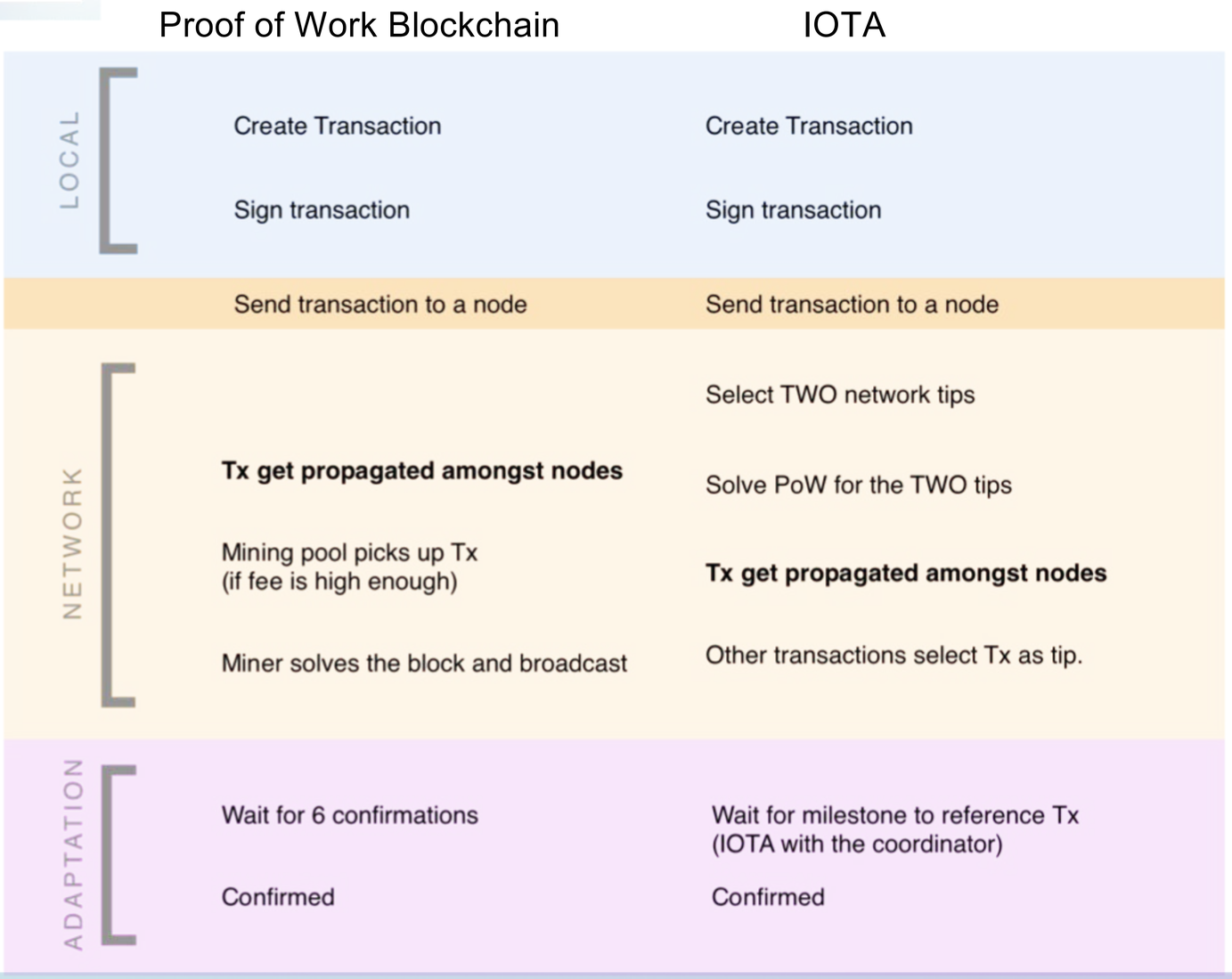
In the current IOTA Mainnet there is a service running call the **Coordinator (COO)**. The COO helps protect the network from 51% Double Spend attacks.

The COO achieves this by publishing transactions with its signature, these transaction are call Milestones. Other clients see this signature and count the transactions indirectly referenced by it as confirmed.

The COO is needed in the beginning stages of any Tangle network when there is a comparatively small amount of hashpower on the network.

It is the intention that the Coordinator is removed in the future. We are actively researching the implications and timing of this event. We call it ‘Coordicide’

# Transaction Lifecycle



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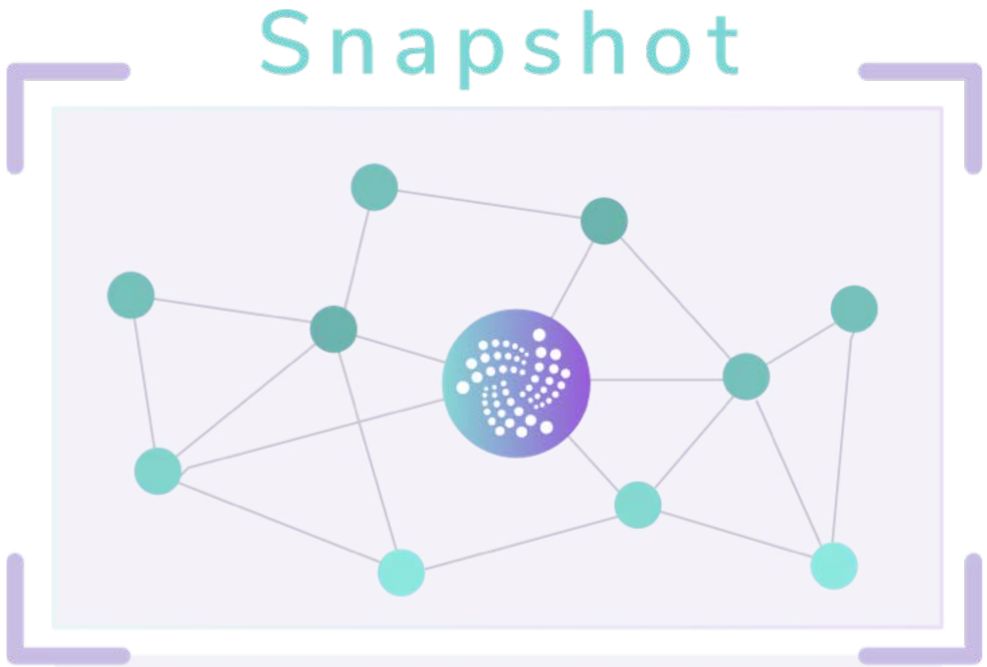
# IOTA and IoT

