TxProbe: Discovering Bitcoin's Network Topology Using Orphan Transactions

Sergi Delgado-Segura, Surya Bakshi, Cristina Pérez-Solà, James Litton, Andrew Pachulski, Andrew Miller and Bobby Bhattacharjee

sr_gi

MOTIVATION

What is the big deal with knowing the network topology?

- Is the network really decentralized?
- Are there supernodes in the network?
- Are there weak spots that can be easily isolated?

Currently, we do not know

THE TOPOLOGY SHOULD LOOK RANDOM

How Bitcoin (Core client) nodes choose their peers?

- Pseudorandomly from the **addrman**
- **8 outbound** connections by default

  No pair of nodes in the same **/16** (IPv4)
- **117 inbound** connection by default (no IP restriction here)

Bitcoin forks based on the Core client follow the same approach

REACHABLE AND NON-REACHABLE NODES

GLOBAL BITCOIN NODES DISTRIBUTION

Reachable nodes as of Thu Feb 07 2019 10:26:44 GMT+0000 (Greenwich Mean Time).

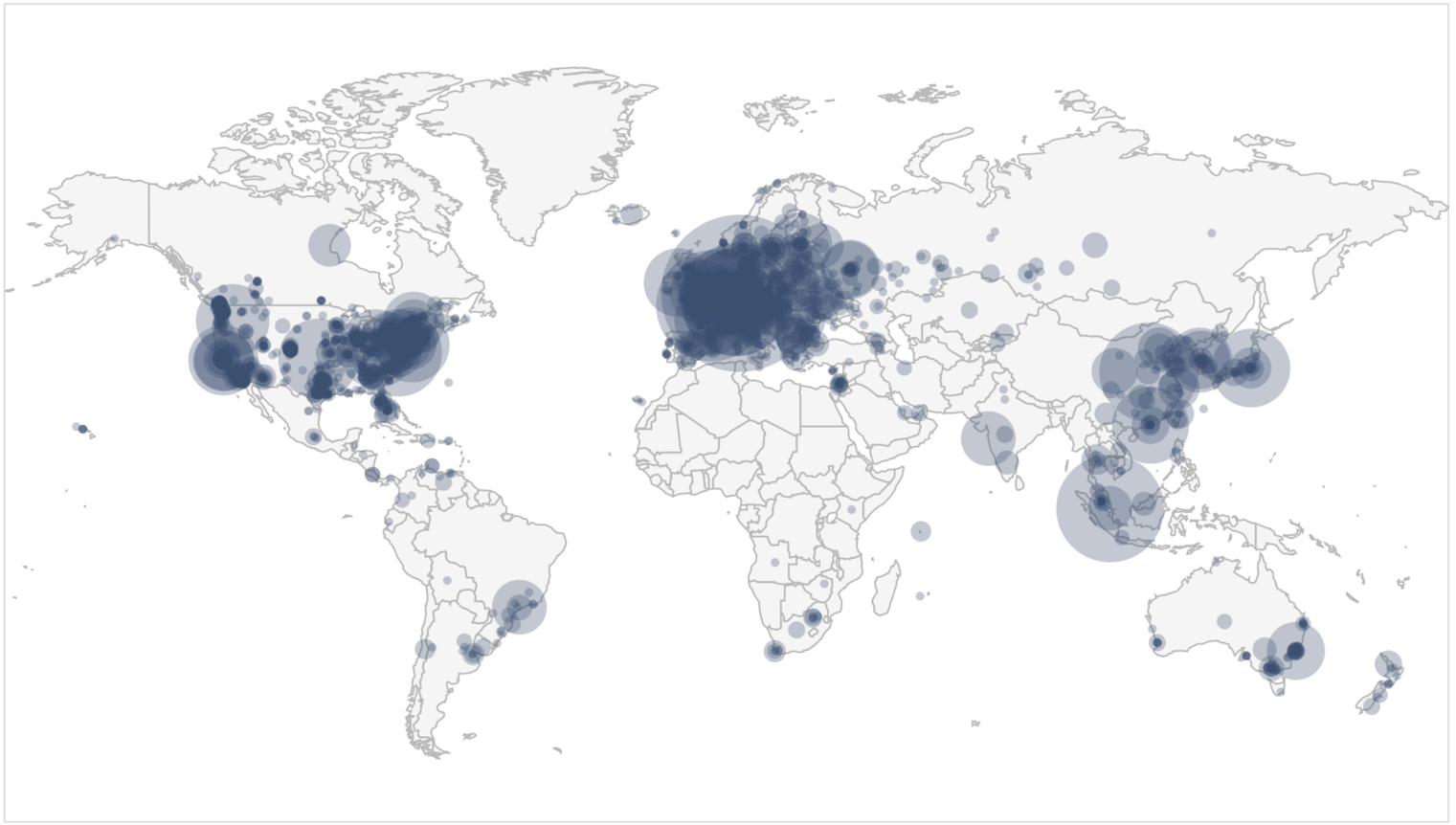
10365 NODES

24-hour charts »

Top 10 countries with their respective number of reachable nodes are as follow.

RANK	COUNTRY	NODES
1	United States	2570 (24.79%)
2	Germany	1968 (18.99%)
3	France	689 (6.65%)
4	Netherlands	514 (4.96%)
5	China	411 (3.97%)
6	Canada	384 (3.70%)
7	United Kingdom	355 (3.42%)
8	Singapore	321 (3.10%)
9	Russian Federation	277 (2.67%)
10	Japan	228 (2.20%)

More (100) »



Map shows concentration of reachable Bitcoin nodes found in countries around the world.

LIVE MAP

Source: https://bitnodes.earn.com/

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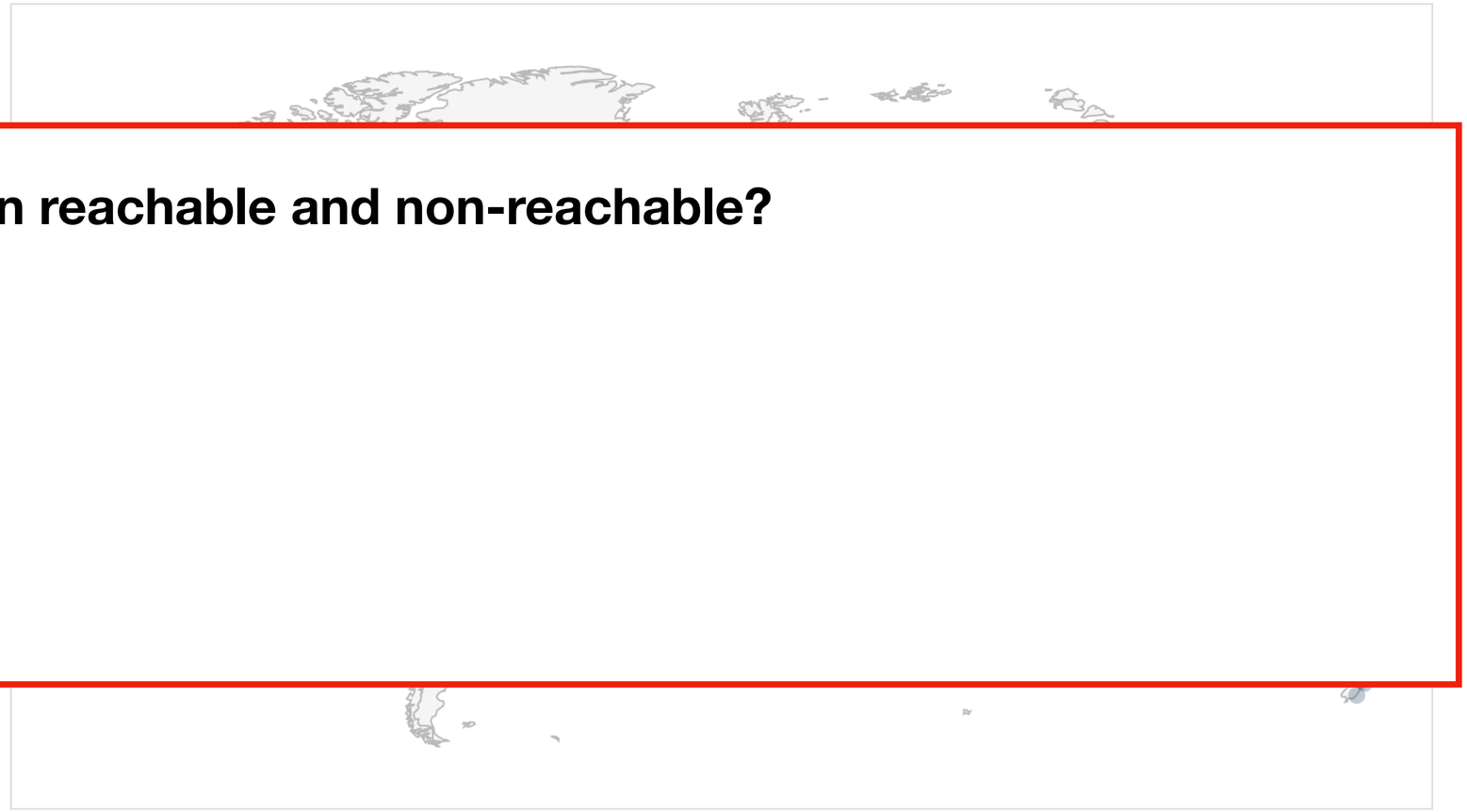

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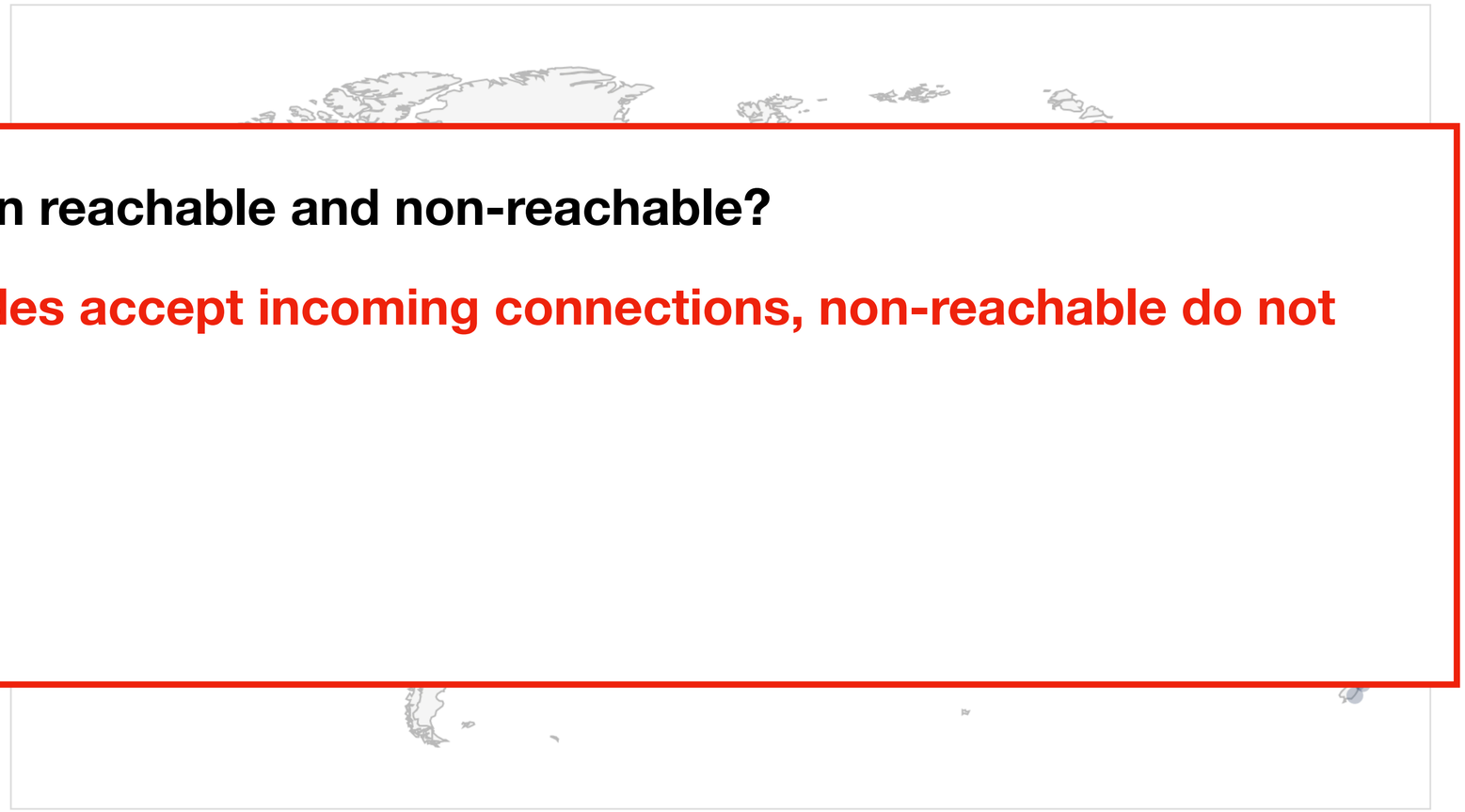

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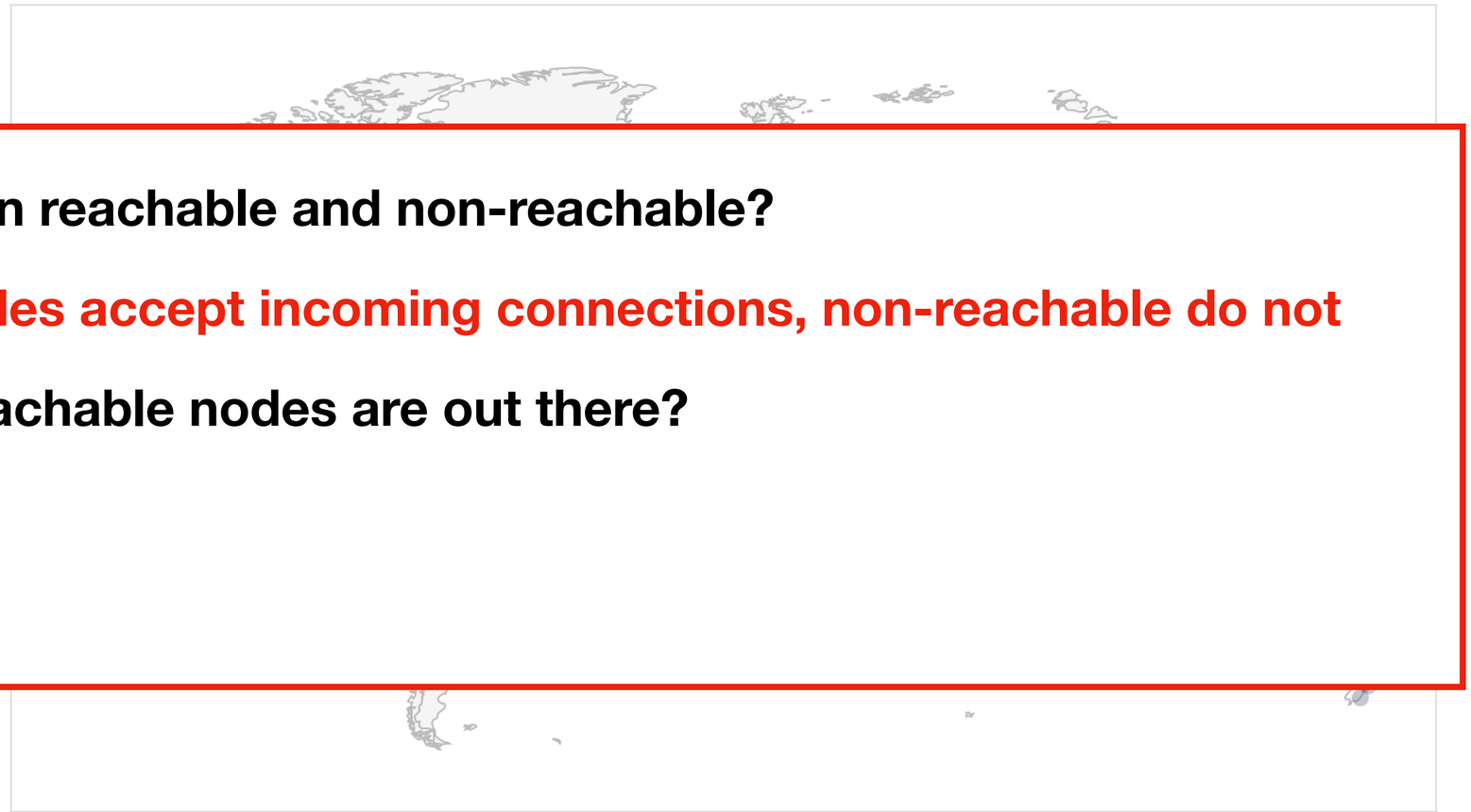

