CS61065: Theory and Applications of Blockchain

Department of Computer Science and Engineering

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

BLOCKCHAIN INTEROPERABILITY

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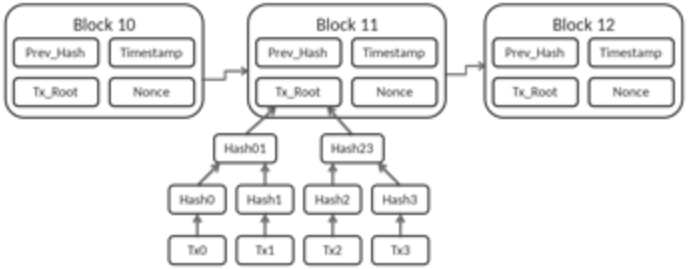
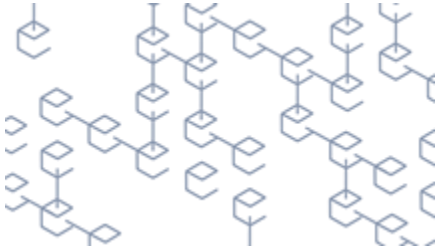
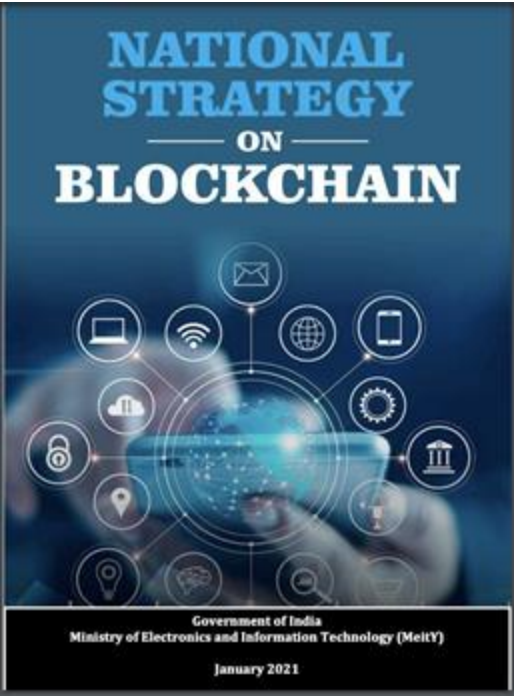


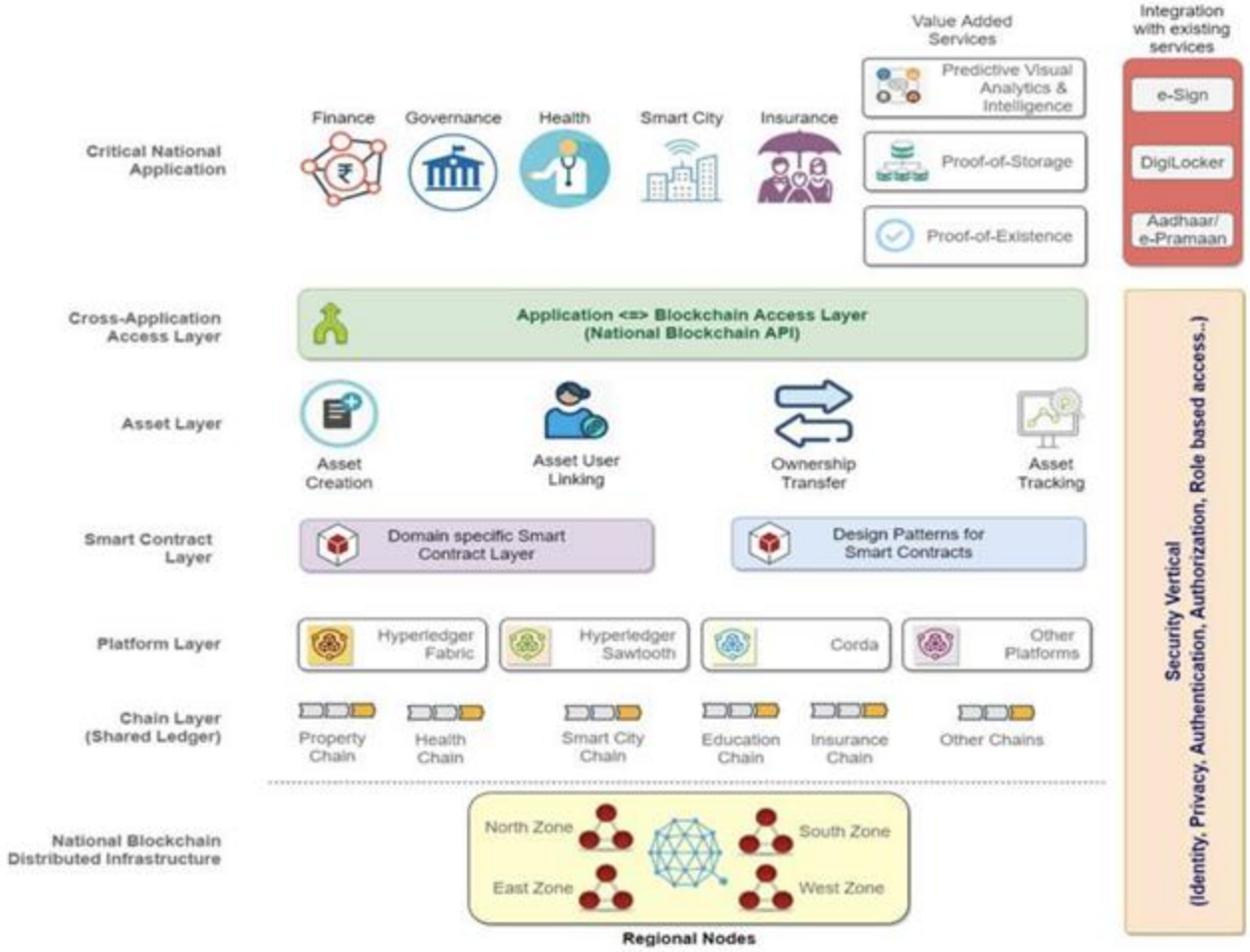
Blockchains

Public/Open (Permissionless)

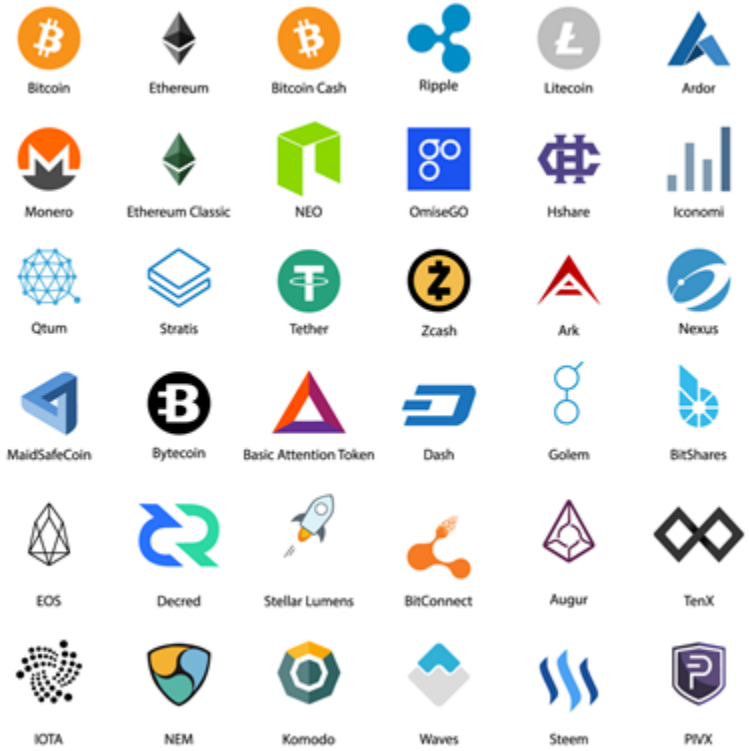


Private/Closed (Permissioned)


NATIONAL STRATEGY
ON
BLOCKCHAIN
Government of India
Ministry of Electronics and Information Technology (MeitY)
January 2021


Value Added Services
Integration with existing services
Predictive Visual Analytics & Intelligence
Proof-of-Storage
Proof-of-Existence
e-Sign
DigiLocker
Aadhaar/ e-Pramaan
Critical National Application
Finance
Governance
Health
Smart City
Insurance
Cross-Application Access Layer
Application <=> Blockchain Access Layer (National Blockchain API)
Asset Layer
Asset Creation
Asset User Linking
Ownership Transfer
Asset Tracking
Smart Contract Layer
Domain specific Smart Contract Layer
Design Patterns for Smart Contracts
Platform Layer
Hyperledger Fabric
Hyperledger Sawtooth
Corda
Other Platforms
Chain Layer (Shared Ledger)
Property Chain
Health Chain
Smart City Chain
Education Chain
Insurance Chain
Other Chains
National Blockchain Distributed Infrastructure
North Zone
South Zone
East Zone
West Zone
Regional Nodes
Security Vertical
(Identity, Privacy, Authentication, Authorization, Role based access..)