# Snapshots




‘Pruning of the ledger’

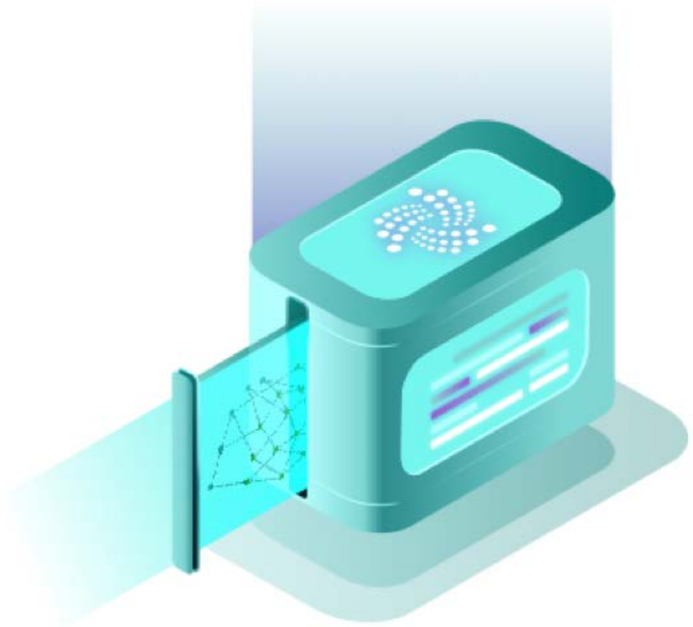
From Global

1. Synchronous
2. Consensus need to be achieved
3. Switch is not automatic

to Local Snapshots

1. Permanodes

# Permanodes



Do not take part to Local Snapshots

Store the entire Tangle history

Useful for auditing purpose

Make it available for an incentive

Benefits vs risks

A. Cost and freedom vs trust

# Step 3: 2nd Layer

MASKED AUTHENTICATED MESSAGING

FLASH CHANNELS

The base IOTA protocol was build to be as flexible and minimal as possible to enable developers to create a number of different **2nd Layer** technologies that augment and extend the functionality of IOTA.

These 2nd Layer solutions can take many forms and have different focuses. Two examples of libraries which do this are **Masked Authenticated Messaging** & **Flash Channels**. Both of these libraries utilise the IOTA protocol in interesting ways to extend the capabilities of the network.

These 2nd Layer libraries do not require protocol changes or hardforks, they can be built and supported by anyone to ensure that IOTA fits their needs.

# MASKED AUTHENTICATED MESSAGING

## Encrypted Messaging Streams

Emit and access a forward-secret and encrypted data stream over the Tangle.

# Masked Authenticated Messaging

Masked Authenticated Messaging (MAM) allow for public or encrypted messaging streams to be published to the Tangle.

These streams can be read back by anyone who has access to the Ledger, and anyone who has the encryption key. These message streams are signed so you are also able to attest to the authenticity of the data.

Current MAM is written in **RUST** with bindings for **Javascript** and **Java**.

# Offline State Channels

Flash Channels enable off-tangle token transactions in a safe environment.