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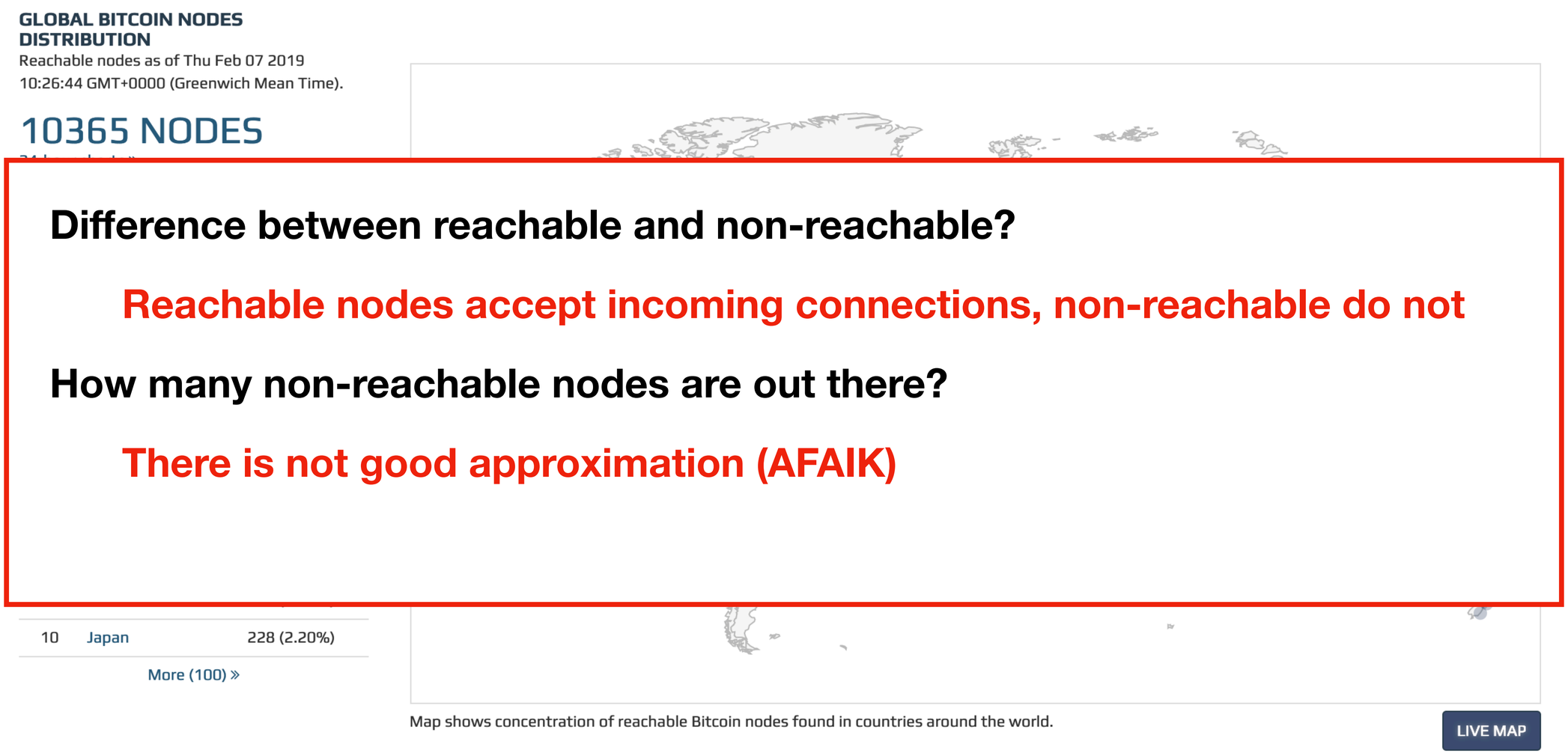

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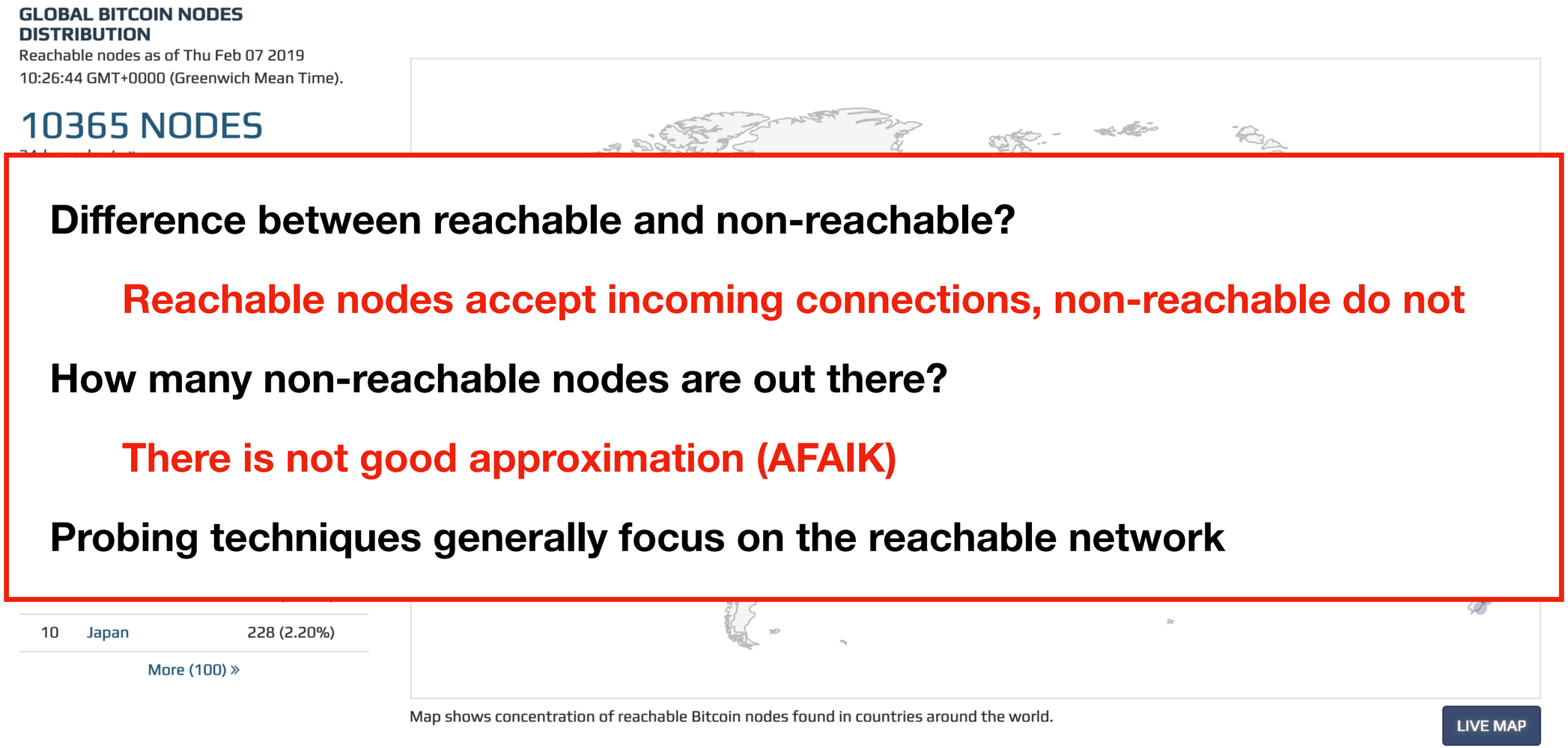

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Probing techniques generally focus on the reachable network

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TRANSACTION PROPAGATION IN BITCOIN

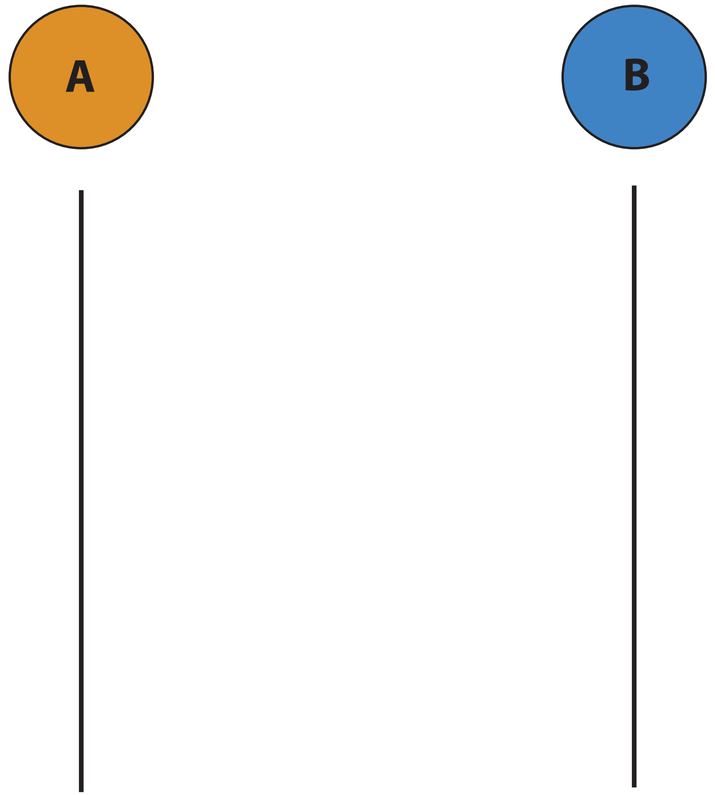
Our inferring technique is based on transaction propagation

We take advantage of how some kind of transactions (**orphans** and **double-spending)** are handled by nodes

How does it roughly work?

TRANSACTION PROPAGATION IN BITCOIN

Transactions are shared between peers in a push manner



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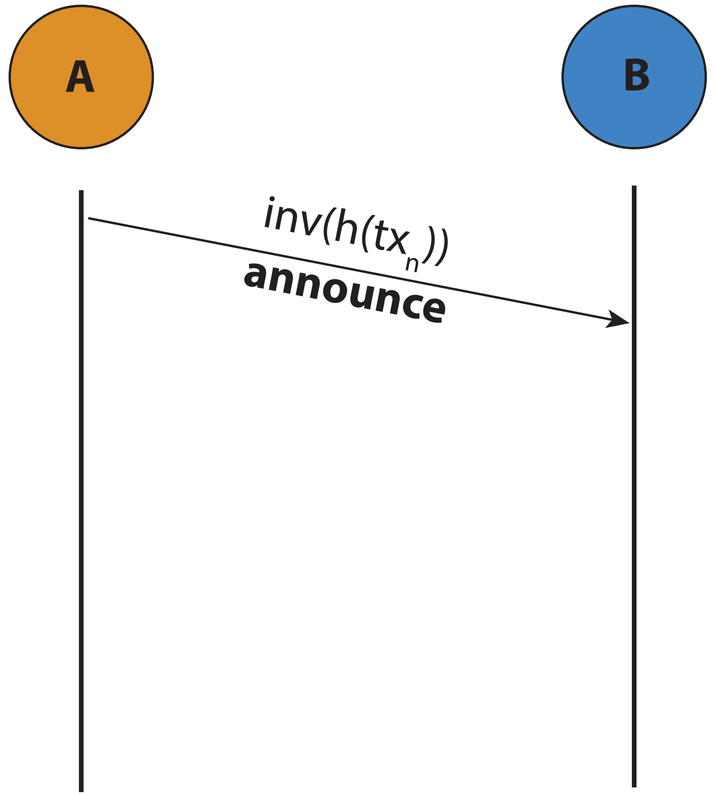

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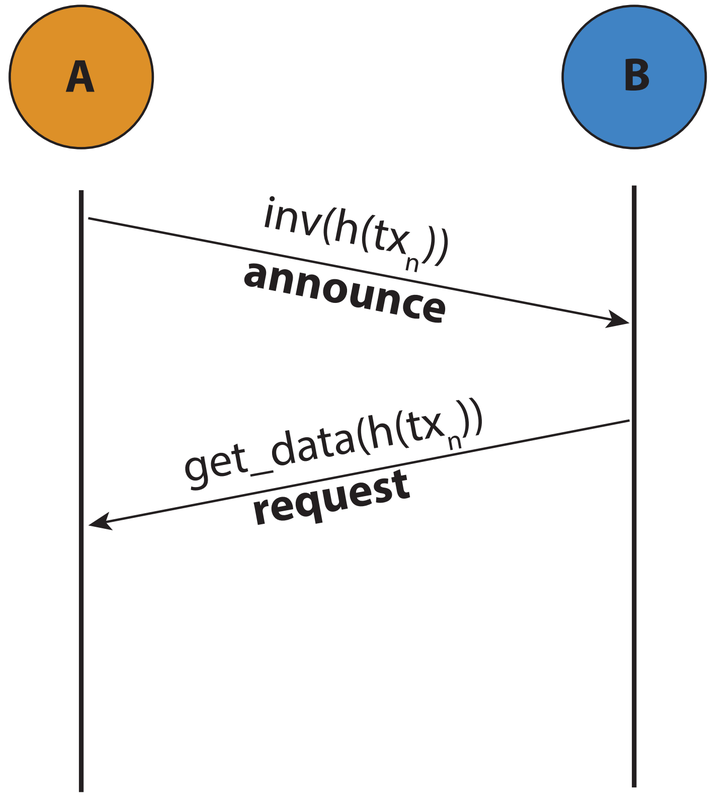

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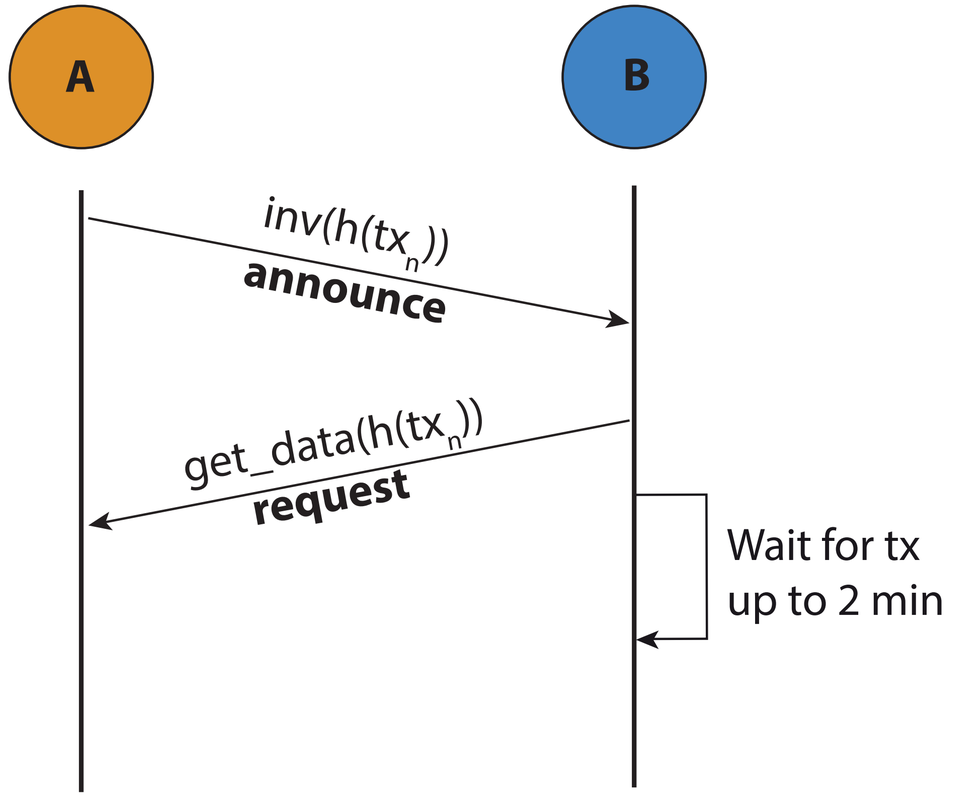

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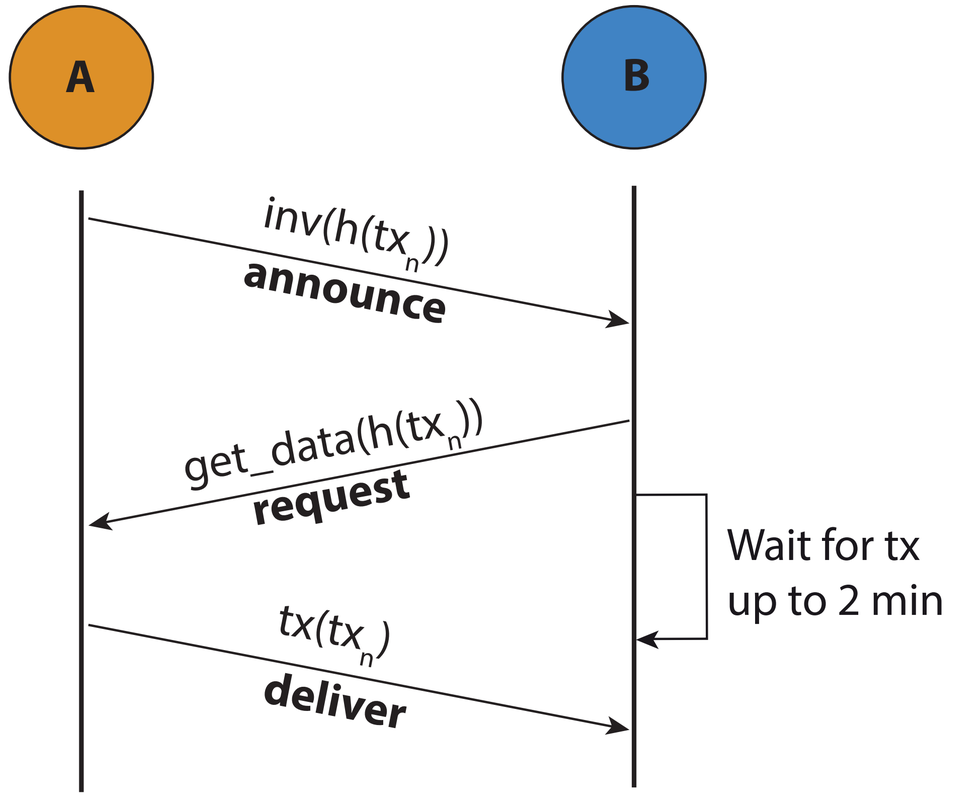
Upon receiving a request of a known item, a node will reply back with it (**deliver**)