Public/Open (Permissionless)



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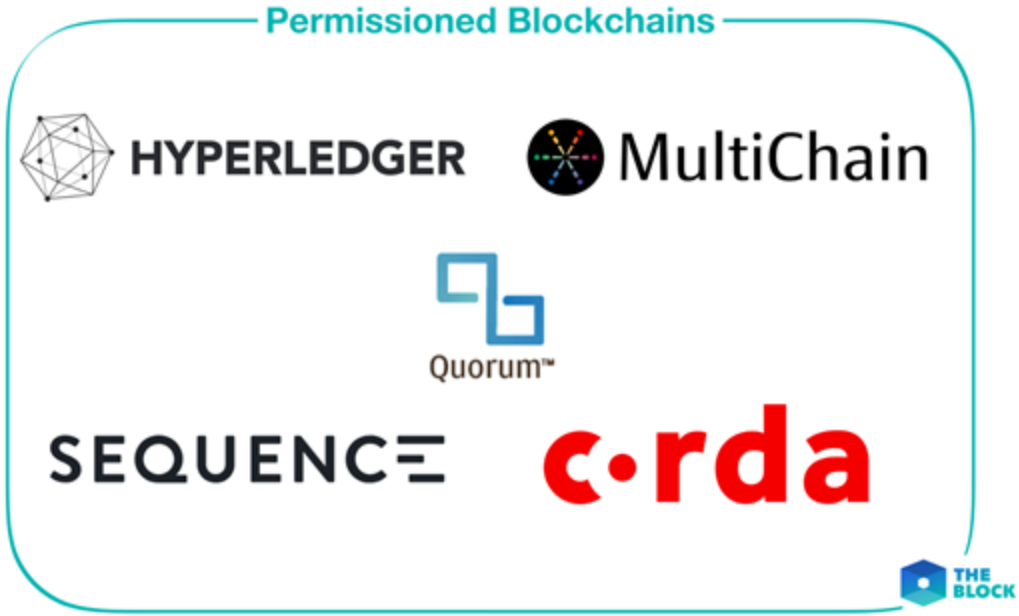


Interoperability in Permissionless and Permissioned Blockchains

- Permissionless Blockchain
  - Asset Transfer
  - Crypto currency driven
- Permissioned Blockchain
  - Data Transfer
  - Consensus-driven

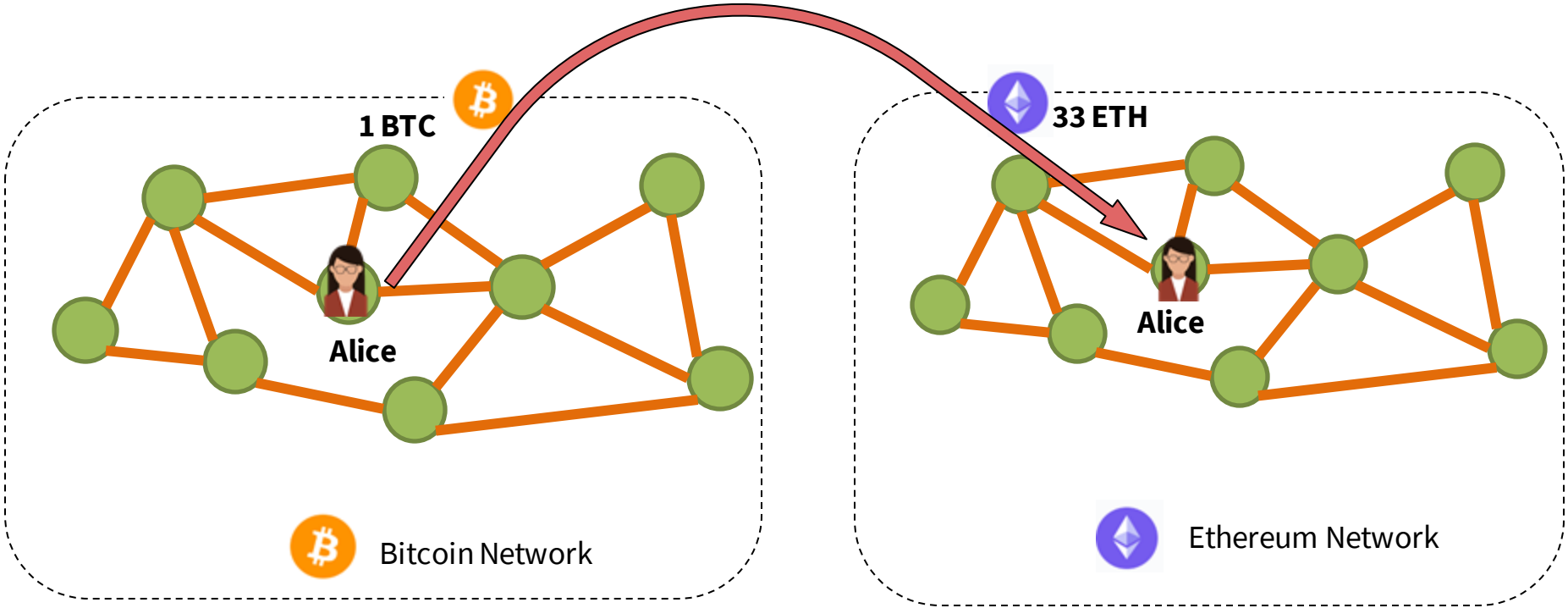
Permissionless Blockchain Interoperability

Public Blockchains as Isolated Silos

- Blockchain-based cryptocurrencies enable secure and trustless currency transactions between parties.
- There are currently **over 2000** different cryptocurrencies in operation.
- Separate blockchain networks with often different protocols and standards
- **Continue to operate in complete isolation from one another.**