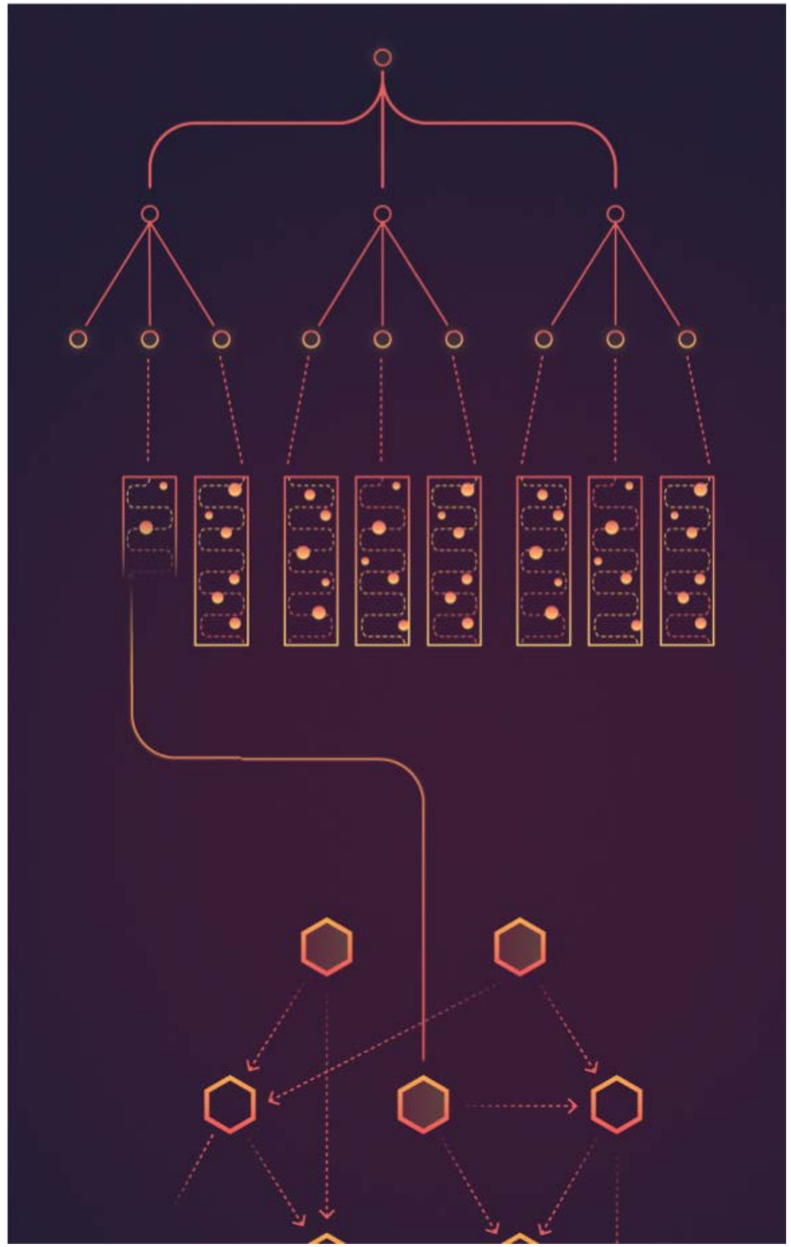
Perfect for token streaming application such as EV Charging or Video Streaming.

# Flash Channels

Flash Channels are a protocol centered around a multisignature wallet and key reuse. Flash lets two or more participants open a state channel, commit funds into it and then sign bundles back and forth transferring value instantaneously off Tangle.

Once the channel is opened you are able to communicate the transfers through any medium.

Currently the implementation of the Flash Channel protocol is in **Javascript**.