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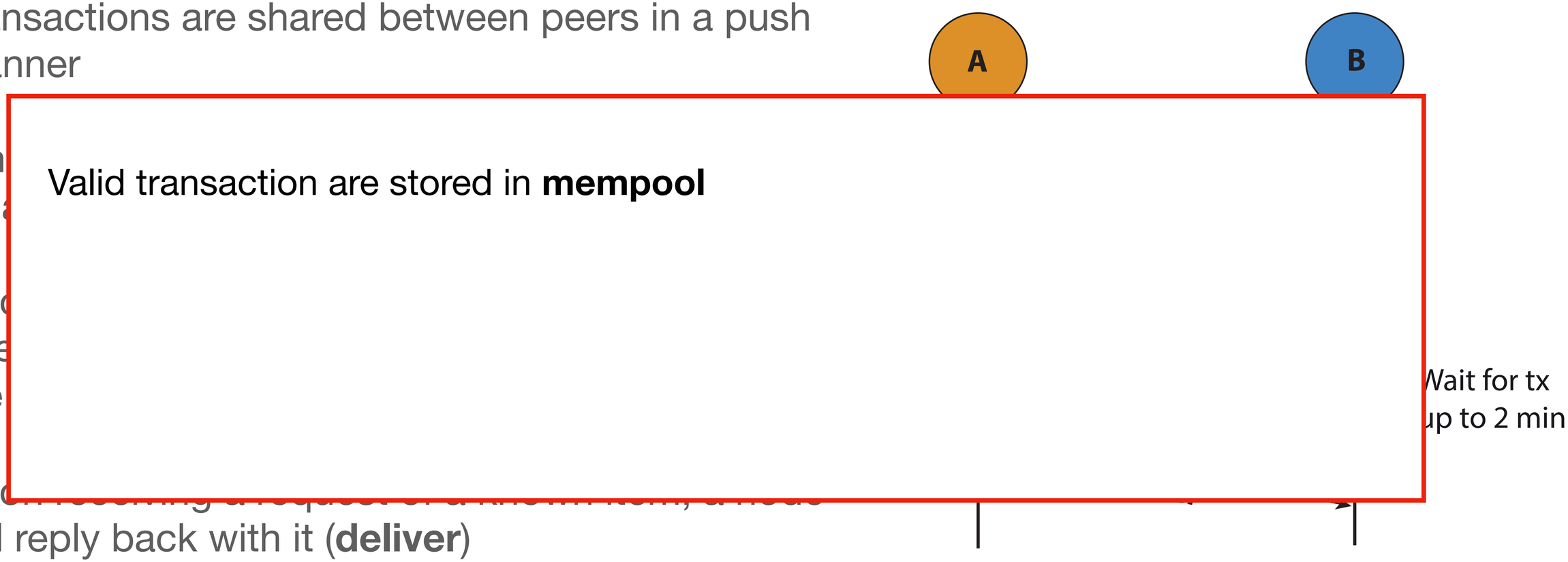

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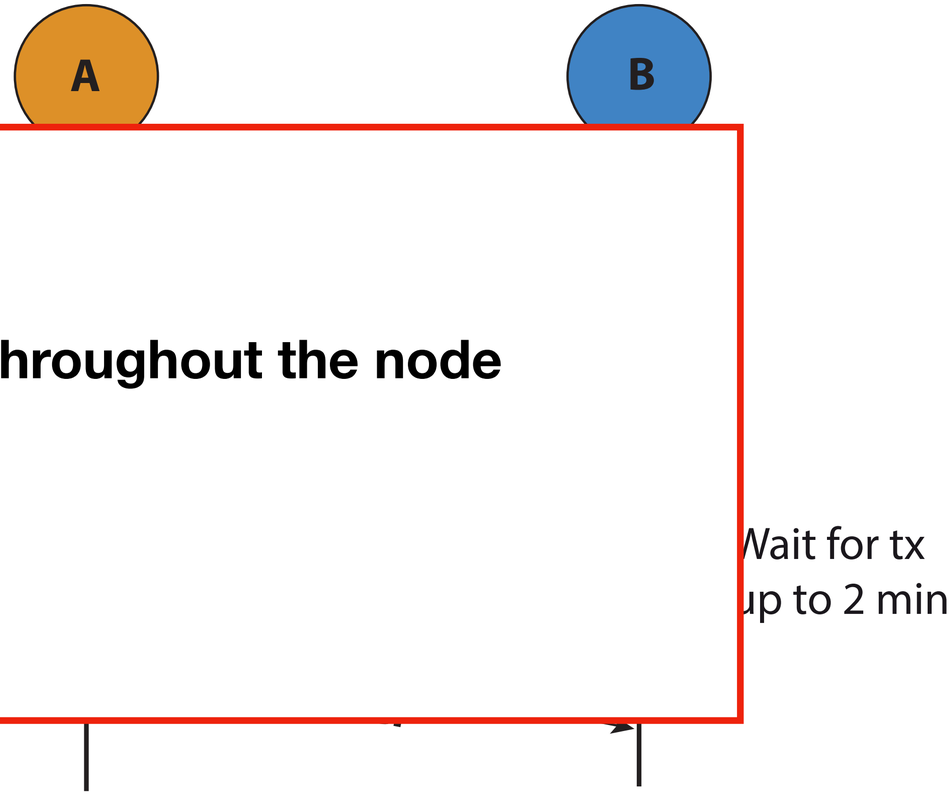

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Transaction in **mempool** are eventually **propagated throughout the node neighborhood**

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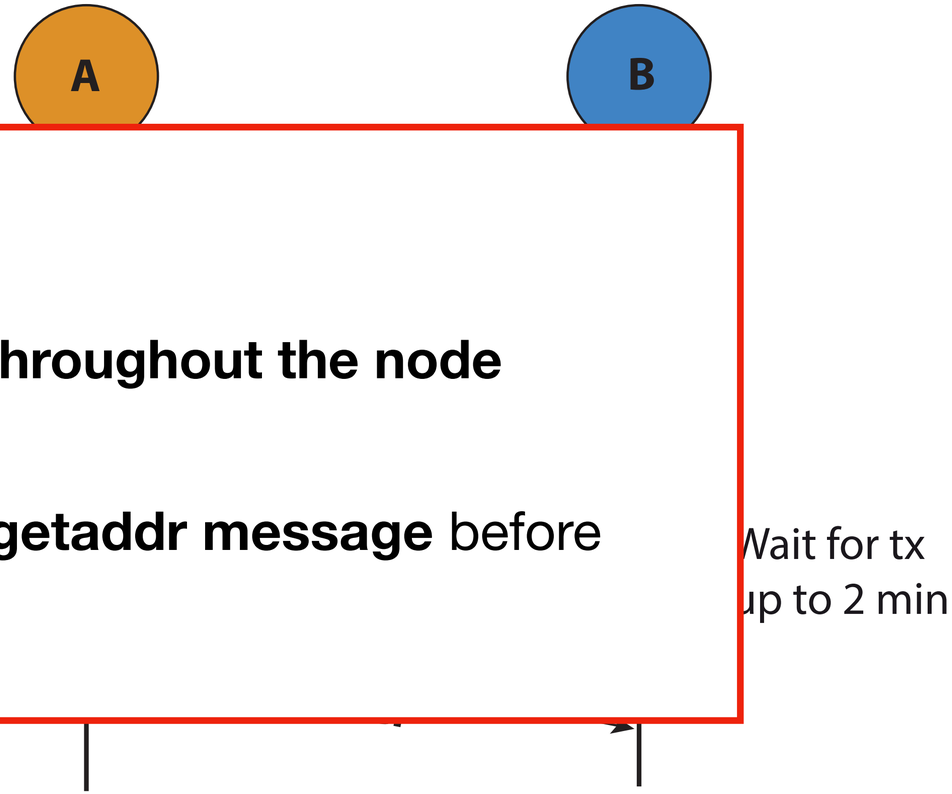
A node will wait **up to 2 minutes** for a response to a **getaddr message** before asking any other peer



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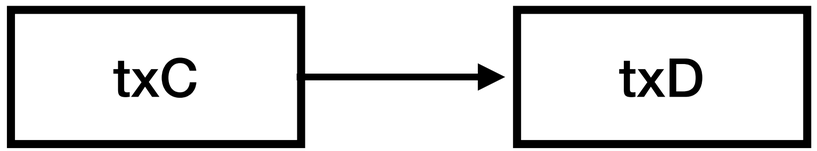

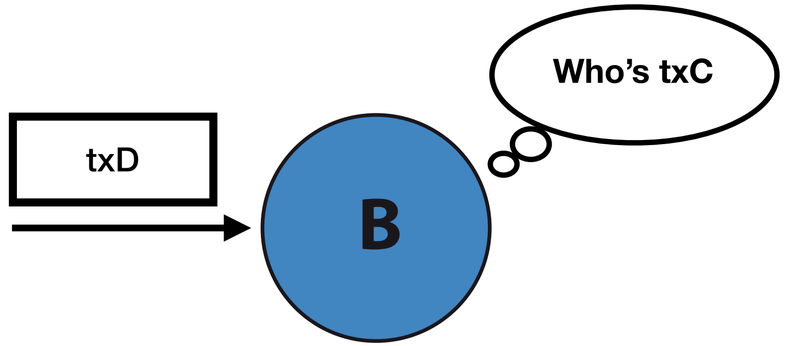

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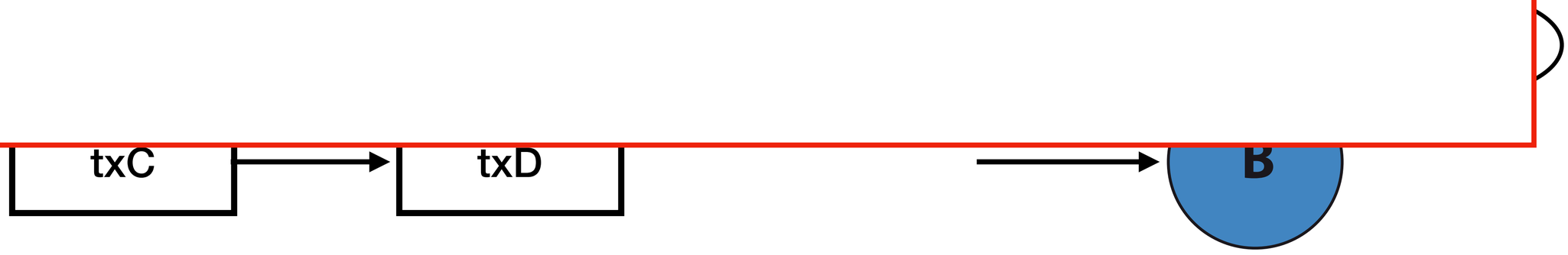
If the same transactions is offered again to the node (**inv message**), it will not ask back for it (**getaddr**)



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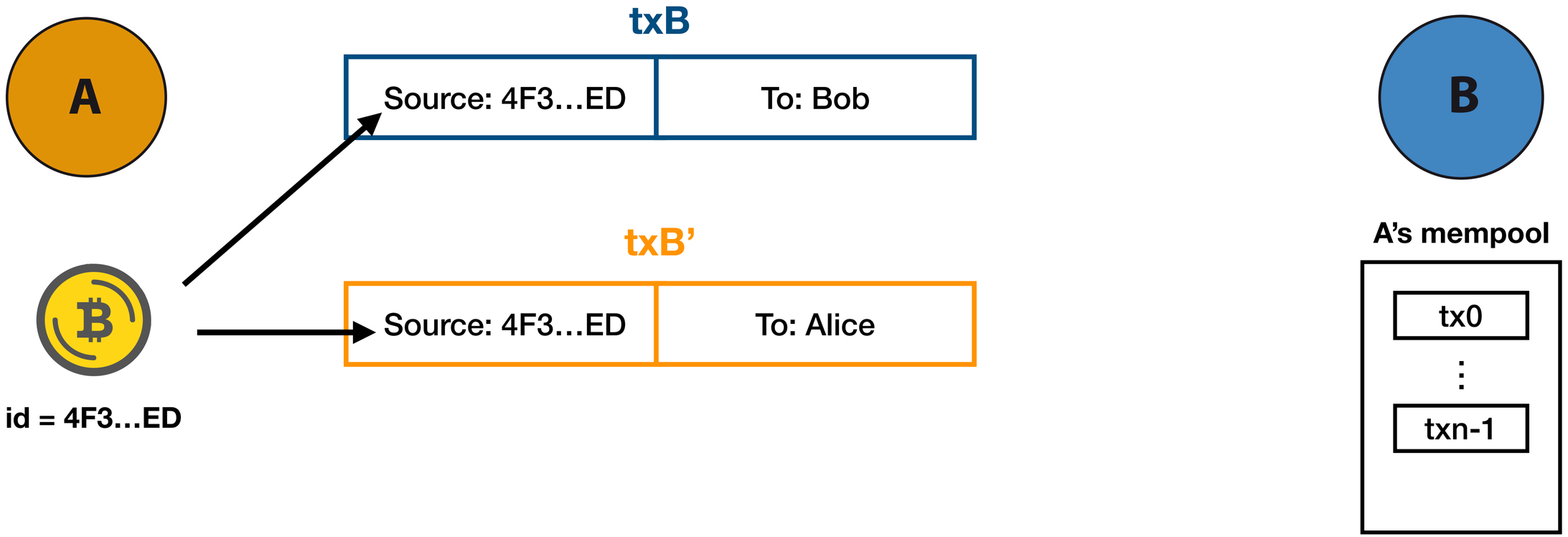

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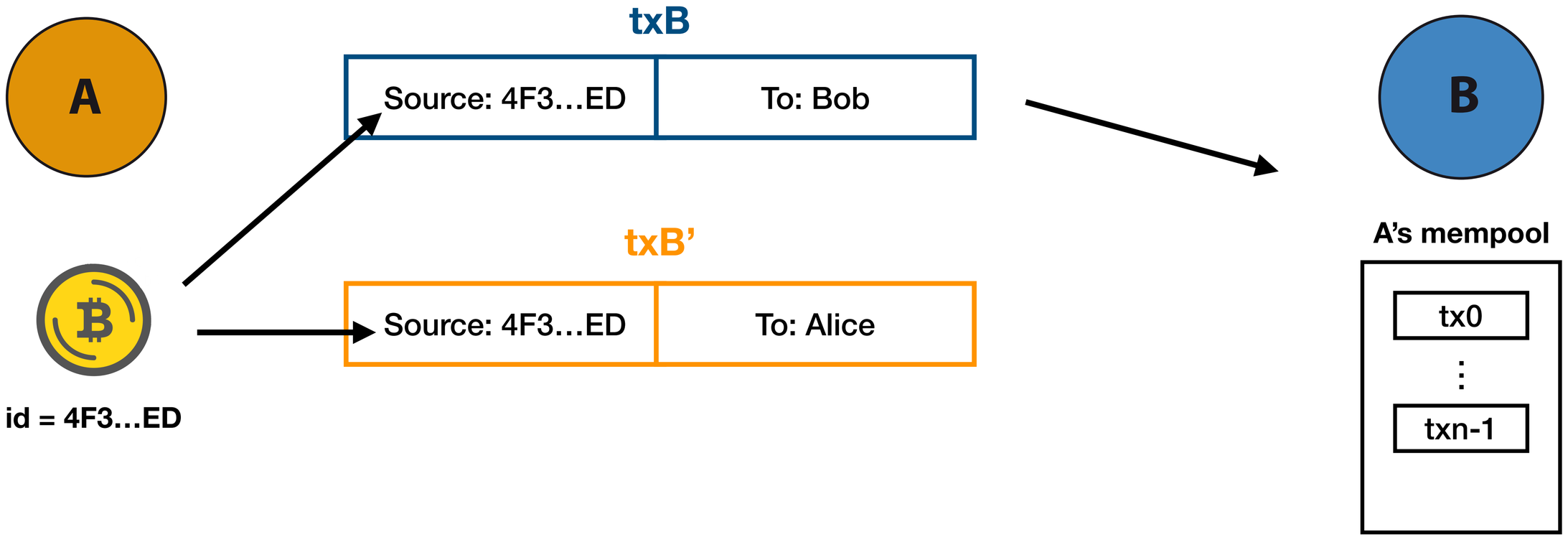