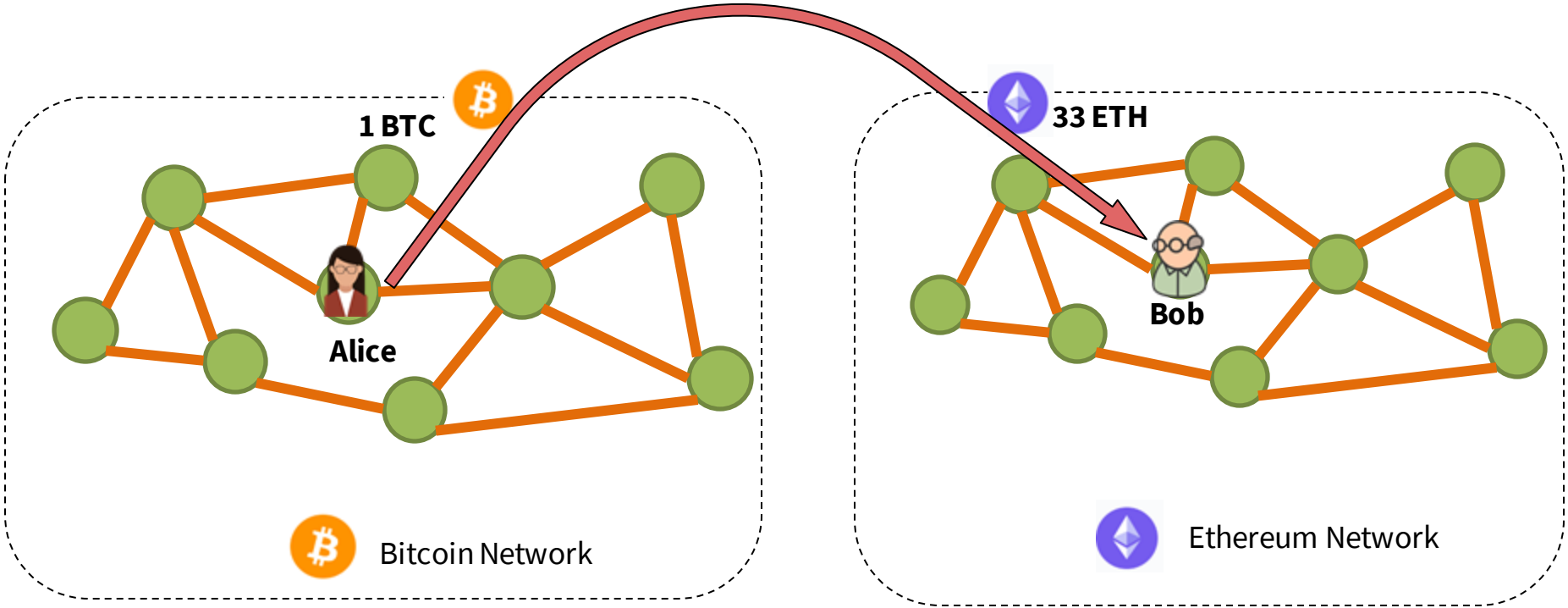
Bentov, Iddo, Yan Ji, Fan Zhang, Lorenz Breidenbach, Philip Daian, and Ari Juels. "Tesseract: Real-time cryptocurrency exchange using trusted hardware." In Proceedings of ACM SIGSAC Conference on Computer and Communications Security. 2019.

Cross Chain Asset Transfer



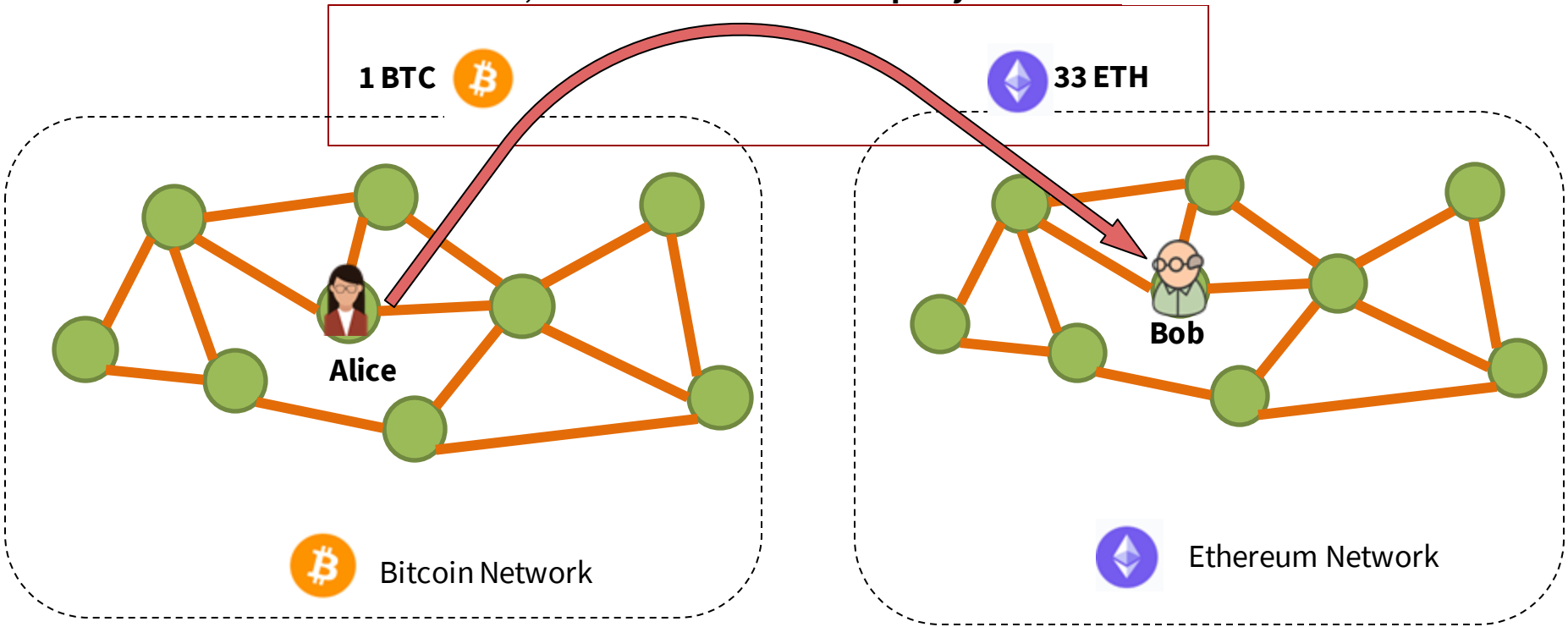
Cross Chain Asset Transfer

Possible between different accounts and holders also.

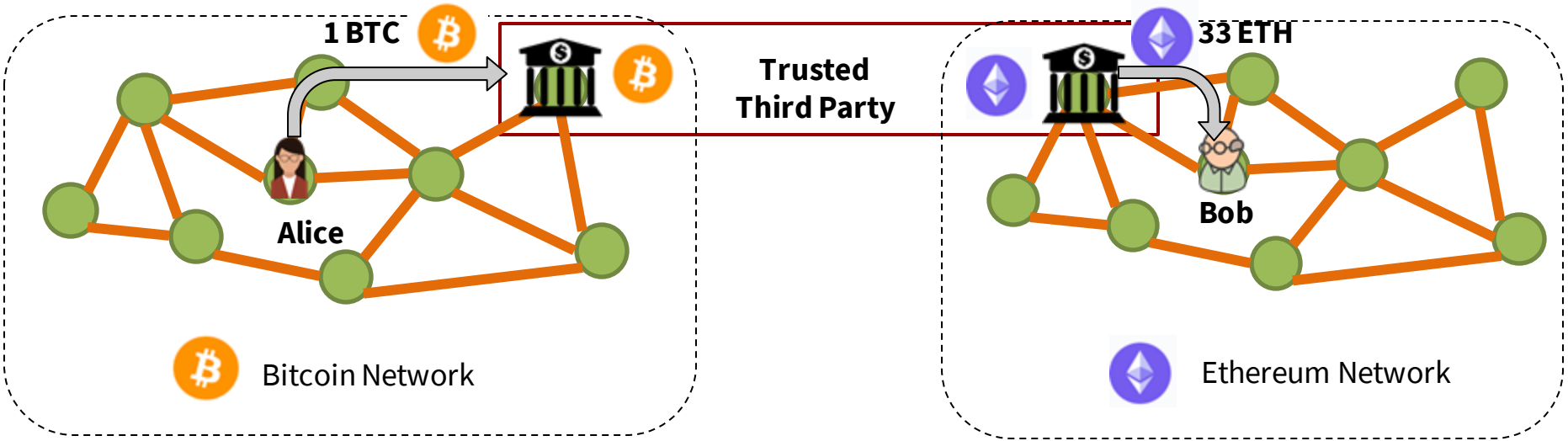


Cross Chain Asset Transfer

To do the transfer, **Alice** must use some **third party who owns** ≥ 33 ETH



Cross Chain Asset Transfer - TTP

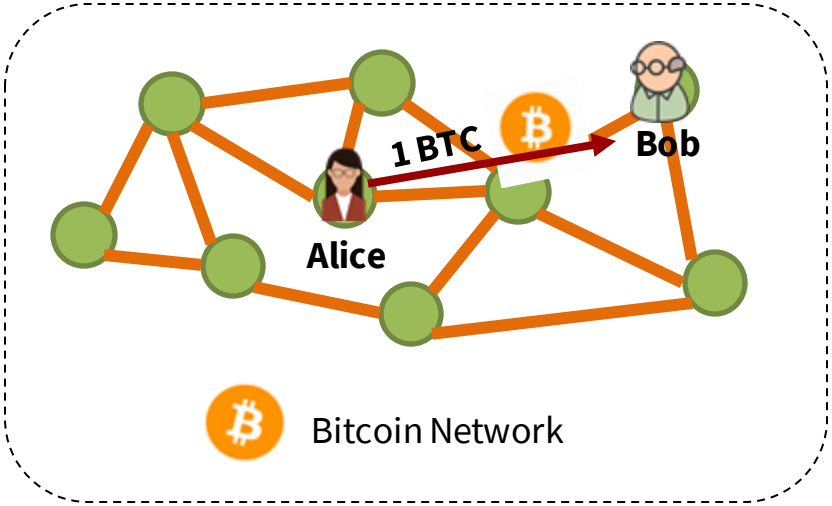


TTP based Asset Transfer

- There are hundreds of centralized cryptocurrency exchanges now.
- **Centralized,** users transfer ownership of their funds to the sole control of the exchange administrator.
- **Fast,** once the deposit is done, the transfer to the destination network is often very fast (in milliseconds).
- **Lack of security:** There has been **numerous cases of theft** from centralized exchanges.
- **650,000 bitcoins lost** when the **MtGox** exchange shut down in 2014.
- Users of the Bitfinex exchange lost approximately **120,000 bitcoins** in 2016