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# What do DLTs Enable

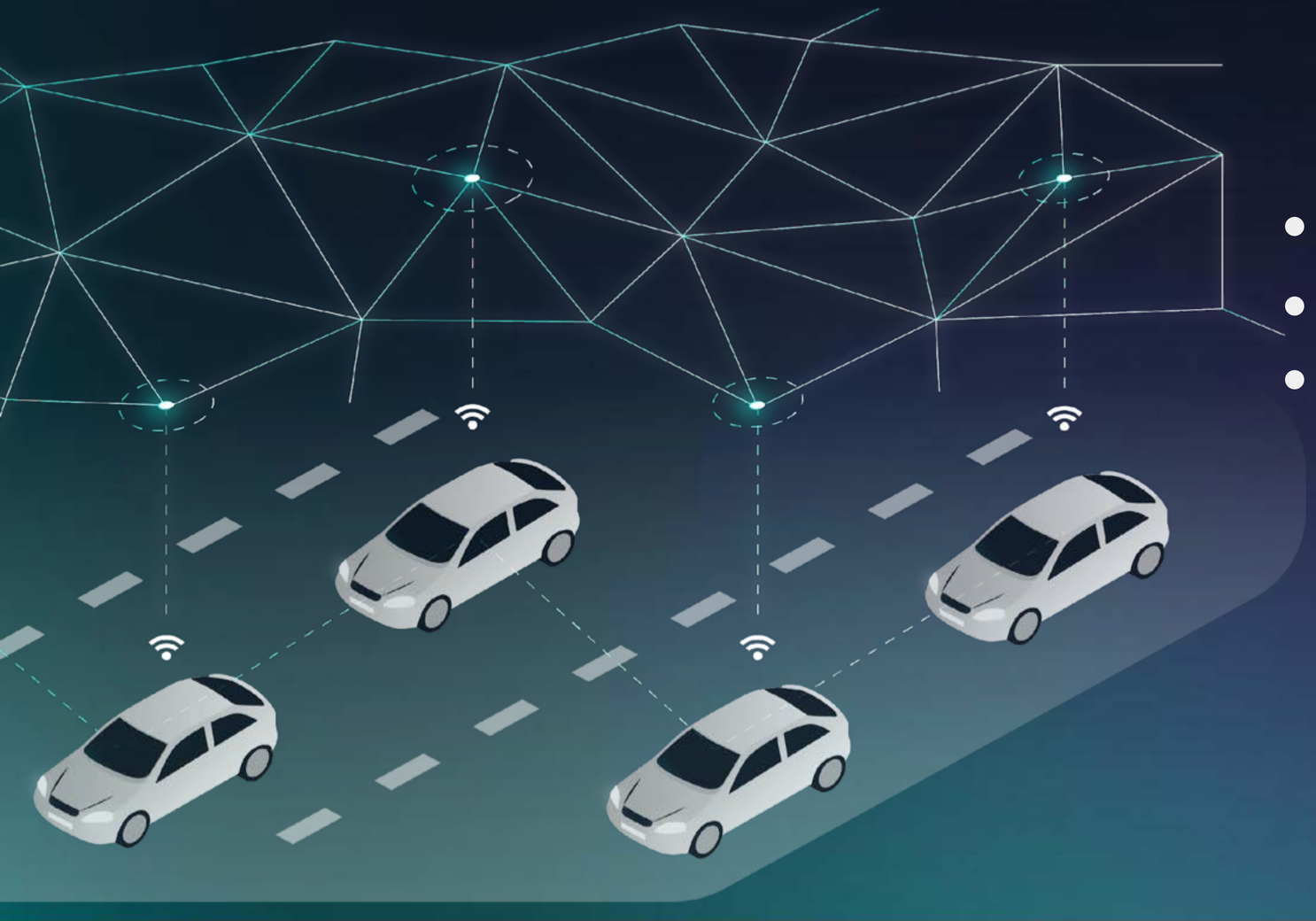
# Trustless & Open Ecosystems

**Permissionless** Distributed Ledger Technologies (DLT) enable open innovation without the requirement of trust.

# Automotive

# Trust In The Data

*Over the Air (OTA) Secure Software update*

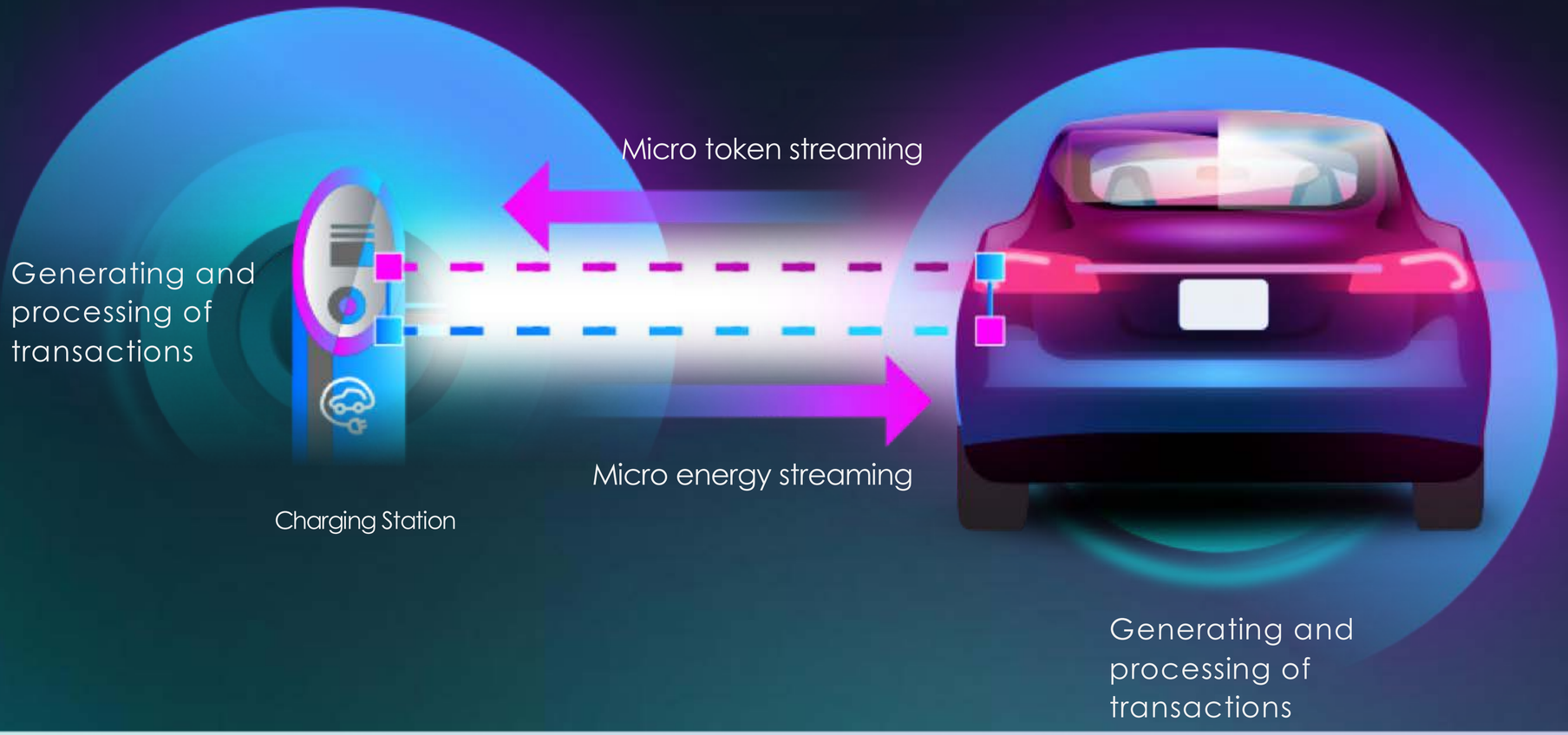


- Authenticity and Security of OTA Updates
- Secure audit trail of the software history
- Fleet management  security

# Smart Charging
*by ElaadNL, Consortium Dutch Grid Operators*

Elaadnl

## Real Time Token Streaming between exchange modules




- unlimited scaling ability
- instantaneous validation of nano-payments at high volume
- no need smart contracts
- exponential decay of transaction costs