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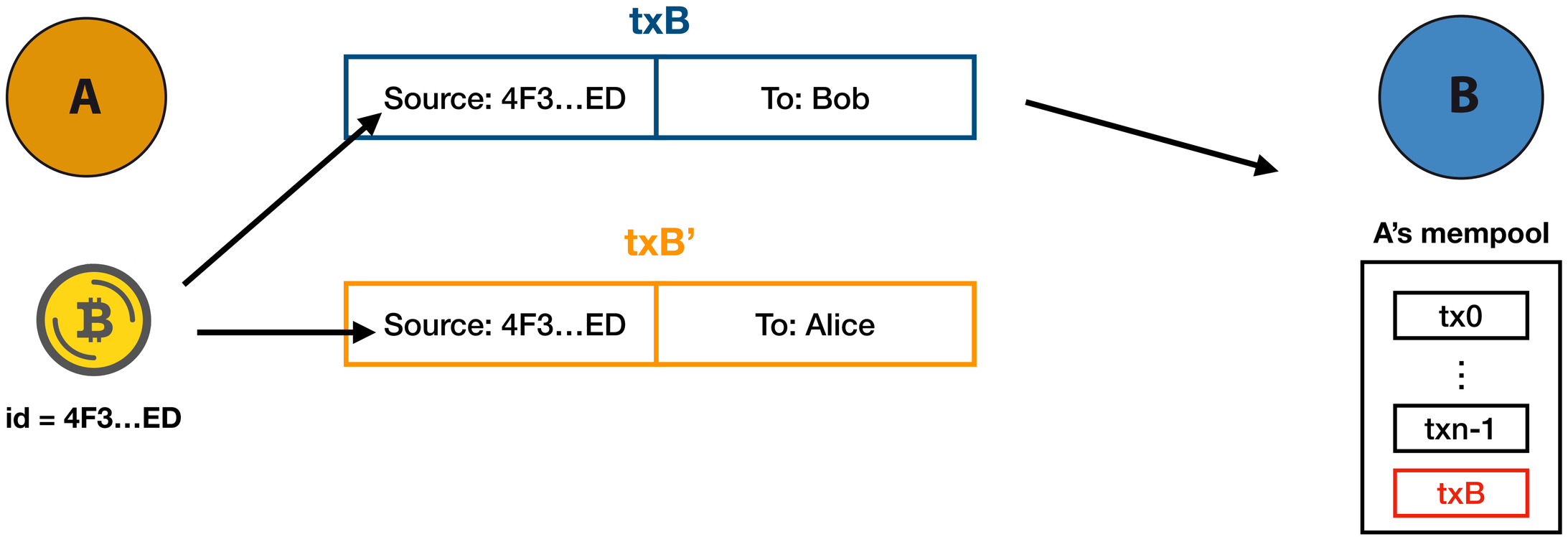

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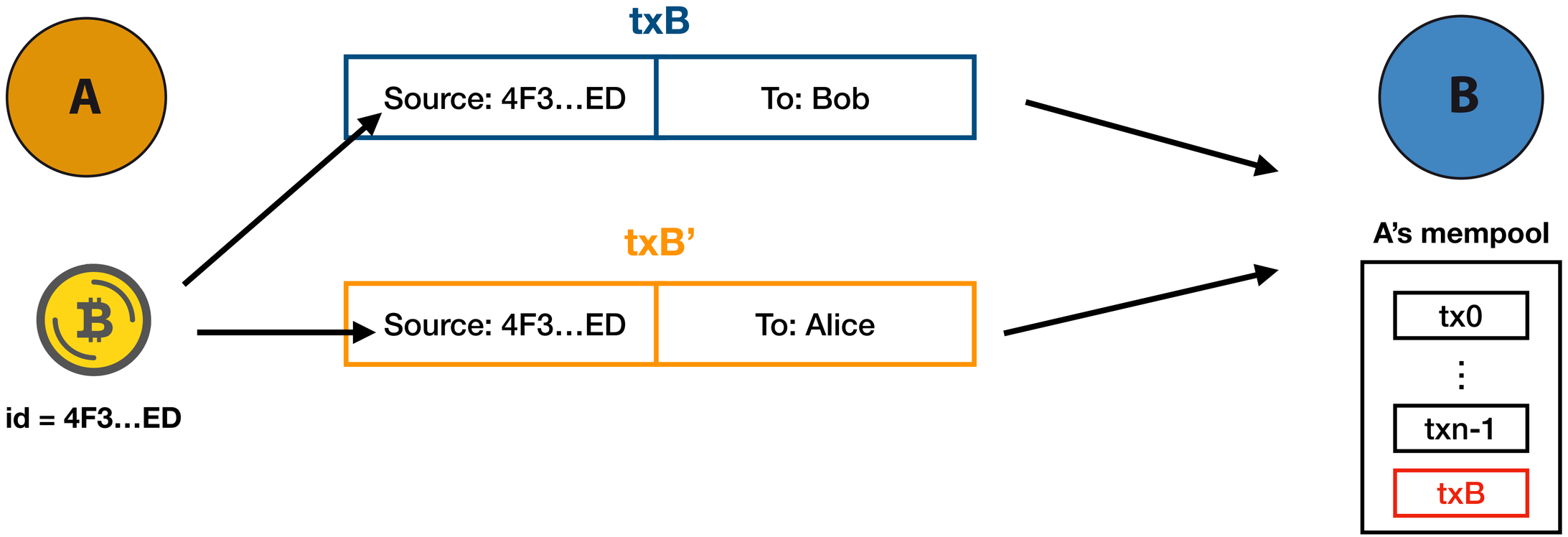

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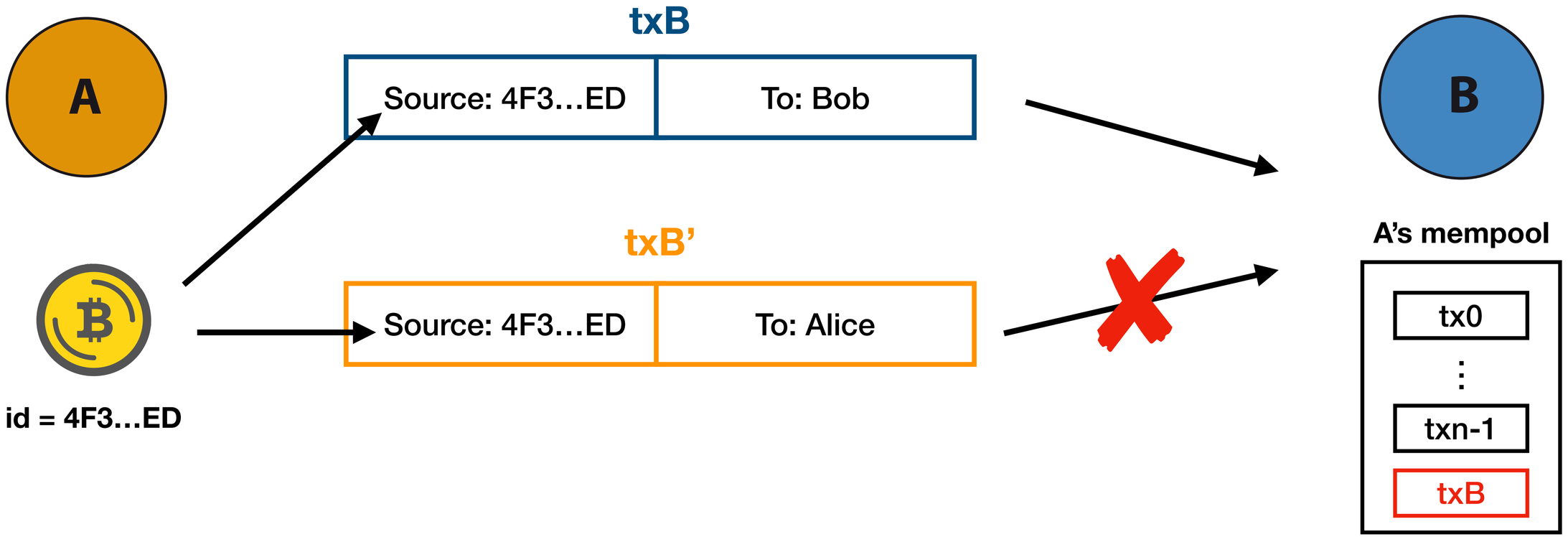
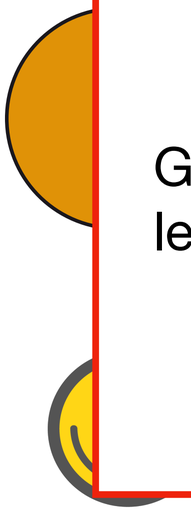


DOUBLE-SPENDING TRANSACTIONS

Given a pair of double-spending transactions, a node will **pick the first one** it learns about



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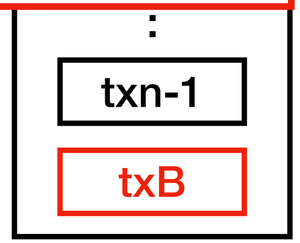

A BASIC TOPOLOGY INFERRING TECHNIQUE

Two nodes

Three transactions

Observation tool

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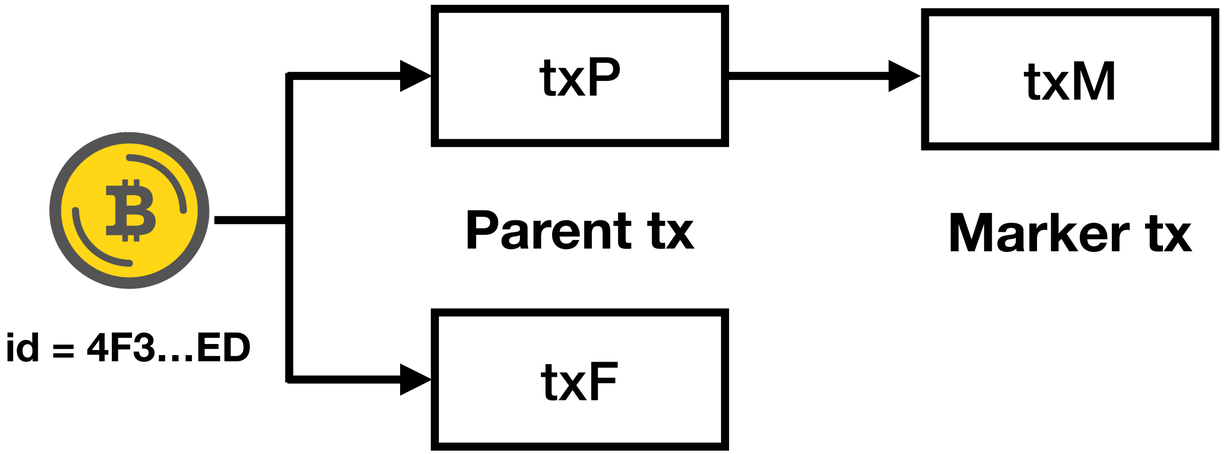

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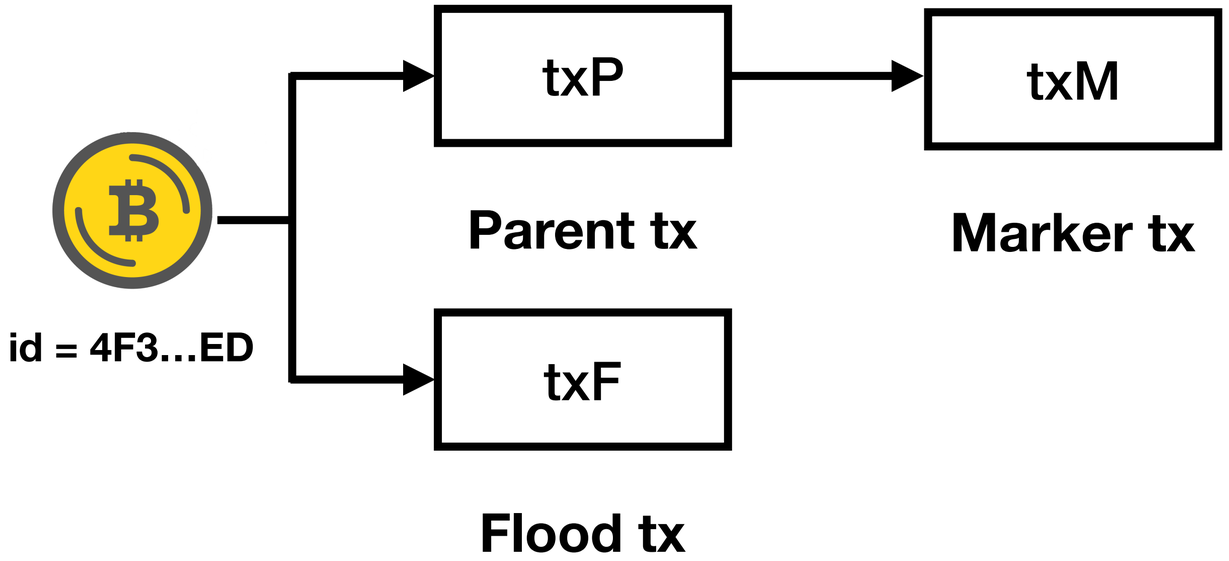

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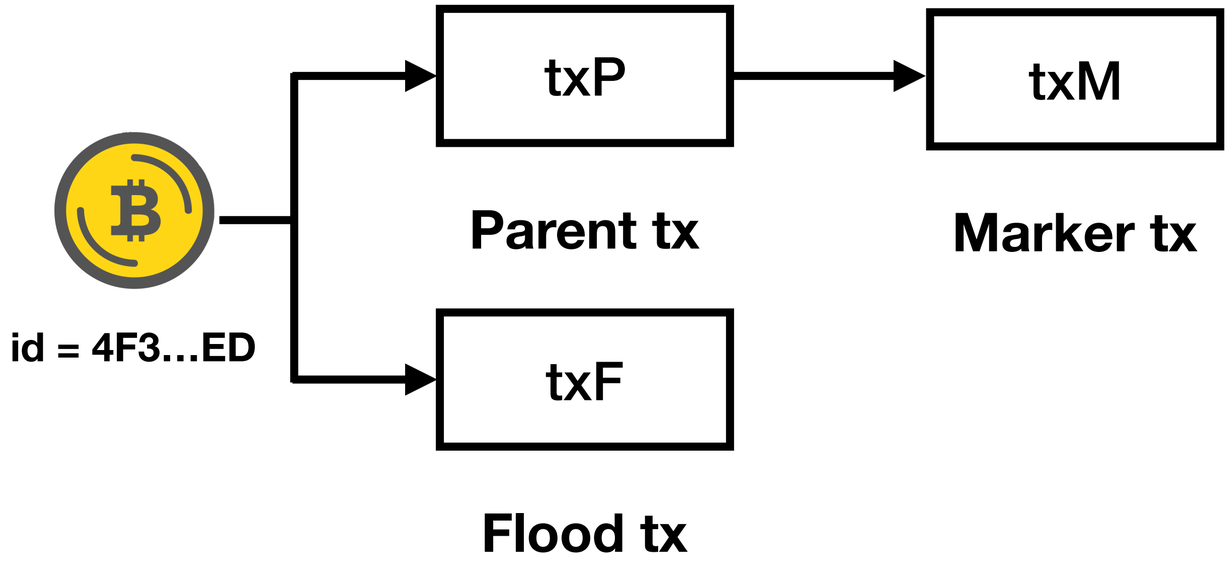

Andrew Miller, James Litton, Andrew Pachulski, Neal Gupta, Dave Levin, Neil Spring, Bobby Bhattacharjee

Discovering Bitcoin's Public Topology and Influential Nodes

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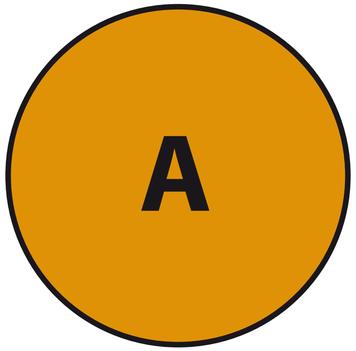