https://bitcointalk.org/index.php?topic=576337
https://www.reuters.com/article/us-bitcoin-mtgox-wallet-idUSBREA2K05N20140321
https://www.reuters.com/article/us-bitfinex-hacked-hongkong-idUSKCN10E0KP

Asset Exchange



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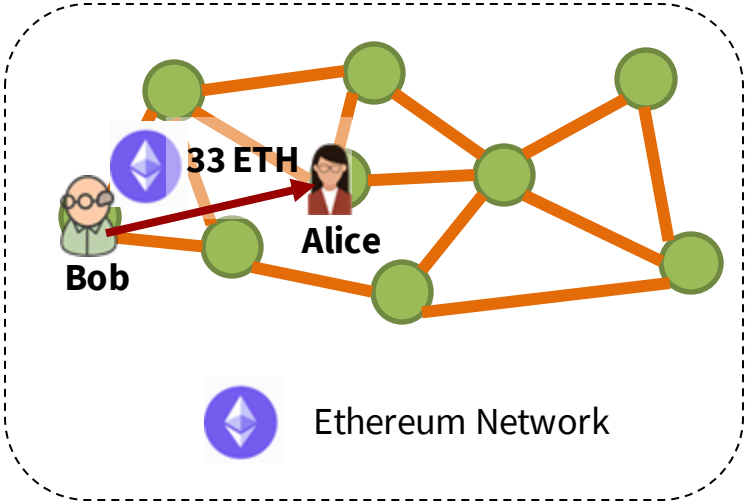


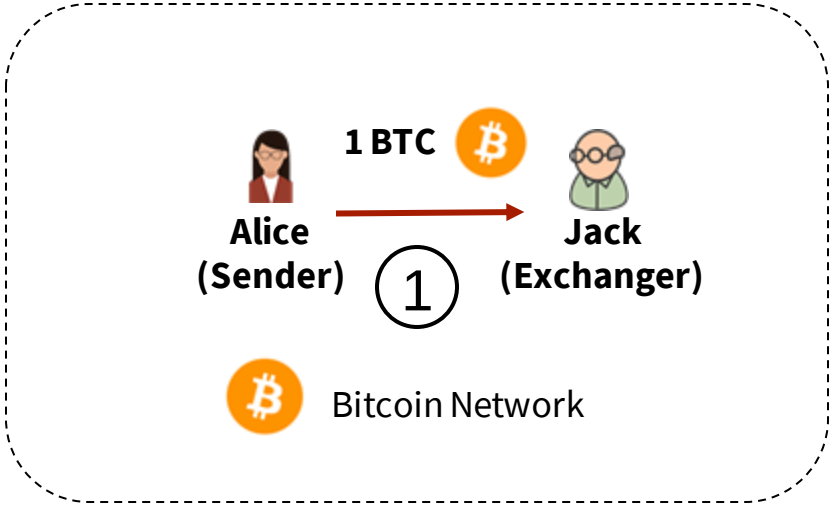
2

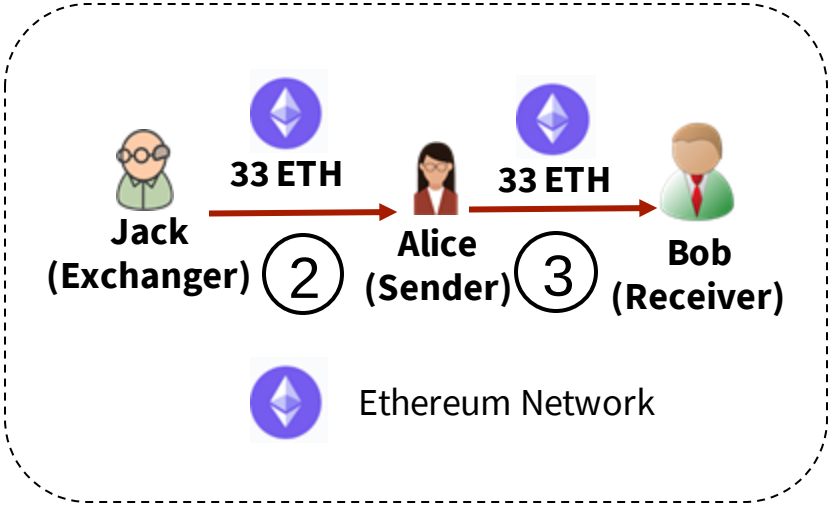
- Transfer in both the networks from Alice to Bob (1) and from Bob to Alice (2) must be **ATOMIC**.

Asset Exchange - Problems

- Without the presence of any Escrow, the funds are in control of the sender and receiver parties.
- One party might **abort** the exchange after receiving funds.
- Synchronization problems between the two networks, as well as sender and receiver.
- Difficulty in agreement on exchange rates which may keep on changing every second.

Cross Chain Asset Transfer using Atomic Exchange





1 2 **Atomic Exchange**

3 **Transfer**

Therefore, solving atomic exchange will solve most challenges of asset transfer.

Atomic cross-chain swaps (PODC ‘18)

Atomicity: An atomic transaction is an indivisible series of operations, such that either all occur, or none occurs.

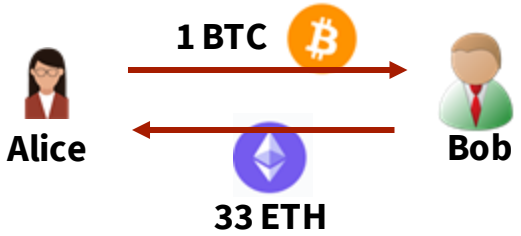
An atomic swap protocol guarantees:

(1) if all parties conform to the protocol, then all swaps take place

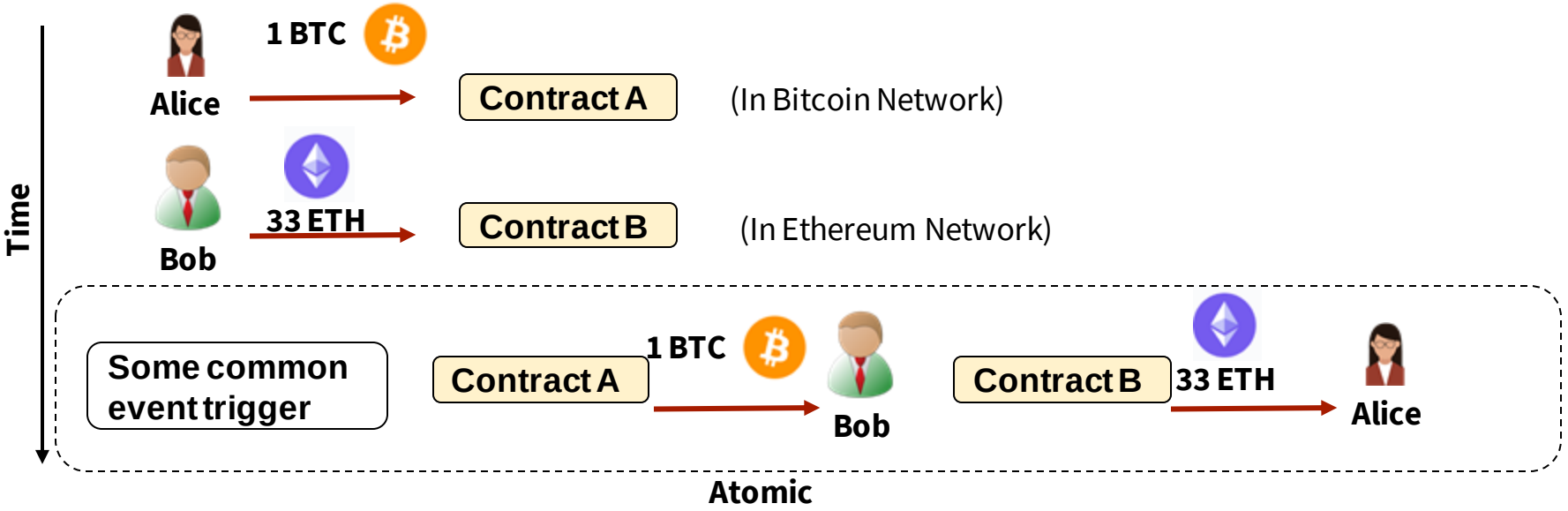
(2) if some parties deviate from the protocol, then no conforming party ends up worse off