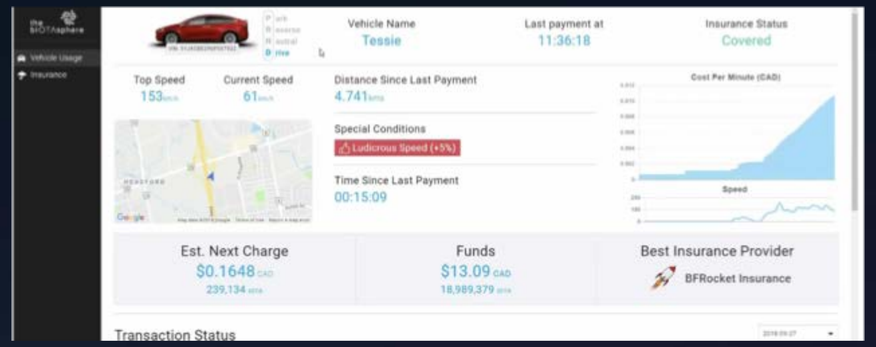
IOTA

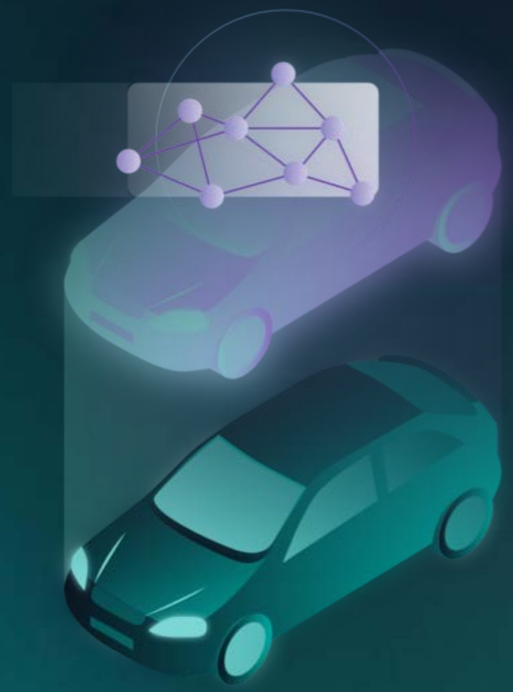
# Enabling Autonomous Economic Agents

*For a seamless smart city experience*

Smart Vehicles can now pay directly peer to peer
Mobility as a Service takes shape

# UBI - Usage Based Insurance



While driving the car transmits usage data to insurance companies without necessarily disclosing personal information: **Location, speed, time of day**

Based on the transmitted data, Insurance companies offer their insurance packages in real-time

Car automatically picks/negotiates insurance package based on predefined budget, preference, risk profile, etc.

# Since Nov 17, IOTA develops a Data Marketplace Proof of Concept, explores new business models and grows a global open innovation ecosystem

## An OpenSource Proof of Concept

*The Data Marketplace PoC*

*Connected devices and sensors can now get paid through zero fee micropayment for sharing securely their data streams*

## 80+ large participants across industries

Smart city

Industry IoT
Supply chain

Energy

Universities

Telco

Consulting

Others

http://data.iota.org

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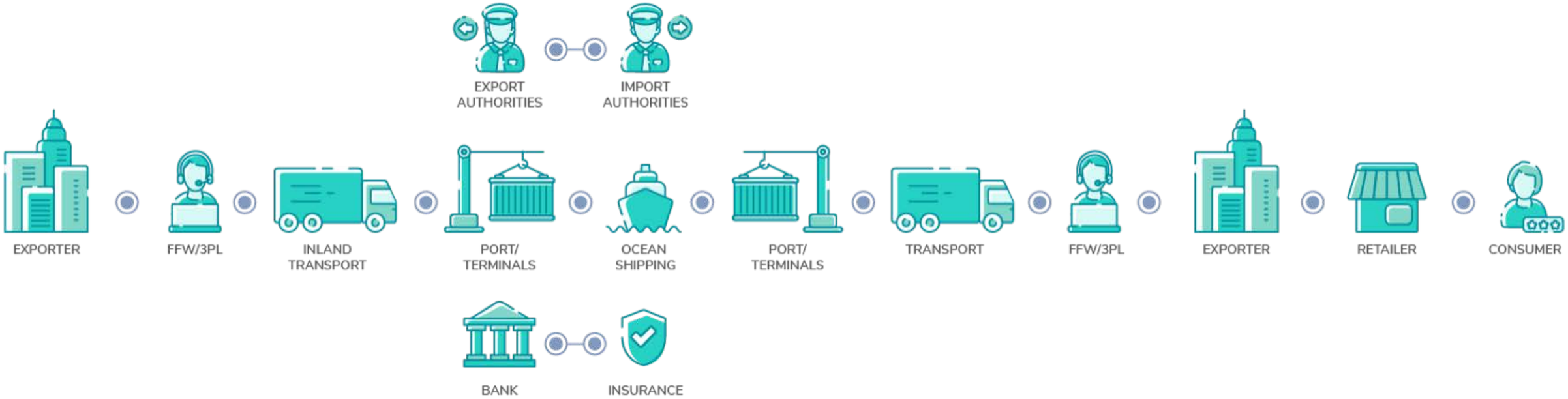
# Supply Chains