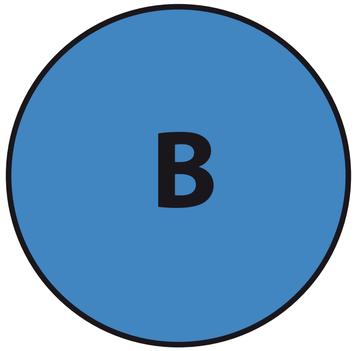

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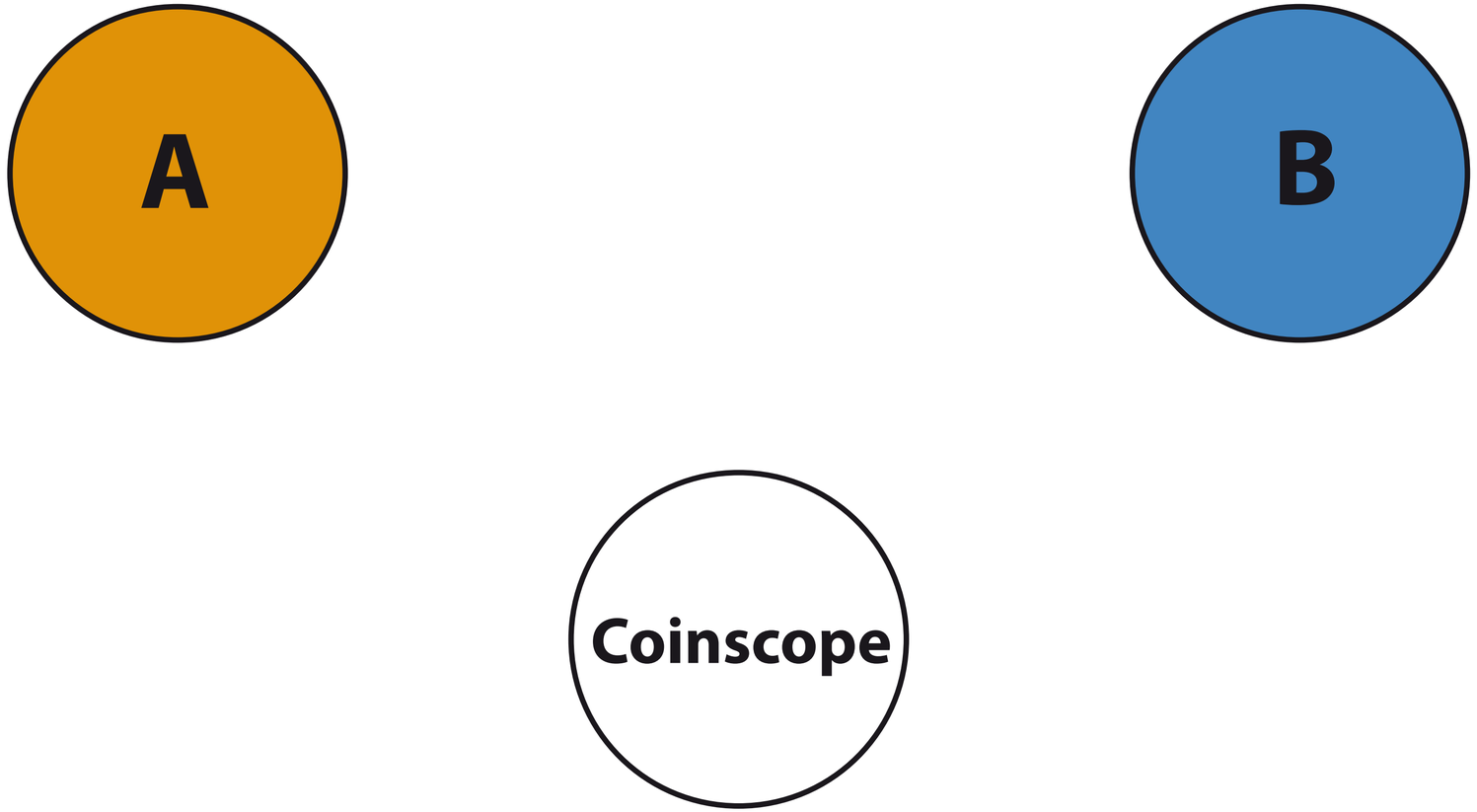

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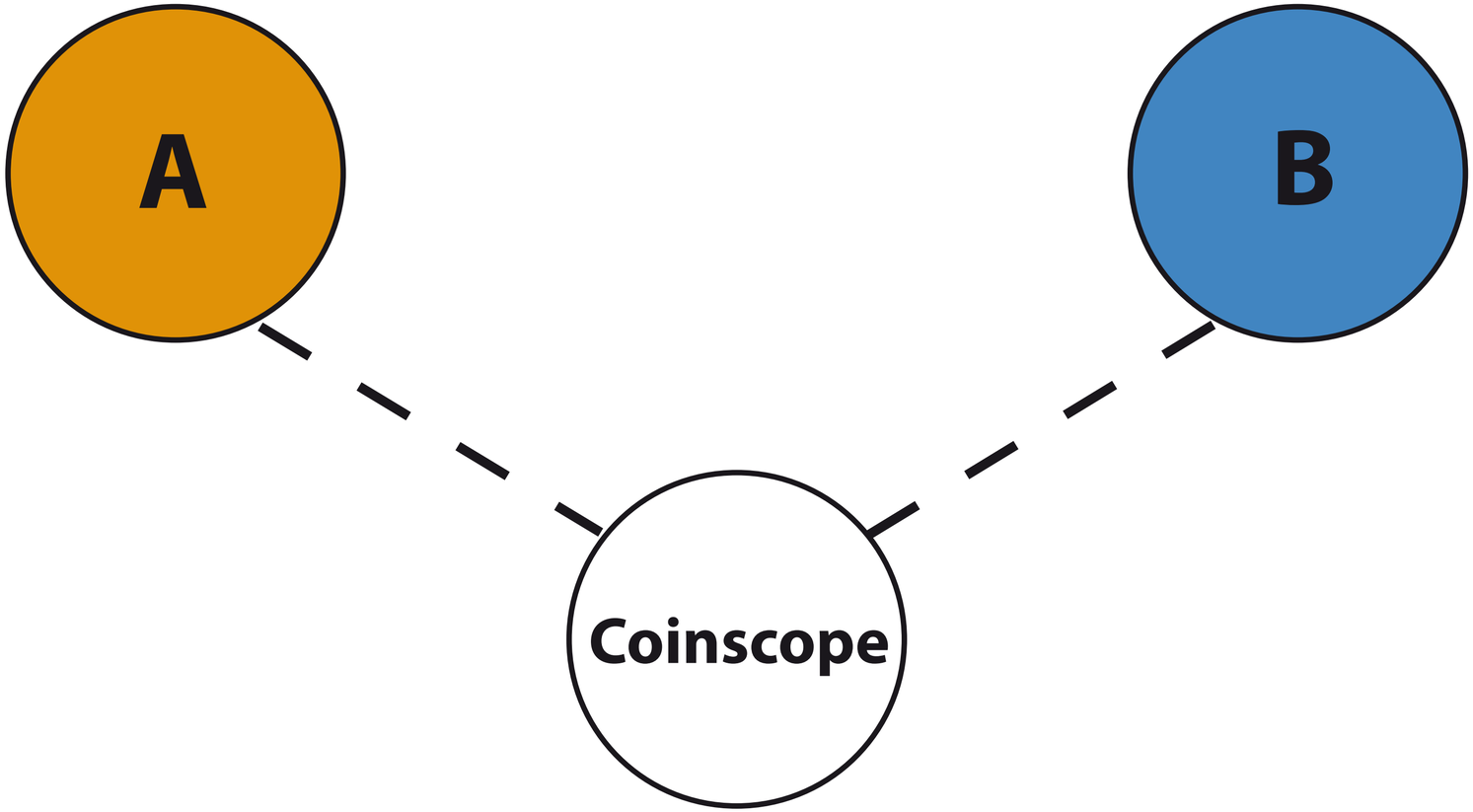

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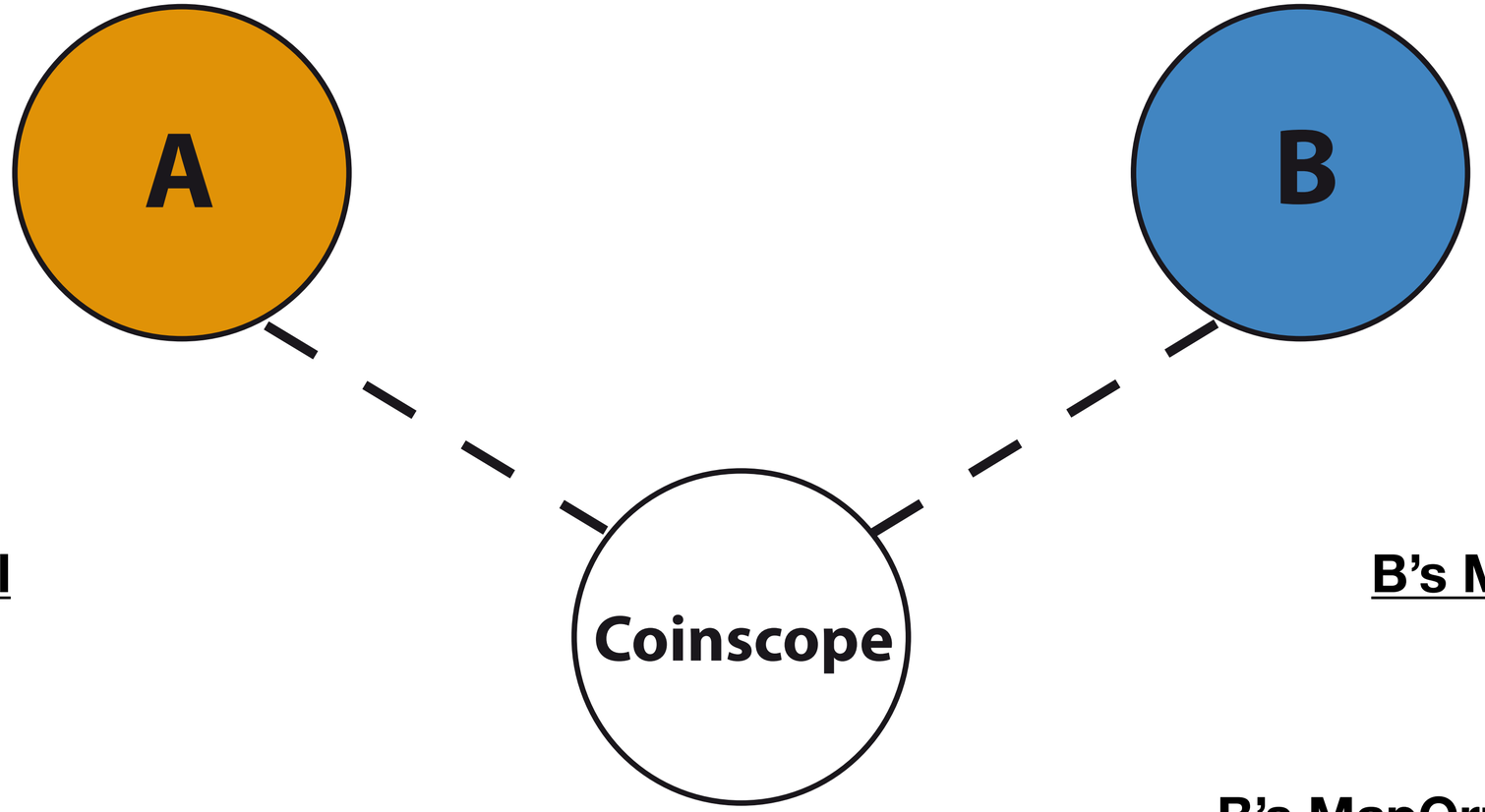

A's Mempool

∅

B's Mempool

∅

B's MapOrphanTransactions

∅

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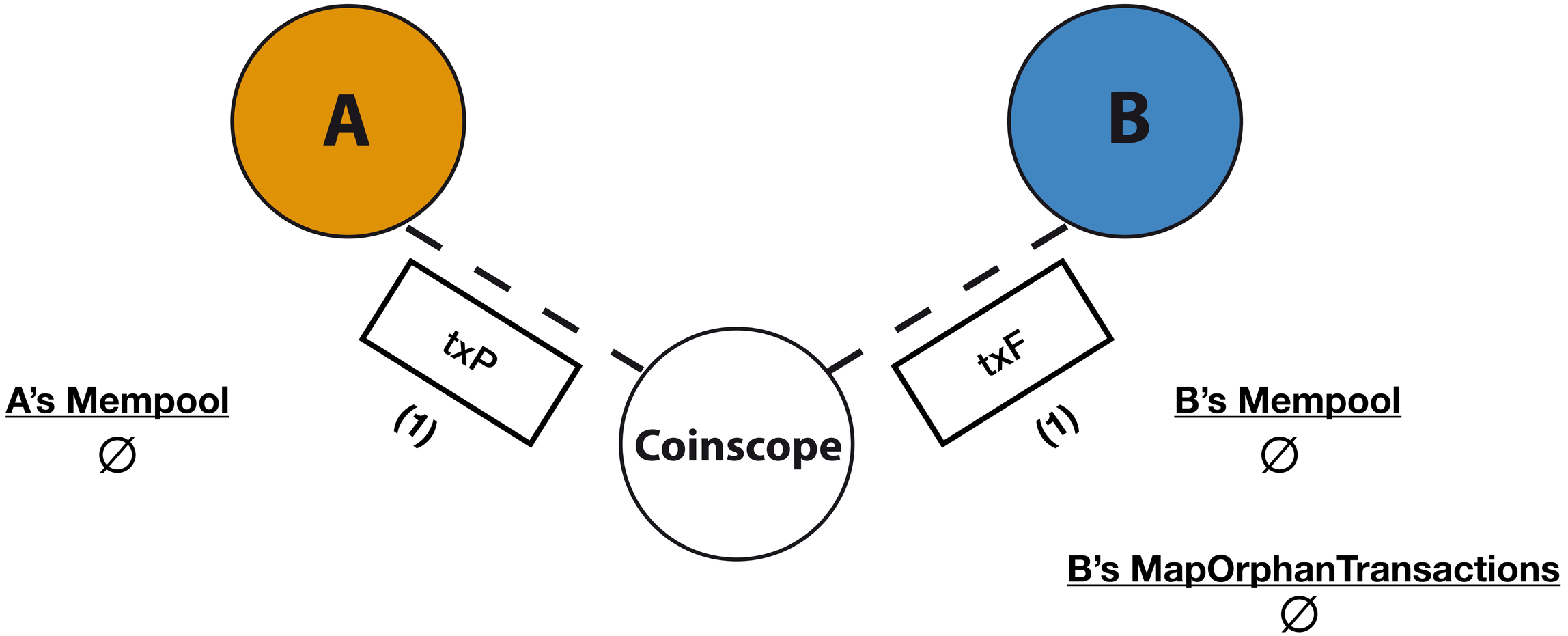

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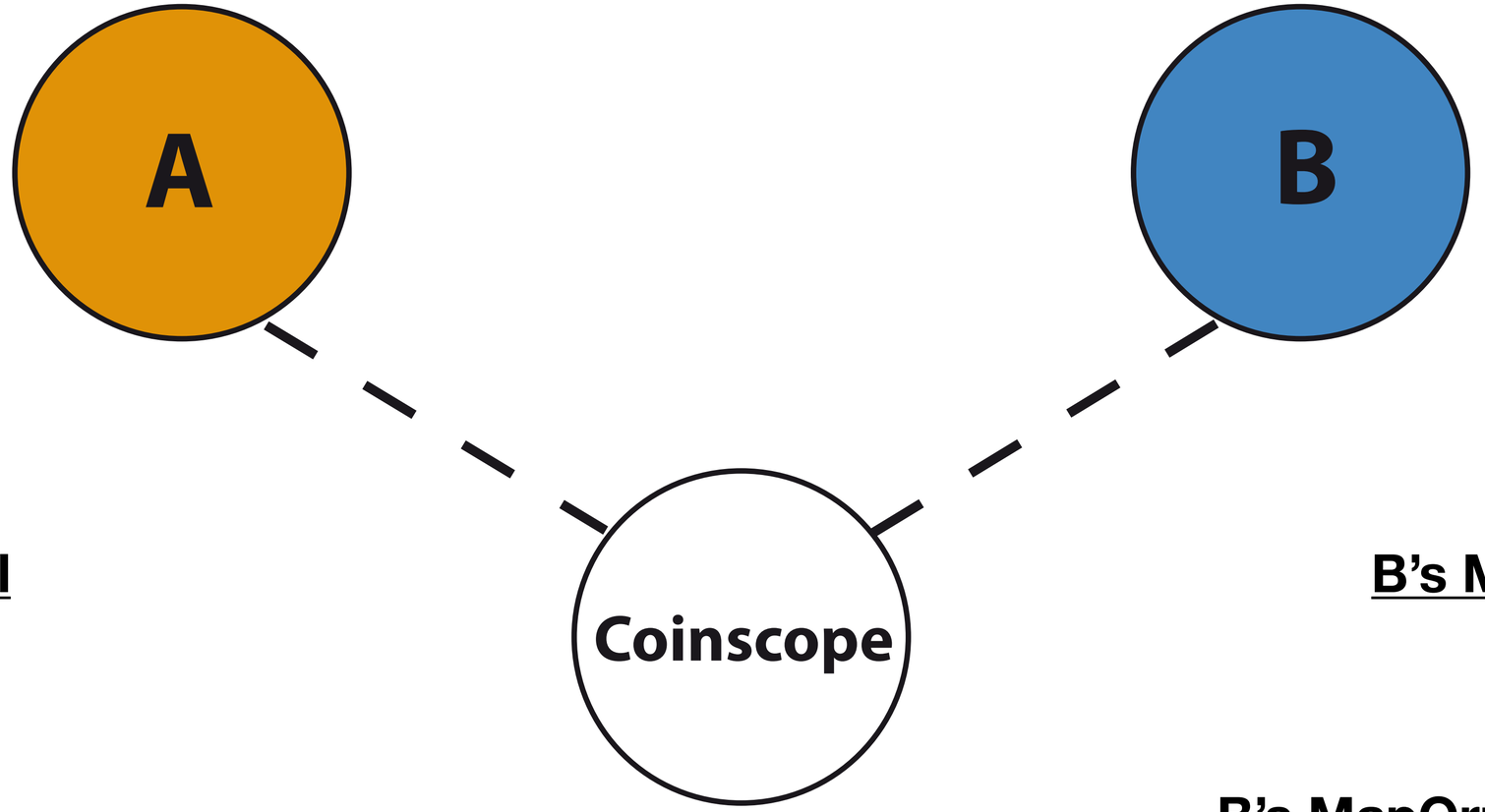