(3) no coalition has an incentive to deviate from the protocol

Basic Idea



1. Initialize smart contracts on both ends with the amount.
2. Add a **common spending condition**, such that when the condition is met, **both the parties are paid simultaneously**.



Hashlock and Timelock

- **Hashlock:** a function that restricts the spending of funds until a certain piece of data is publicly disclosed (as a cryptographic proof).
  - Hash of a secret pre-image is posted as a hashlock.
  - When the secret is revealed, the funds are released.

- **Timelock:** is a function that restricts the spending of funds until a specific time (**or block height**) in the future.

Hash Locks

Hashlock is a type of encumbrance that restricts the spending of an output until **a specified secret key is publicly revealed**.

Inherent Property: Once any hashlock is opened publicly, any other hashlock secured using the same key can also be opened.

Example:
Alice generates a secret **key** **"I love strawberries"**
Alice computes the Cryptographic Hash of the key: **f1b81571baac90bed544d1910f79ea5c31fa4509**

Alice initiates a Hash Locked contract of **1 BTC** (some amount) which has the **conditions**:
If **key is revealed** - **pay BOB** with 1 BTC.

The contract also contains the Hash, which allows any miner to verify the revealed key.

Time Locks

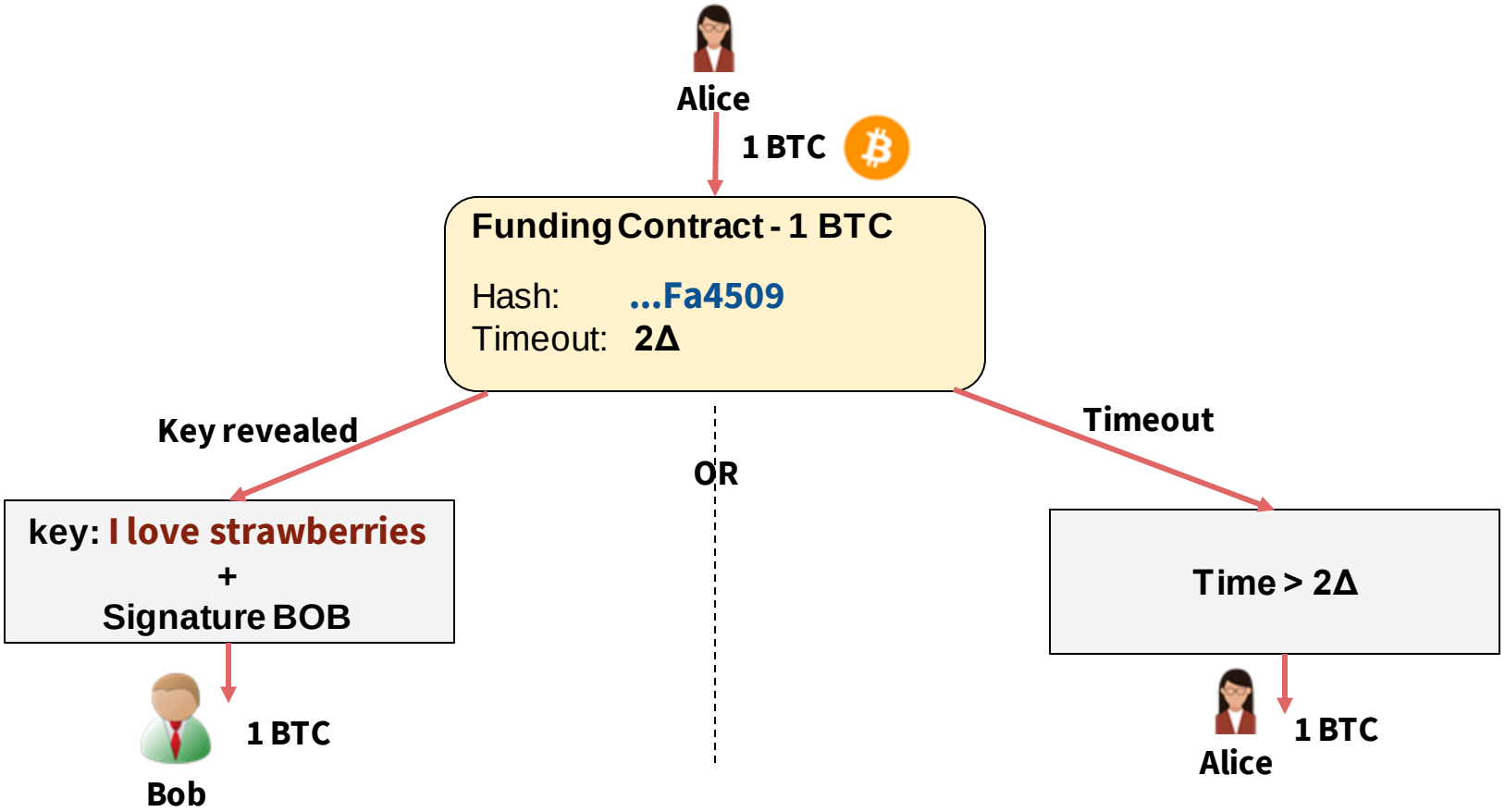
Timelock is a type of smart contract primitive that restricts the spending/transfer of some currency until a specified future time.

Block height may be used as a proxy for time.

Example:
Alice generates a timelocked contract with 1 BTC, and time = 2Δ (Δ = some time unit)

Therefore, after 2Δ time, 1 BTC will be transferred to a **target account**.
(The target account can be Alice's own account)

HTLC - Hash Time Locked Contract



Poon, Joseph, and Thaddeus Dryja. "The bitcoin lightning network: Scalable off-chain instant payments." (2016).

HTLC for Atomic Swap

(1) Alice samples a random $x \in \{0,1\}^{\lambda}$, computes a hash commitment $Y = \text{hash}(x)$, and broadcasts a transaction TX_A that spends n_1 BTC into an output script that dictates:
   - Alice can gain back possession of her n_1 BTC after $c_0 + t_0 + s_0$ blocks.
   - Bob can redeem the n_1 BTC by supplying a preimage of Y and signing with his secret key.