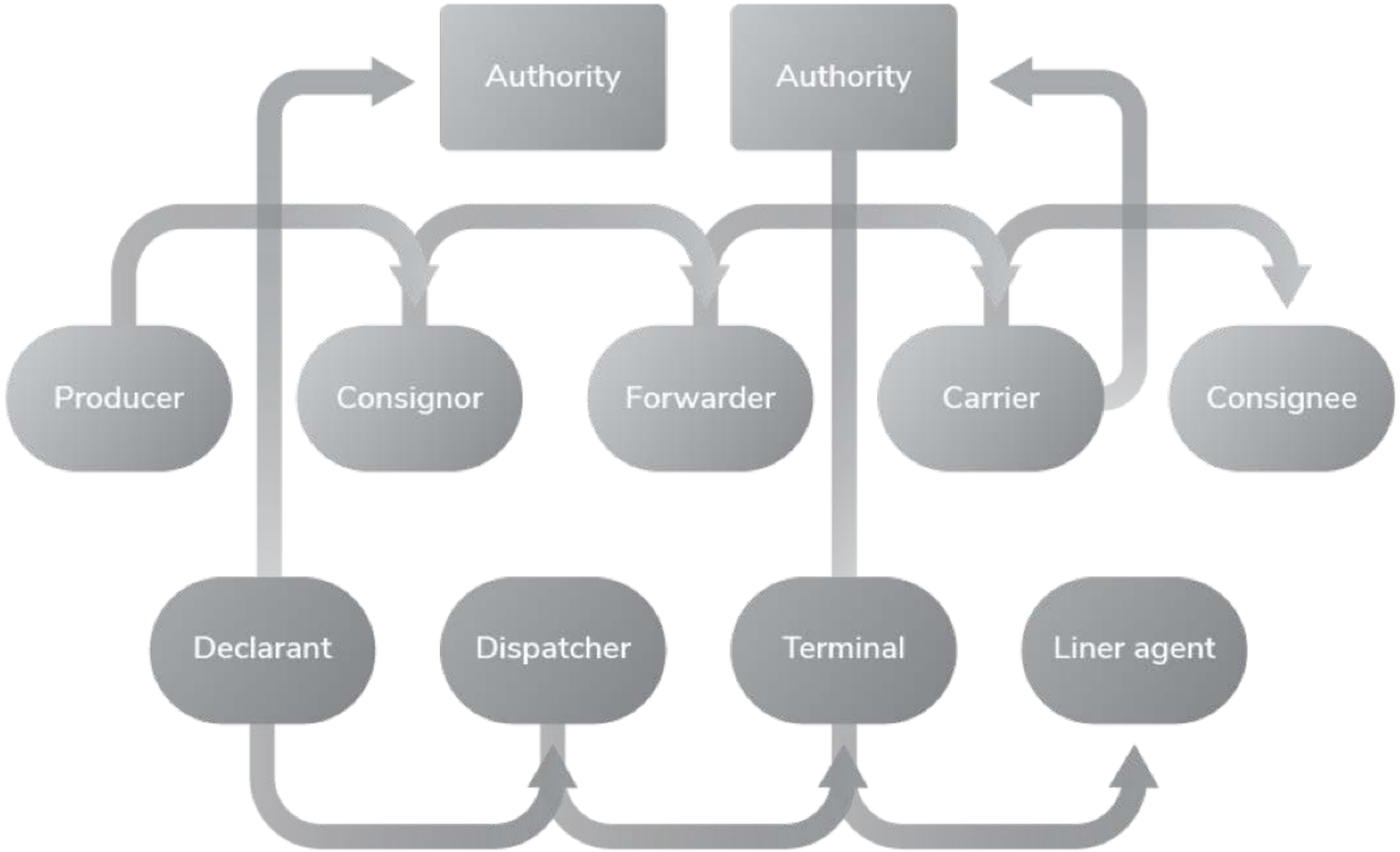
# Global supply chains are complex....