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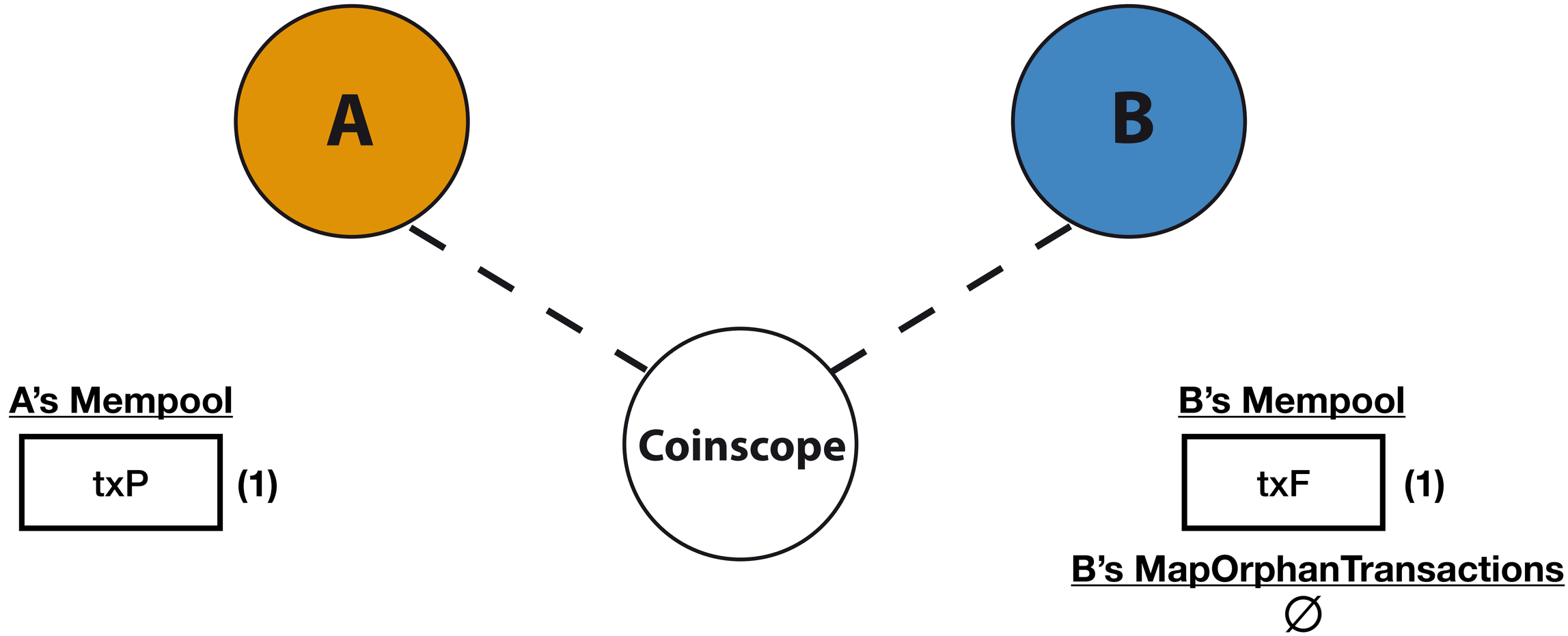

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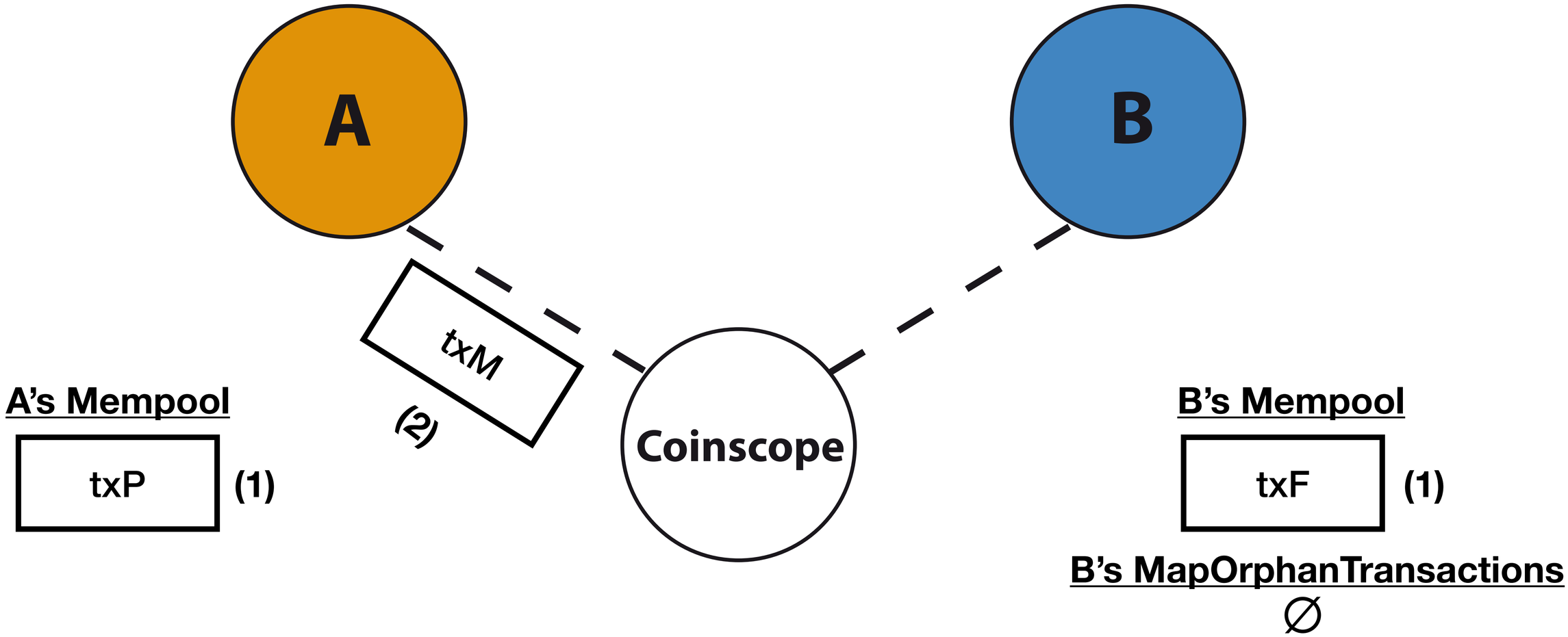

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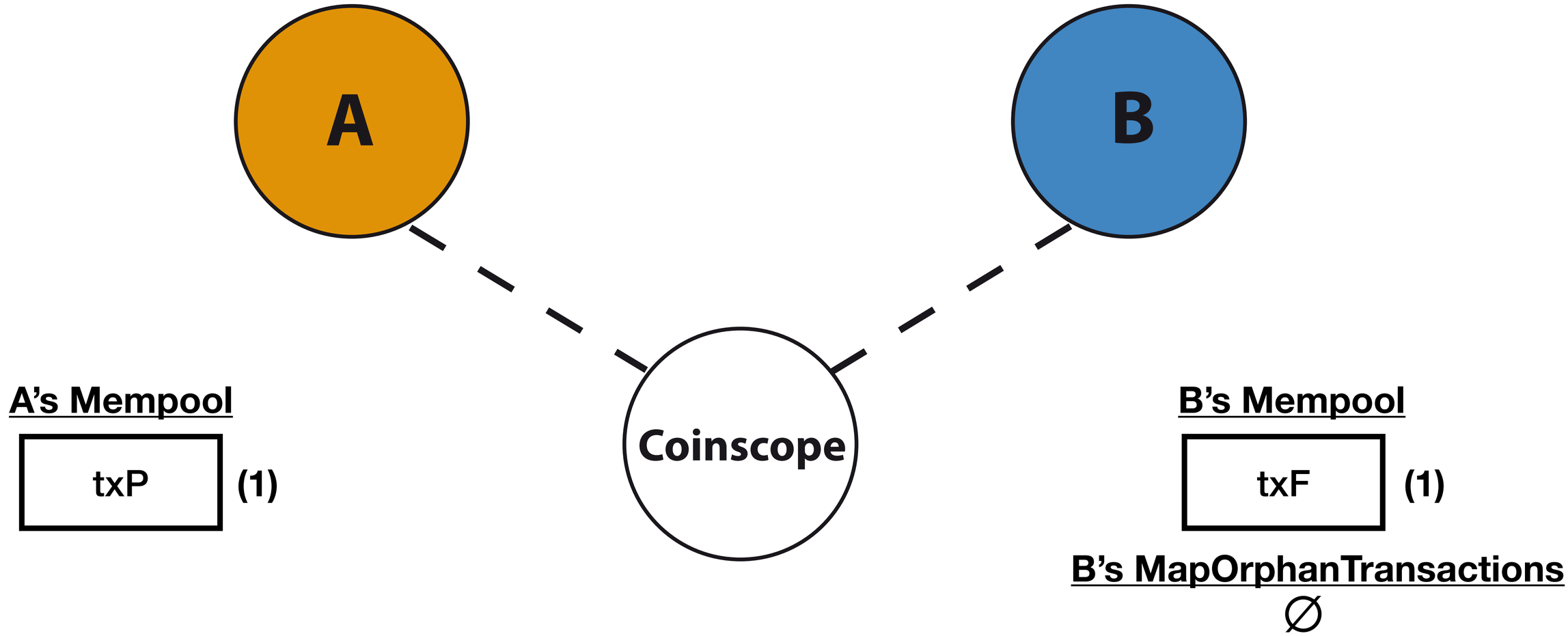

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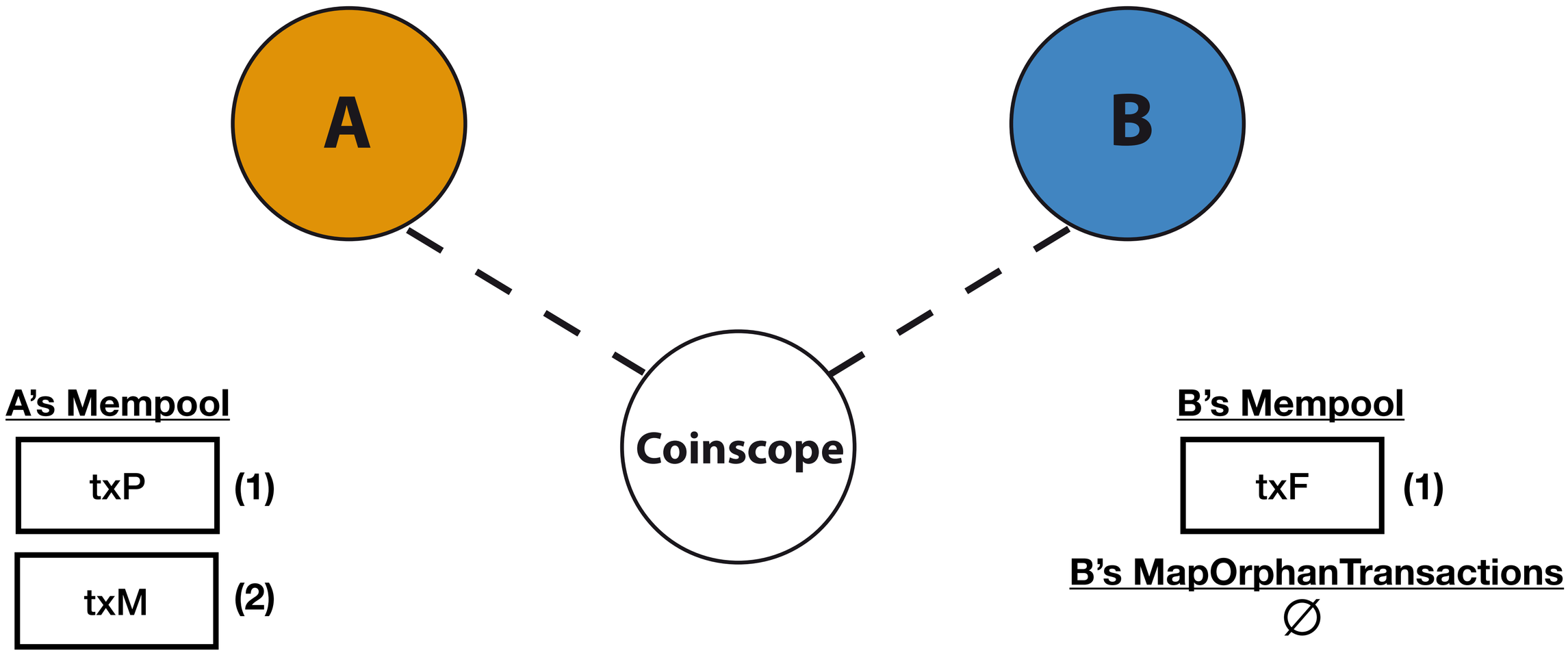


NEGATIVE INFERRING TECHNIQUE

A's Mempool

txP	(1)
txM	(2)

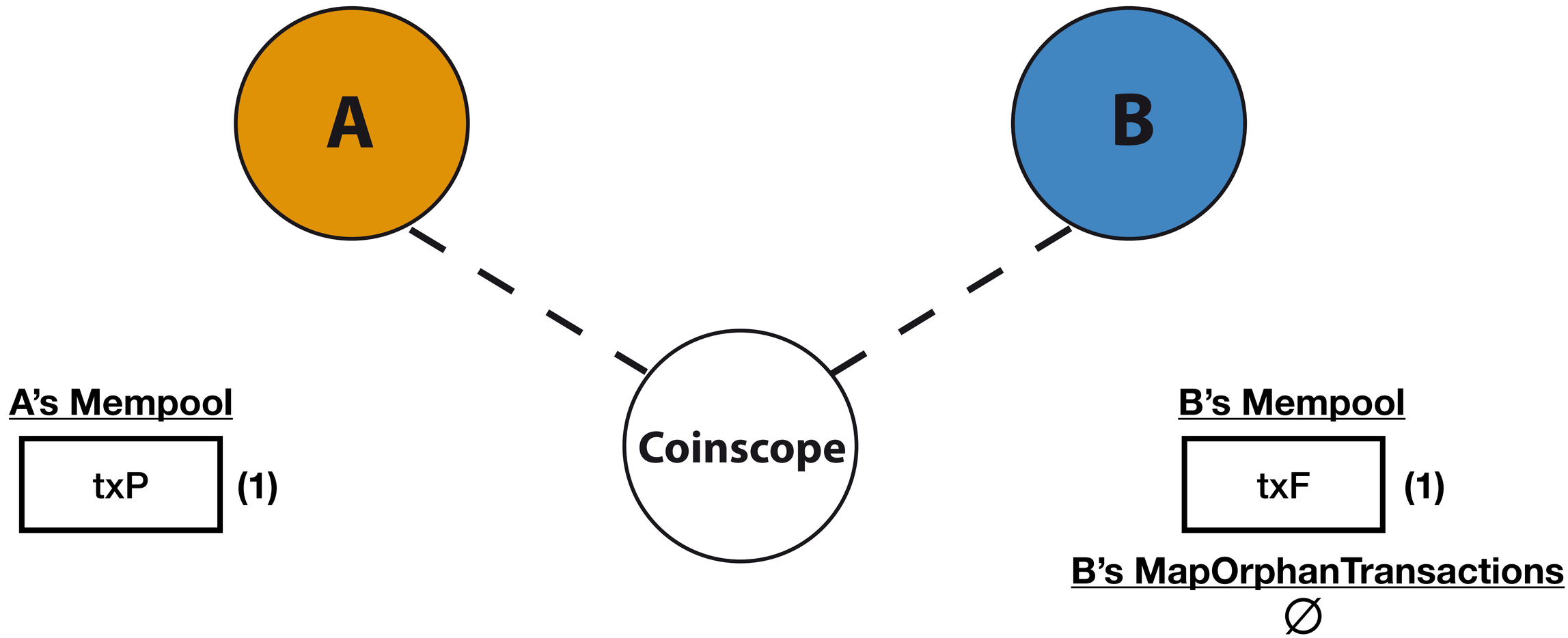
B's Mempool

txF	(1)