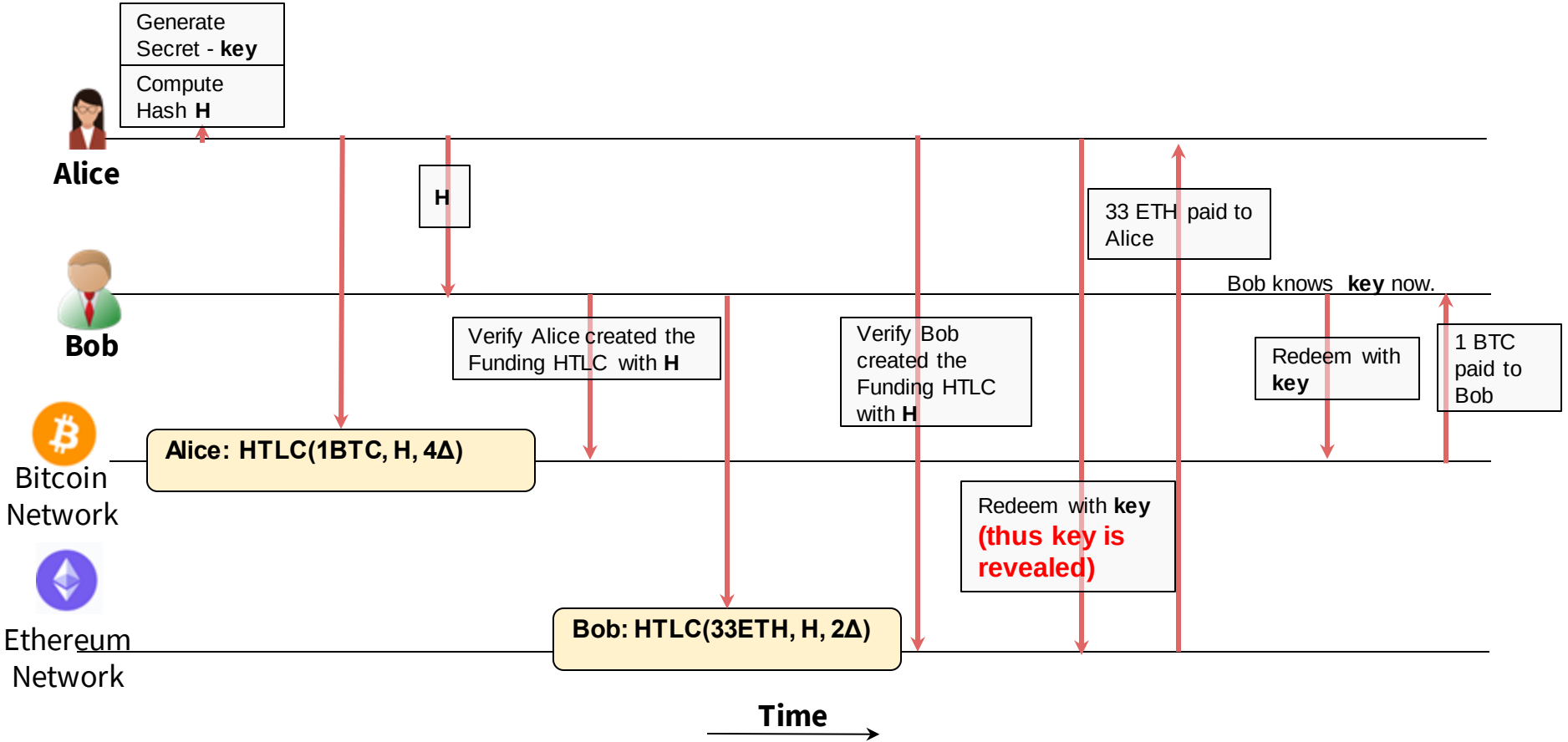
(2) After TX_A is buried under c_0 extra blocks and therefore becomes irreversible w.h.p., Bob broadcasts a transaction TX_B that spends his n_2 LTC into an output script that dictates:
   - Bob can gain back possession of his n_2 LTC after $4t_0$ blocks.
   - Alice can redeem the n_2 LTC by supplying a preimage of Y and signing with her secret key.

(3) After TX_B is buried under $f(c_0)$ extra blocks and therefore becomes irreversible w.h.p., Alice redeems the n_2 LTC of Bob by revealing x.

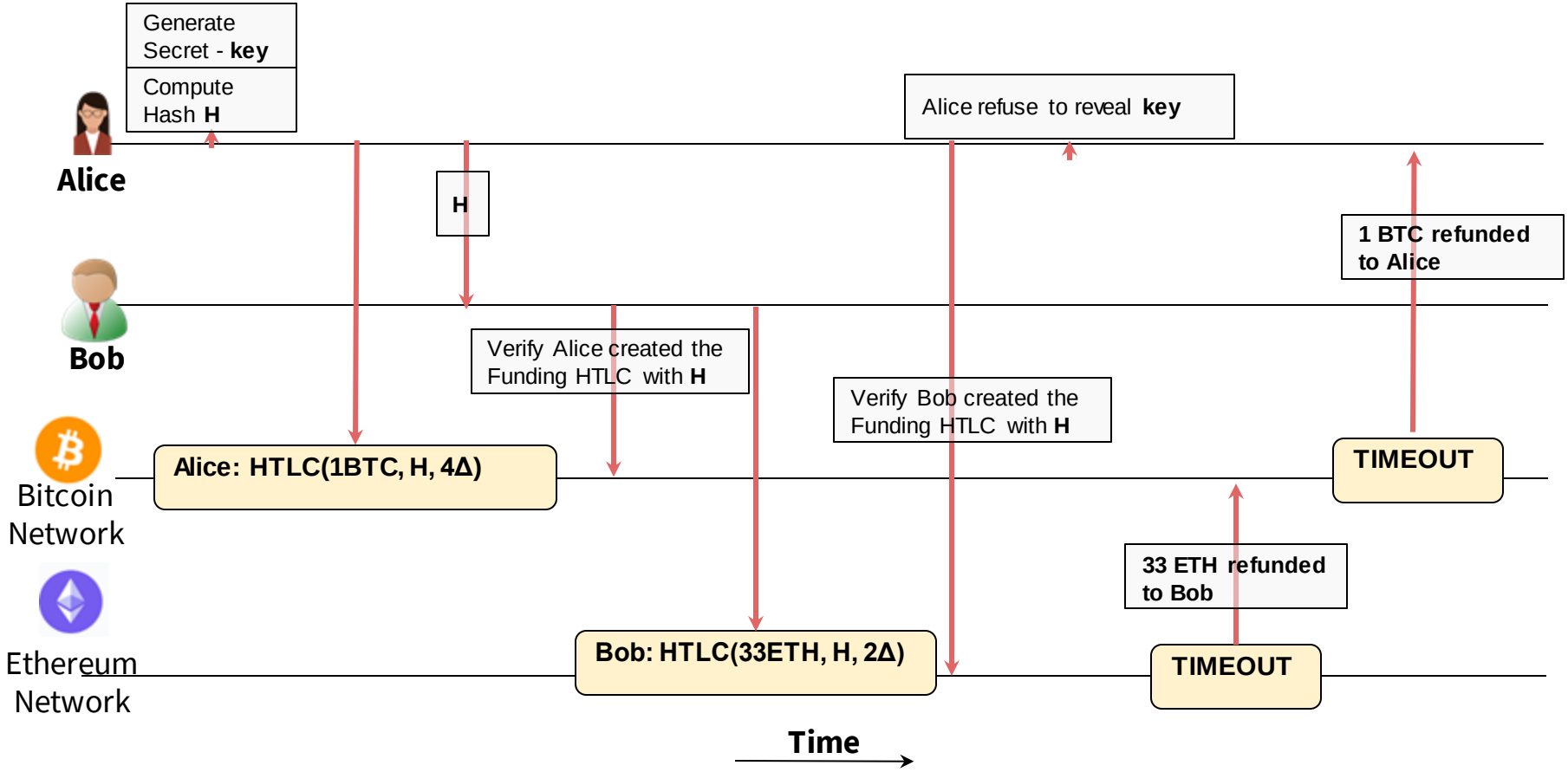
(4) Bob supplies x to redeem the n_1 BTC of Alice.

For a nice illustrative example
Visit this site

HTLC for atomic swap



What if Alice does not reveal key ?



Multi-Party Atomic Cross-chain Swap

- Carol wants to sell her Cadillac for bitcoins. Alice is willing to buy Carol's Cadillac, but she wants to pay in an "alt-coin" cryptocurrency
- Bob is willing to trade alt-coins for bitcoins
- Alice, Bob and Carol need to arrange a three-way swap:
  - Alice will transfer her alt-coins to Bob
  - Bob will transfer his bitcoins to Carol
  - Carol will transfer title of her Cadillac to Alice

M. Herlihy, "Atomic cross-chain swaps," in PODC, 2018.

Multi-Party Atomic Cross-chain Swap

- Alice creates a secret s, h = H(s), and publishes a contract on the alt-coin blockchain with hashlock h and timelock 6Δ in the future, to transfer her alt-coins to Bob.
- When Bob confirms that Alice's contract has been published on the alt-coin blockchain, he publishes a contract on the Bitcoin blockchain with the same hashlock h but with timelock 5Δ in the future, to transfer his bitcoins to Carol.
- When Carol confirms that Bob's contract has been published on the Bitcoin blockchain, she publishes a contract on the automobile title blockchain with the same hashlock h, but with timeout 4Δ in the future, to transfer her Cadillac's title to Alice.
- When Alice confirms that Carol's contract has been published on the title blockchain, she sends s to Carol's contract, acquiring the title and revealing s to Carol.
- Carol then sends s to Bob's contract, acquiring the bitcoins and revealing s to Bob.
- Bob sends s to Alice's contract, acquiring the alt-coins and completing the swap.