3 TYPES OF FLOW *

*SPECIFIC TRADE LANES WILL DETERMINE EXACT FLOWS AND STAKEHOLDERS

# ...and their processes are predominantly manual.

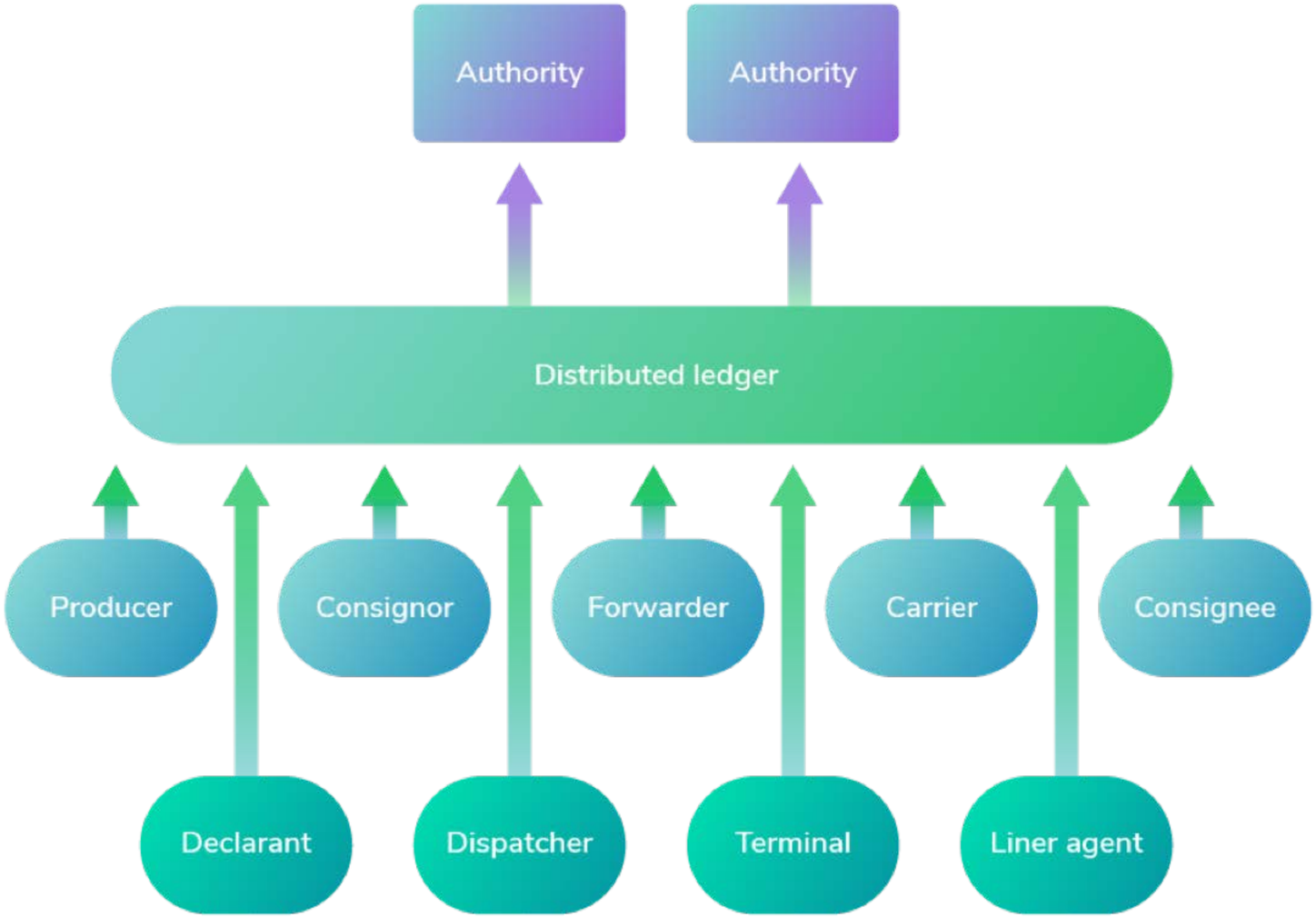



Innovation in the international trading has been so far unsuccessful due to the following too established practices:

- Emails, phone calls and paper documents are the daily details of moving goods;
- Information is delivered bilaterally and retyped into new systems with introduction of errors and loss of data integrity and authenticity;
- Multiple data formats are used and often not compatible one with the other.

As result, actors are unable to automatically broadcast/receive notification of events to relevant parties. This generates delay, inefficiencies and loss.