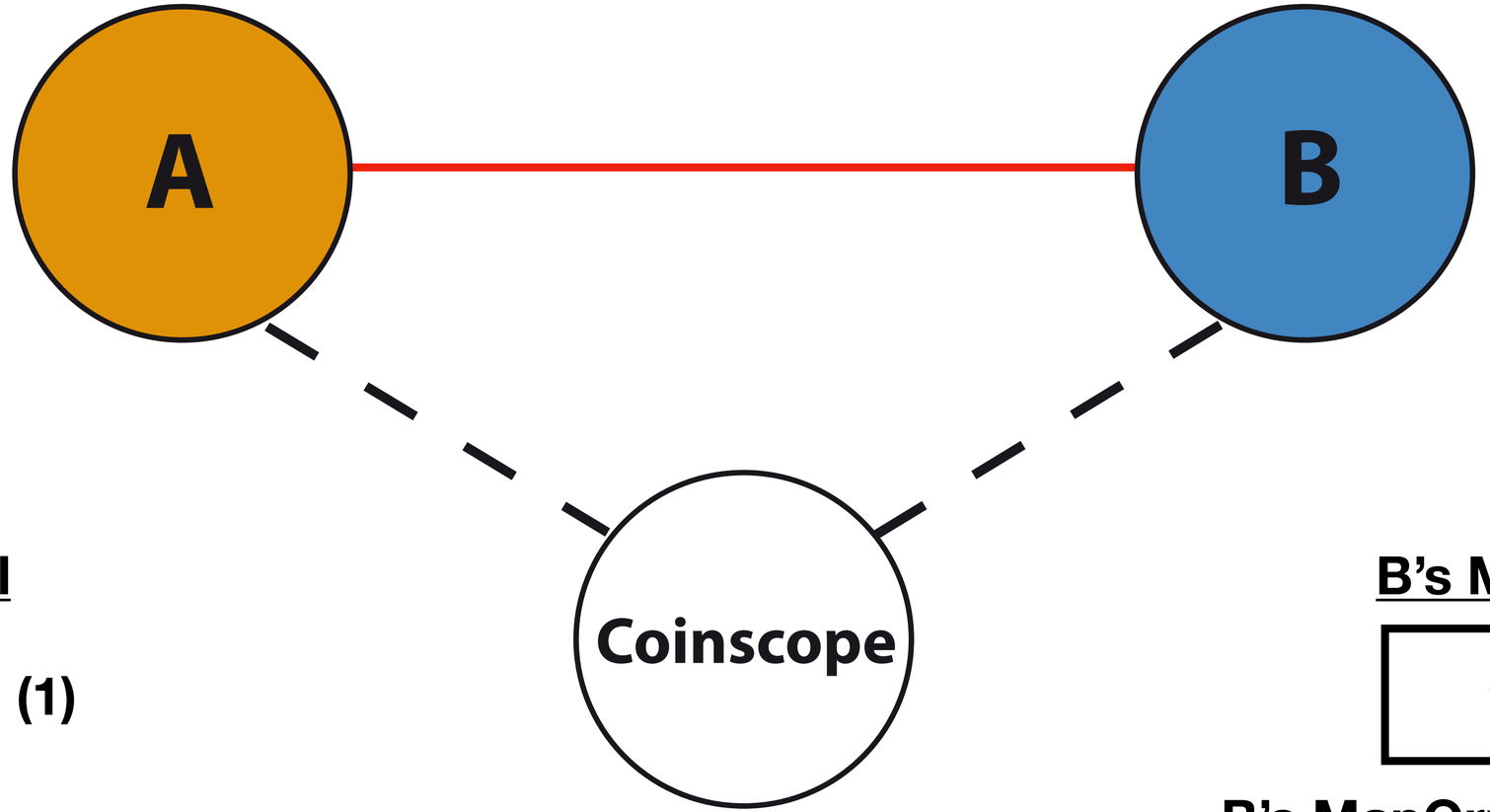
B's MapOrphanTransactions

∅

POSITIVE INFERRING TECHNIQUE



POSITIVE INFERRING TECHNIQUE



A's Mempool

txP (1)

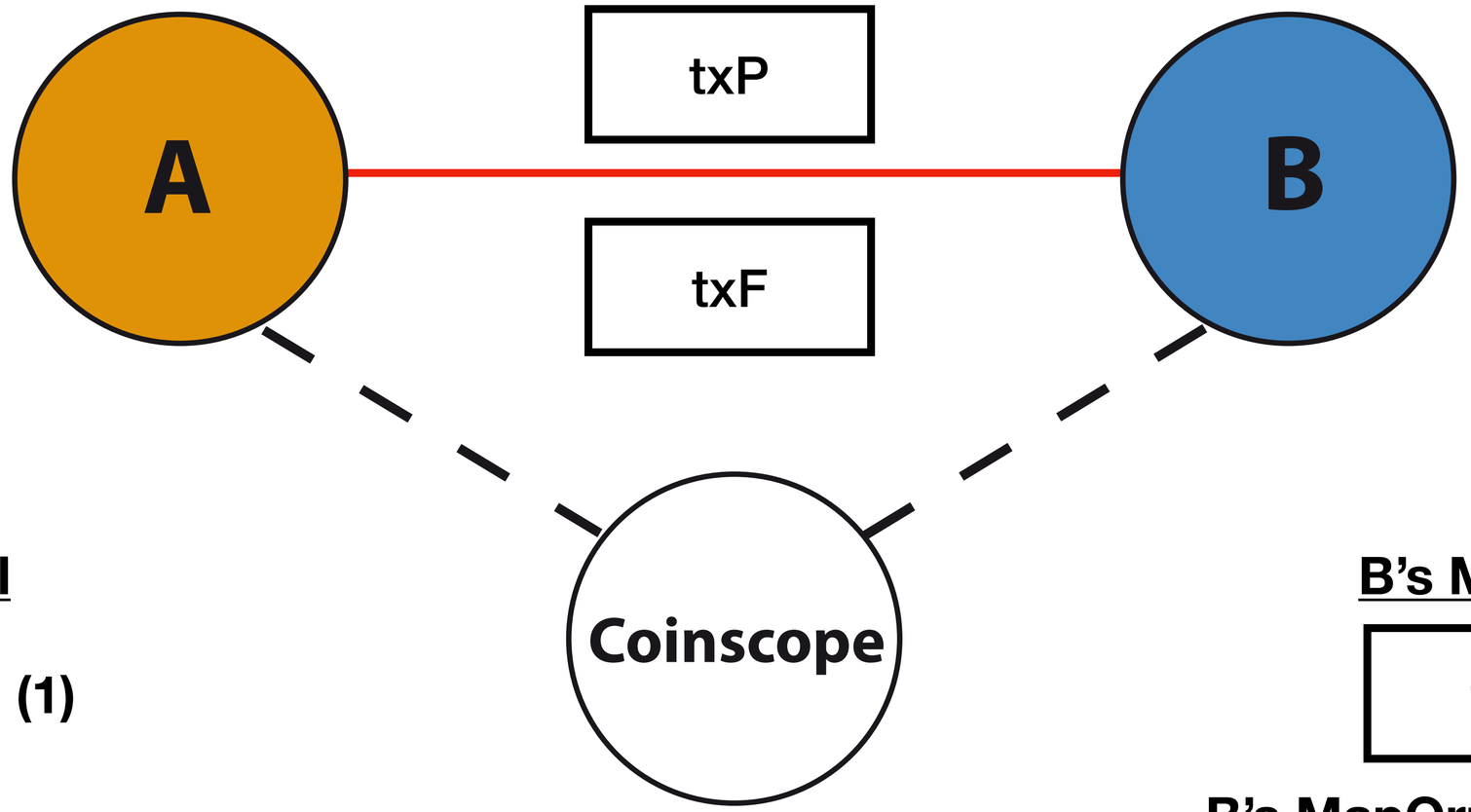
B's Mempool

txF (1)

B's MapOrphanTransactions

∅

POSITIVE INFERRING TECHNIQUE



A's Mempool

txP (1)

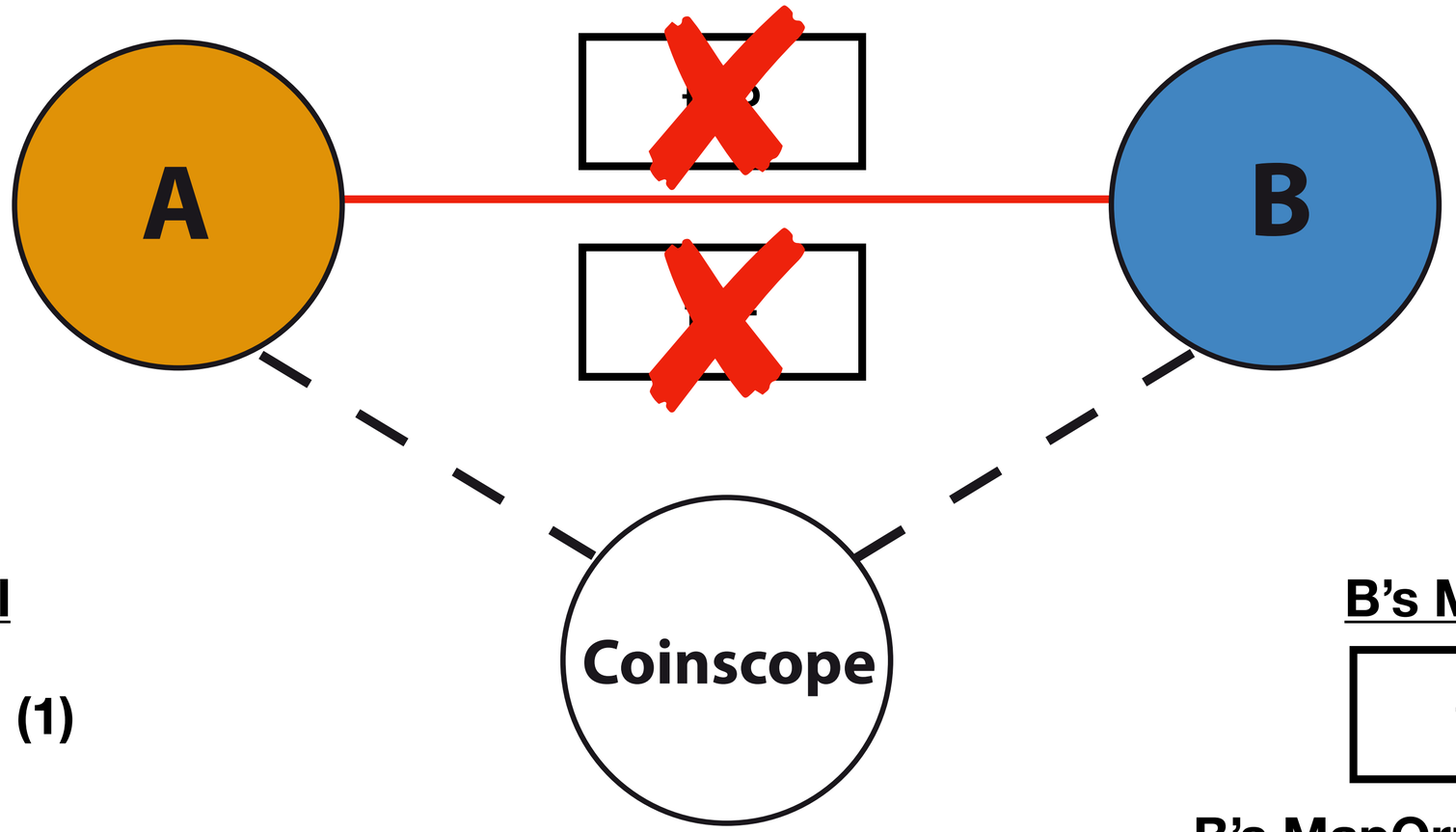
B's Mempool

txF (1)

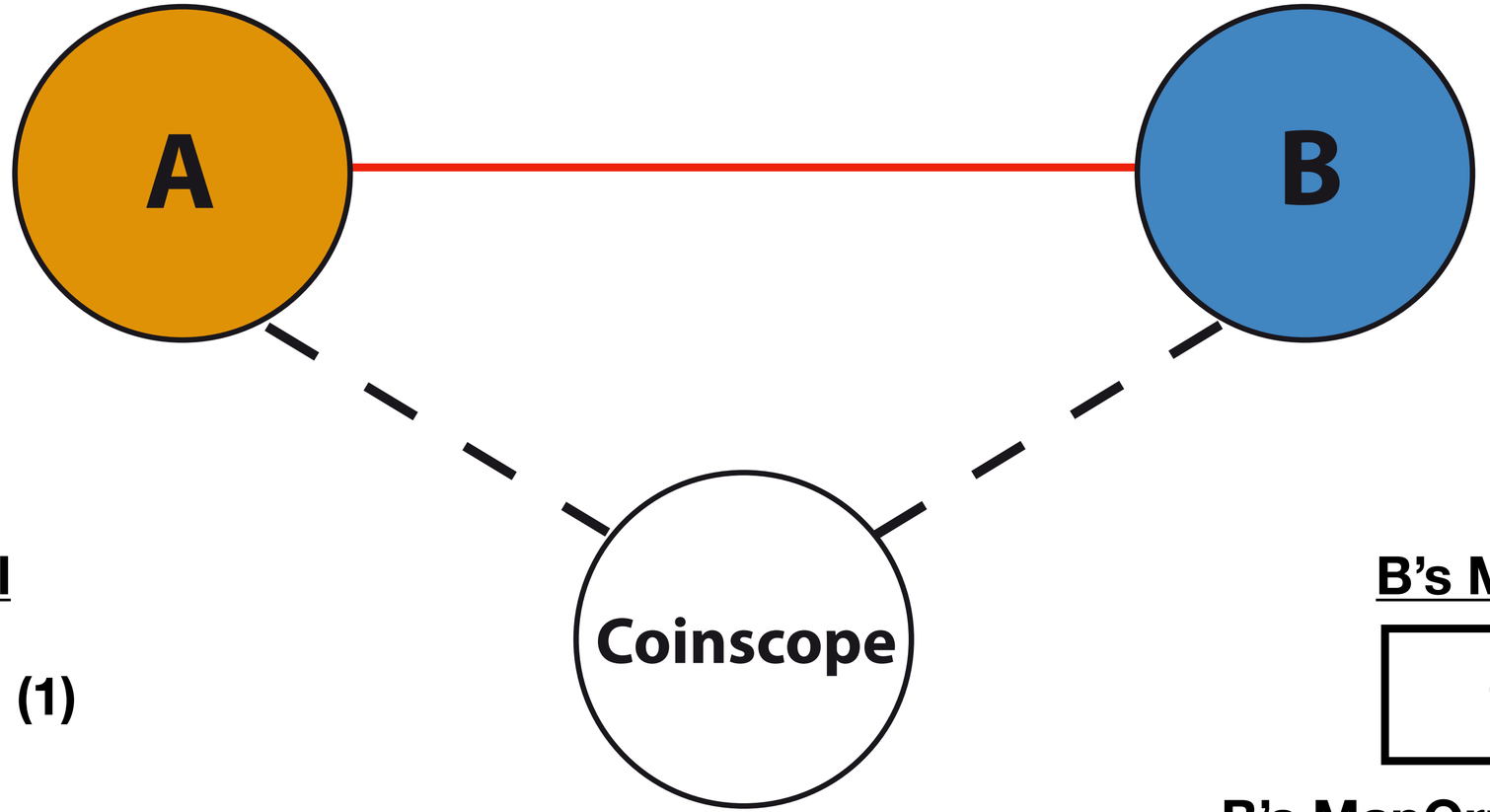
B's MapOrphanTransactions

∅

POSITIVE INFERRING TECHNIQUE



POSITIVE INFERRING TECHNIQUE



A's Mempool

txP (1)

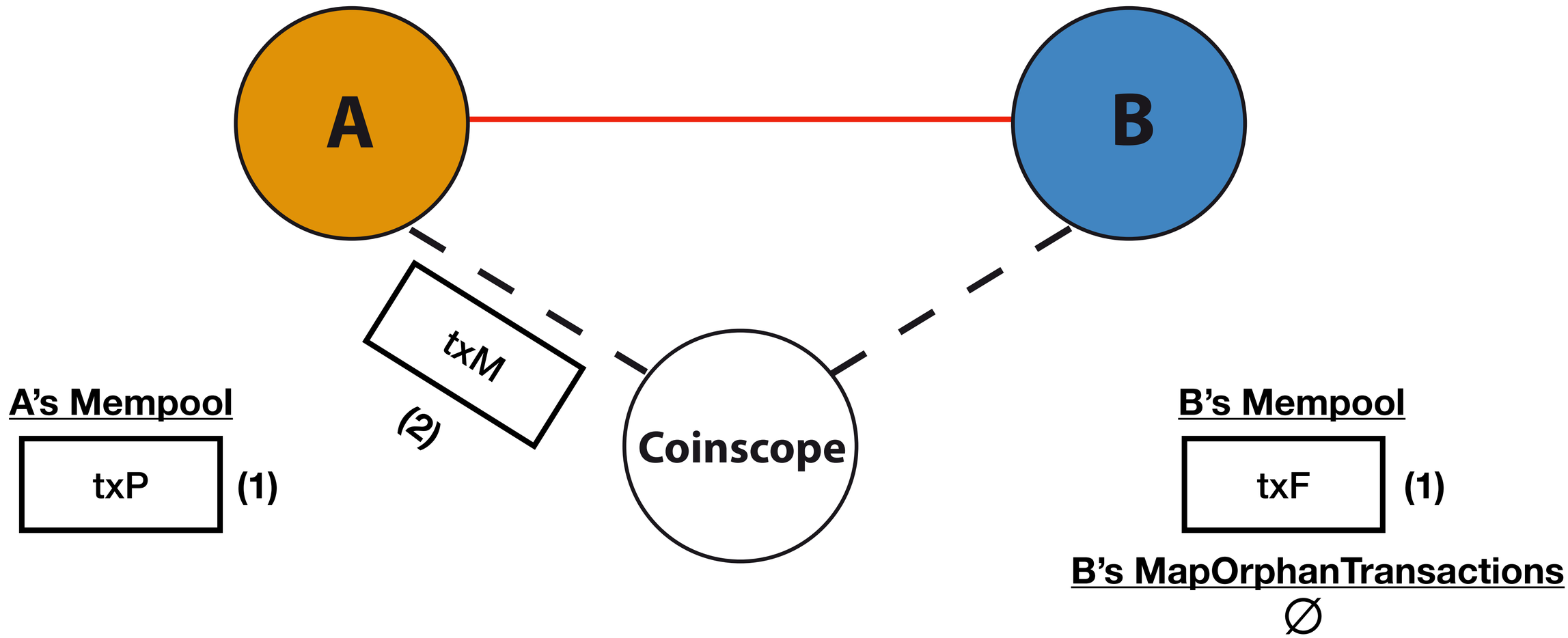
B's Mempool

txF (1)