M. Herlihy, "Atomic cross-chain swaps," in PODC, 2018.

Multi-Party Atomic Cross-chain Swap

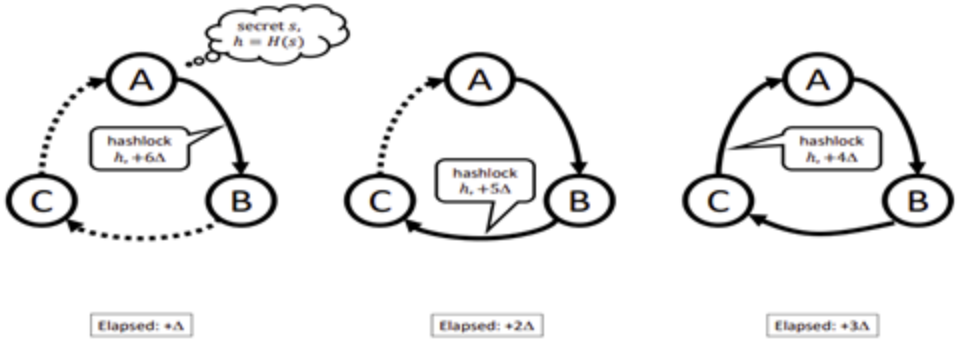


Figure 1: Atomic cross-chain swap: deploying contracts

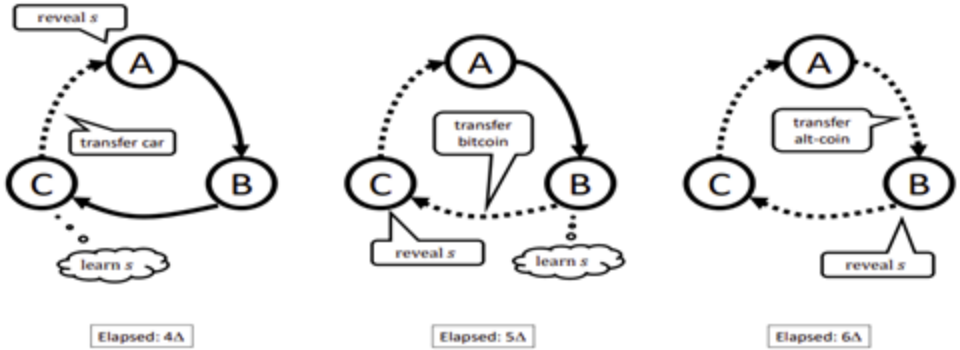


Figure 2: Atomic cross-chain swap: triggering arcs

M. Herlihy, “Atomic cross-chain swaps,” in PODC, 2018.

Validity of the Protocool

- If any party halts while contracts are being deployed, then all contracts eventually time out and trigger refunds.
- If any party halts during triggering of contracts, only that party ends up worse off.
  - If Carol halts without triggering her contract, then Alice gets the Cadillac and Bob gets a refund, so Carol's misbehavior harms only herself.
- The order in which contracts are deployed matters.
  - If Carol were to post her contract with Alice before Bob posts his contract with Carol, then Alice could take ownership of the Cadillac without paying Carol.
- Timelock values matter.
  - If Carol's contract with Bob were to expire at the same time as Bob's contract with Alice, then Carol could reveal s to collect Bob's bitcoins at the very last moment, leaving Bob no time to collect his alt-coins from Alice.

M. Herlihy, "Atomic cross-chain swaps," in PODC, 2018.

Multi-Party Atomic Cross-chain Swap

- What if parties behave irrationally?
  - If Alice (irrationally) reveals s before the first phase completes, then Bob can take Alice's altcoins and perhaps Carol can take Bob's bitcoins, but Alice will not get her Cadillac, so only she is worse off.
- Atomic swap protocol guarantees
  - If all parties conform to the protocol, then all swaps take place
  - If some parties deviate from the protocol, then no conforming party ends up worse off
  - No coalition has an incentive to deviate from the protocol

M. Herlihy, "Atomic cross-chain swaps," in PODC, 2018.

Limitations of this approach

- Slow, often takes **hours to execute**.
- Parties cannot respond to real time price fluctuations due to slow transactions.
- Vulnerable to a weak denial-of-service attack where an adversarial party repeatedly proposes an attractive swap, and then fails to complete the protocol, triggering refunds, but temporarily rendering assets inaccessible.

Permissioned Blockchain Interoperability

Interoperation in Permissioned Blockchains

- Permissioned blockchain networks are designed to be **private**, for a closed consortium.
- **Different business sectors** tend to have different groups of organizations, thus have **separate blockchain networks**.
- Eg: **TradeLens -** Logistics, **We.Trade** Trade finance, **IBM Food Trust** - Food Supply Chain, etc..
- **Continue to operate in complete isolation from one another.**
- Often there is **need for interoperation** between different isolated networks to achieve business goals.

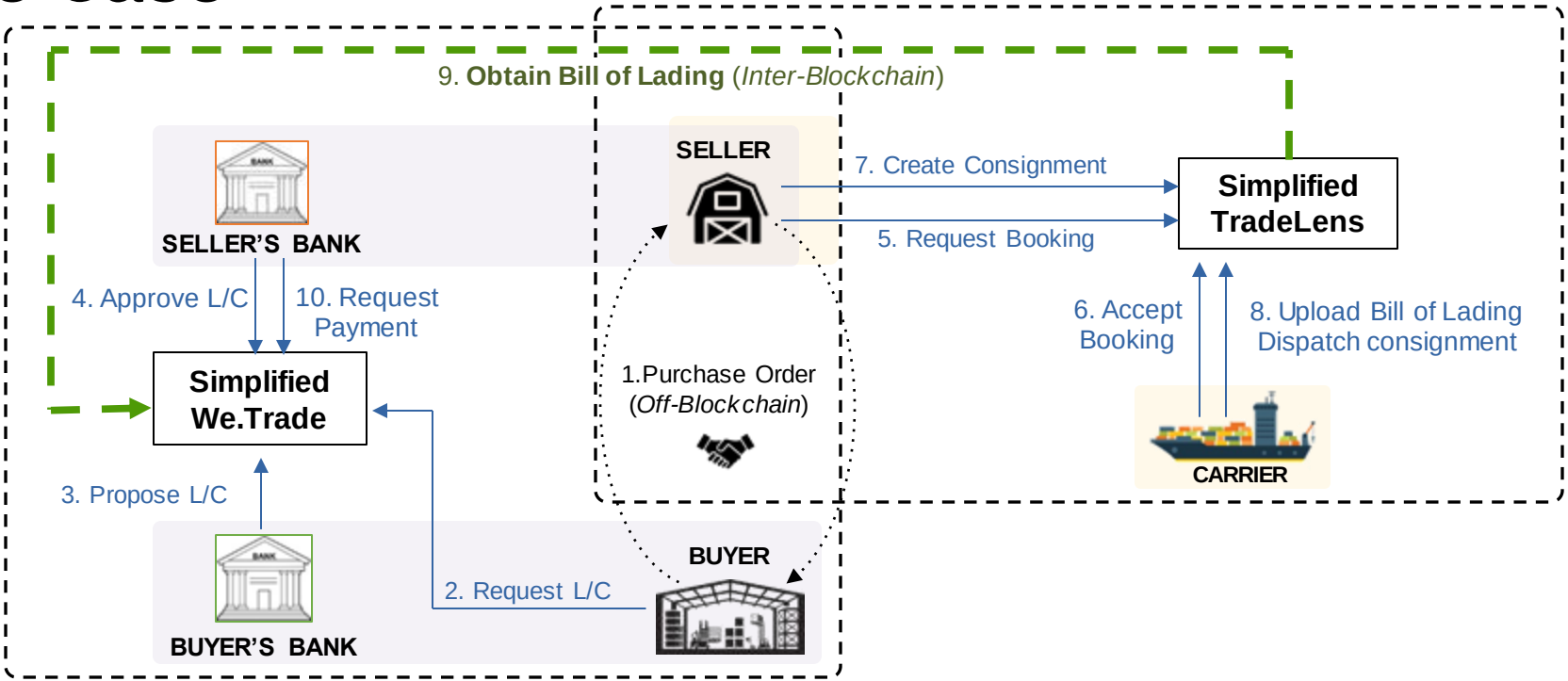
Abebe, E., Behl, D., Govindarajan, C., Hu, Y., Karunamoorthy, D., Novotny, P., Pandit, V., Ramakrishna, V. and Vecchiola, C., 2019, December. Enabling enterprise blockchain interoperability with trusted data transfer (industry track). In Proceedings of the 20th International Middleware Conference Industrial Track