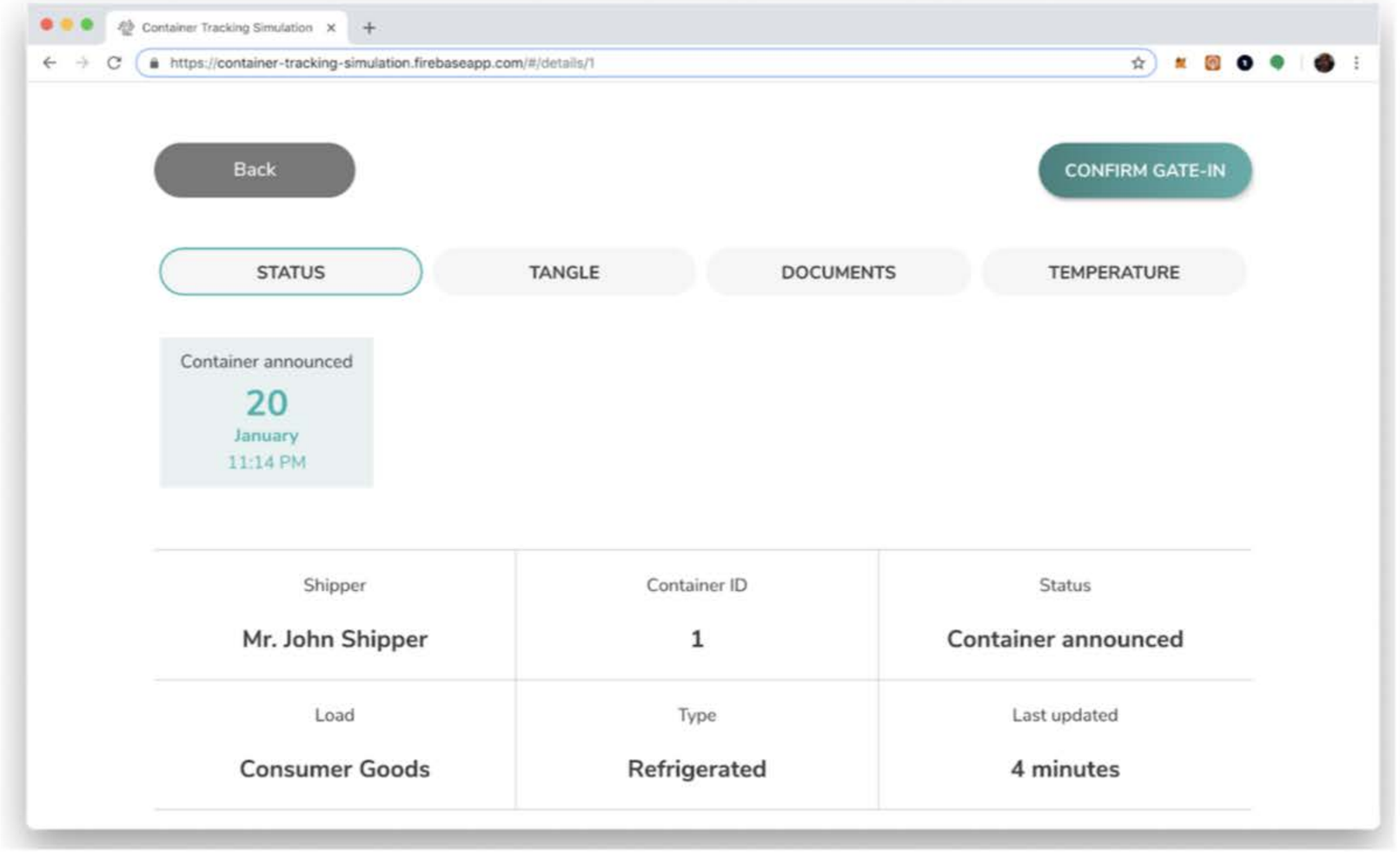
# Introducing DLT to Global Trade

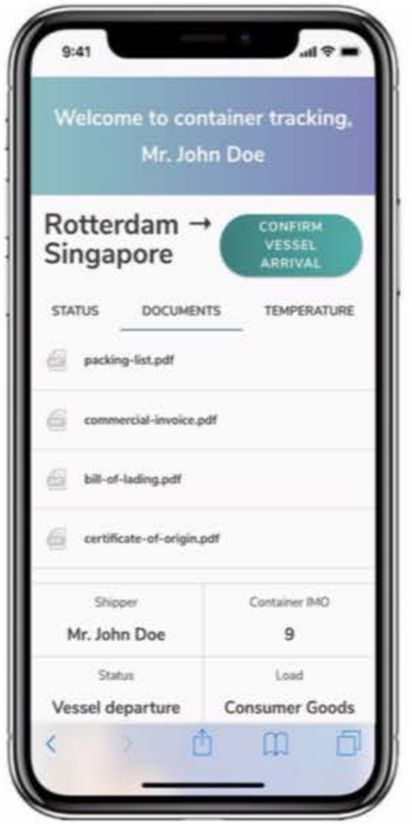



Use of distributed ledger technologies, and IOTA in particular, can help to mitigate these risks.

The permissionless nature of IOTA Tangle allows for any party to start sharing the required information, with guaranteed tamper resistance.

In addition, the use of an IOTA 2nd encryption protocol (MAM) allows for fine grain control of information access, despite the distributed nature of the IOTA Tangle.

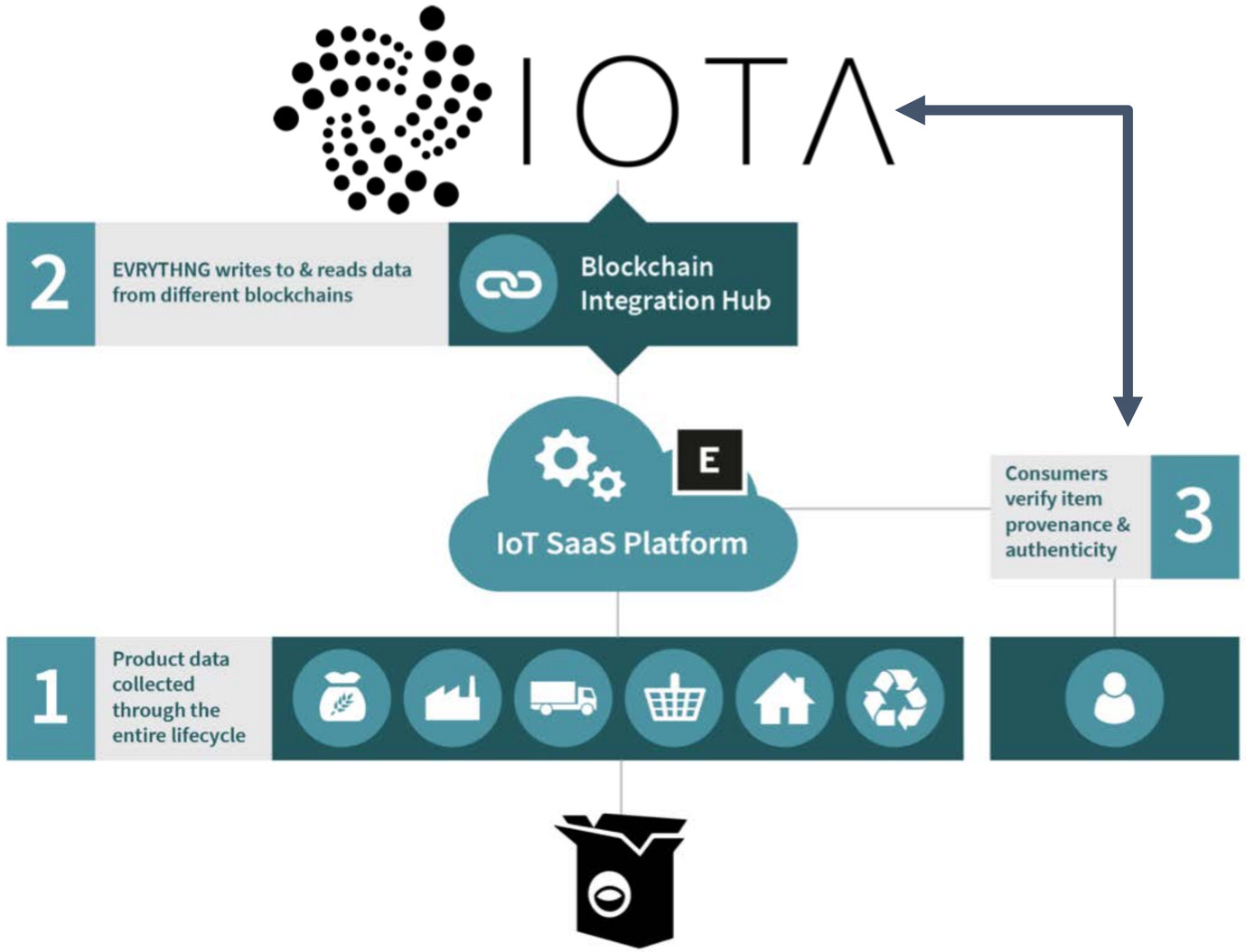



Live Demonstration: https://tradedemo.iota.org/

Open source code: https://github.com/iotaledger/trade-poc

# Products authenticity




- Objects carry a unique digital Identity
- Collected data are stored centrally and into IOTA ledger
- Consumers verify authenticity of data and products

# Asset tracking

IBCS Poland
Relentless Innovation

- Tracking chain of custody of high value stands across value chain and competitors
- Using barcodes for identification (GS1 standard)

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**Useful resources**

https://www.iota.org/research/
https://blog.iota.org/
https://iota.readme.io/docs
https://docs.iota.org/