Interoperation in Permissioned Blockchains

Challenges

- Here interoperation is specifically **Verifiable Data Transfer** between two separate permissioned blockchain networks.
- Data in a blockchain network is generated by transactions going through **consensus process**.
- Data has to be **consistent with the source network's state**.
- **Multiparty Trust -** When one network consumes state from another, it would need to establish the validity of the state according to the shared consensus view of parties in the network.

Use Case

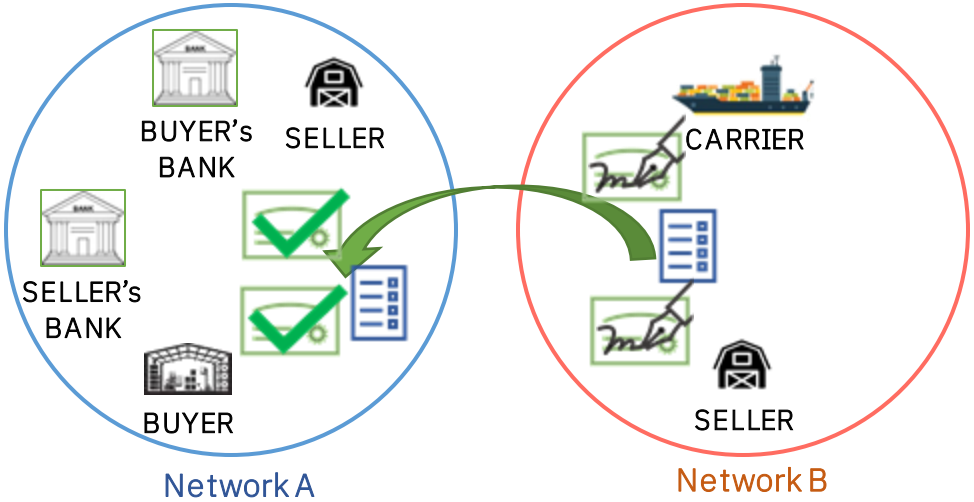


- **We.Trade** is a trade financing network
- **TradeLens** is trade logistics network
- **Letter of Credit (L/C)** – a bank confirmation that ensures payment will be made by the buyer
- **Bill of lading** proves that the seller has dispatched the goods via the carrier,
- It enforces an obligation on the buyer (as per letter of credit terms) to make a payment.

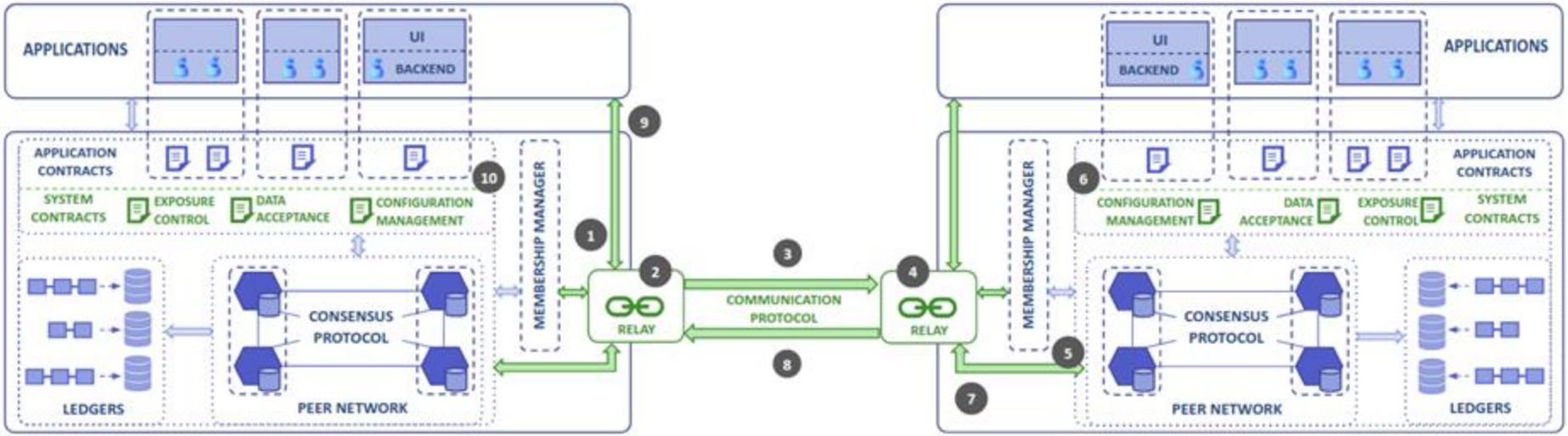
Verifiable Data Transfer in Permissioned Blockchain

Enabling Enterprise Blockchain Interoperability with Trusted Data Transfer (Middleware '2019)

- Each data (block) in a network has a set of **endorsements** (signatures) **for consensus**.
- This set of endorsements confirm the validity of a block in the network.
- Thus, from the source, **data is accompanied with the set of signatures** - **Attestations**.
- The attestations are **validated** in the destination network according to an **data acceptance policy**.



Architecture

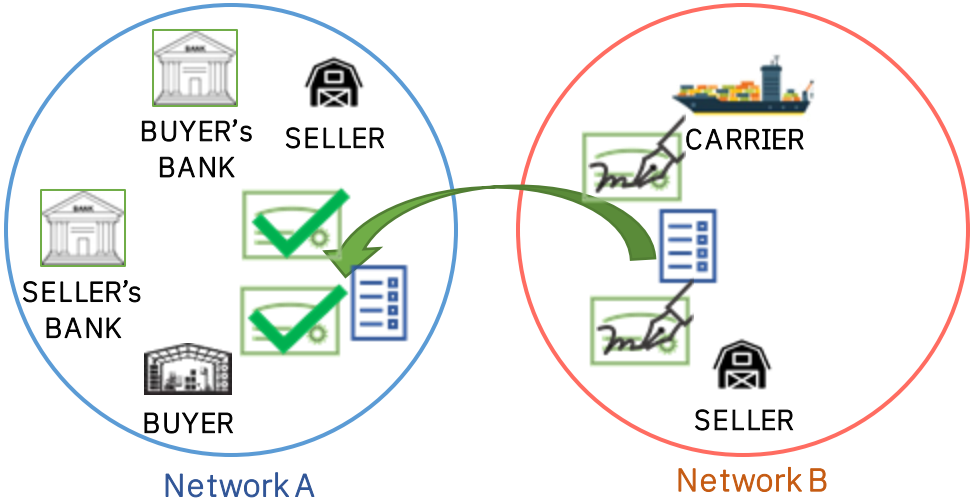


- **Relay Service:** Provides the means of communication between the two separate networks
- **Configuration Management Contract:** Maintain identity (public keys) of the interoperating networks.
- **Exposure Control Contract:** Define and enforce policies on what data to expose to which network.
- **Data Acceptance:** Validate the data received from a foreign network against the policy that defines how many signatures are required (and other conditions) to verify a data.

Protocol Overview

Steps:

1. Proof request is generated consisting of a verification policy which has to be met by the source network.
2. Access control policies are checked.
3. Response data along with proofs (endorsements) is sent back through the relay.
4. The proofs are validated against the verification policy.



Protocol Overview