B's MapOrphanTransactions

∅

POSITIVE INFERRING TECHNIQUE



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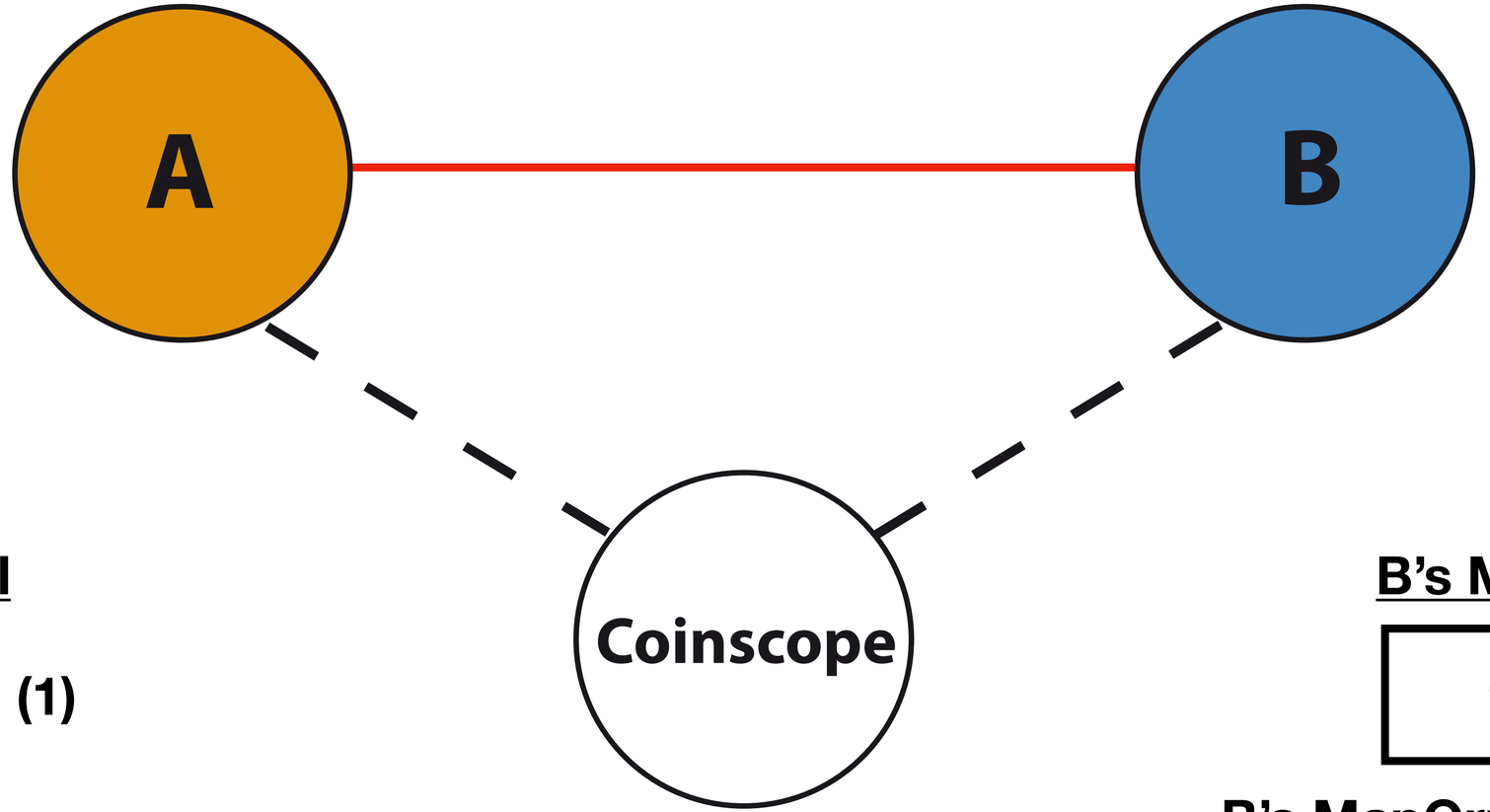


A's Mempool

txP (1)

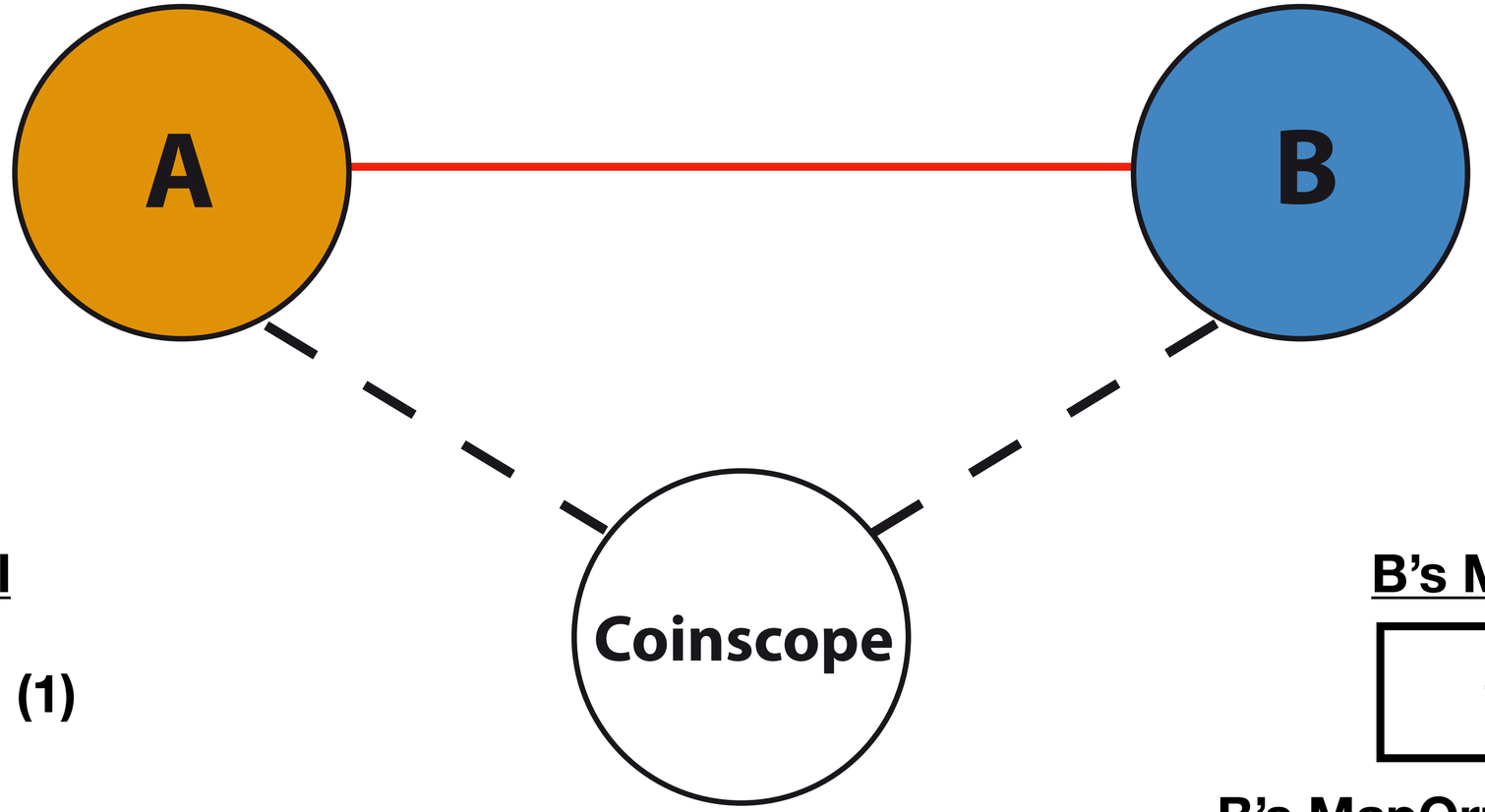
B's Mempool

txF (1)

B's MapOrphanTransactions

∅

POSITIVE INFERRING TECHNIQUE



A's Mempool

txP (1)

txM (2)

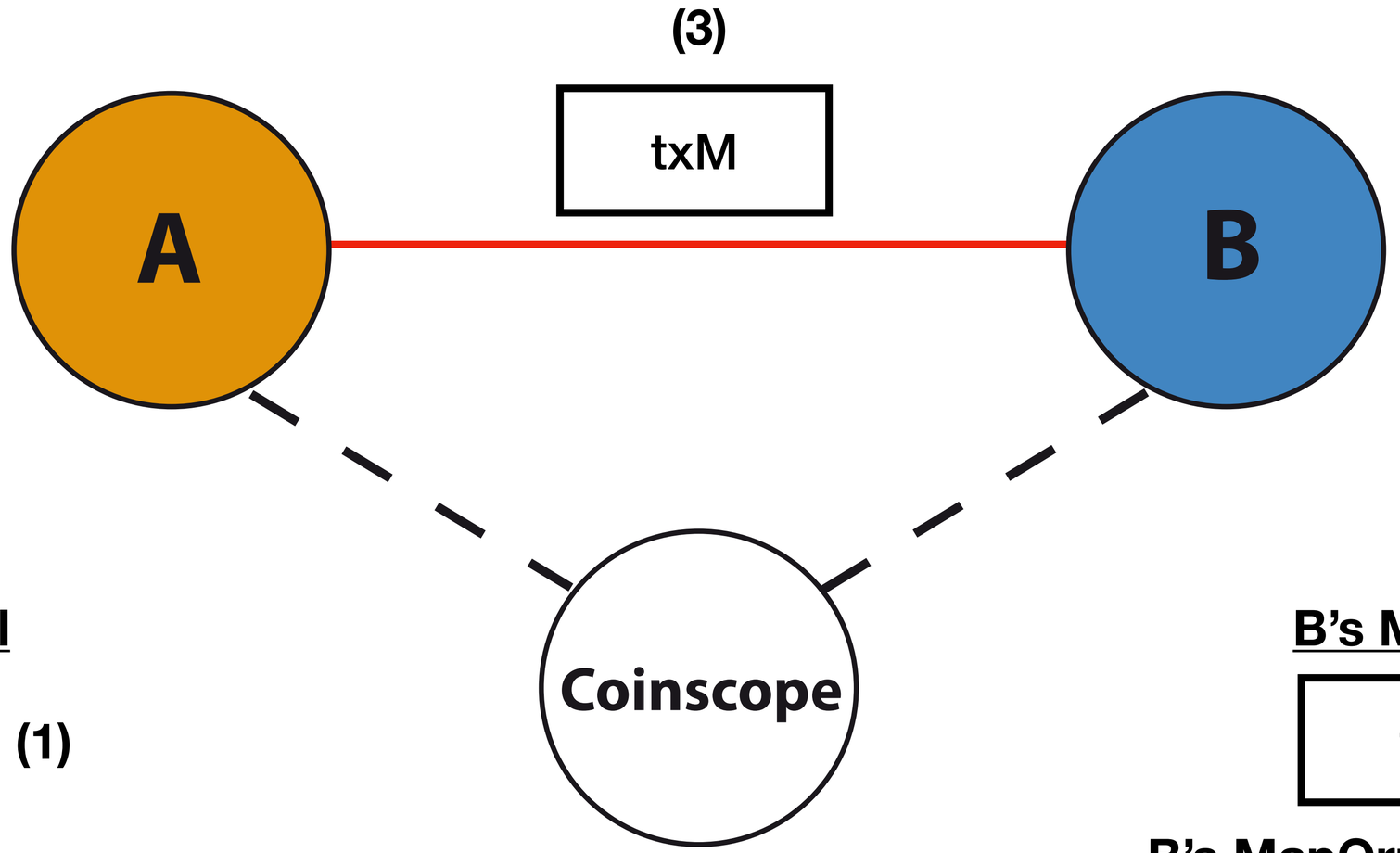
B's Mempool

txF (1)

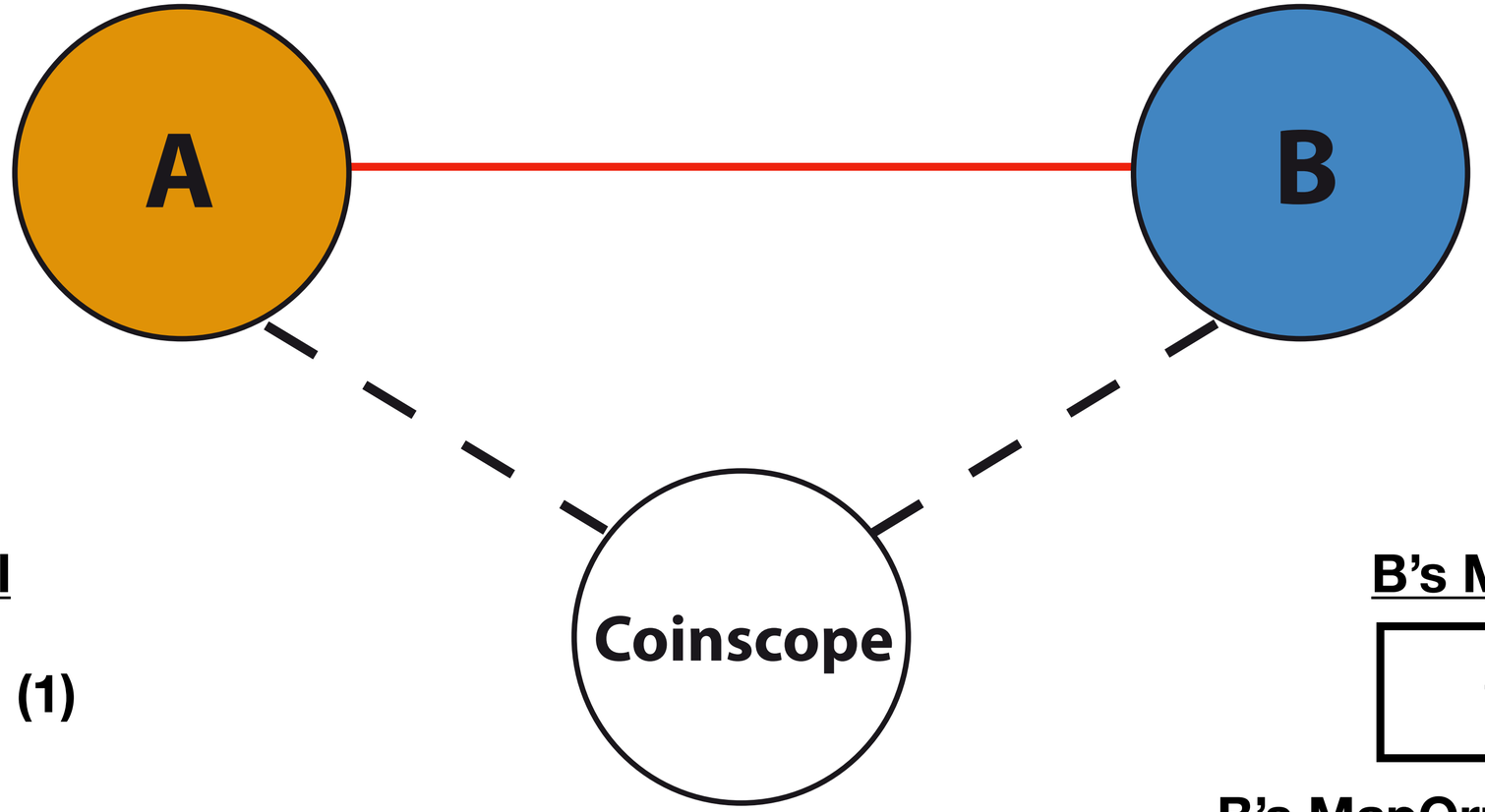
B's MapOrphanTransactions

∅

POSITIVE INFERRING TECHNIQUE



POSITIVE INFERRING TECHNIQUE



A's Mempool

txP (1)

txM (2)

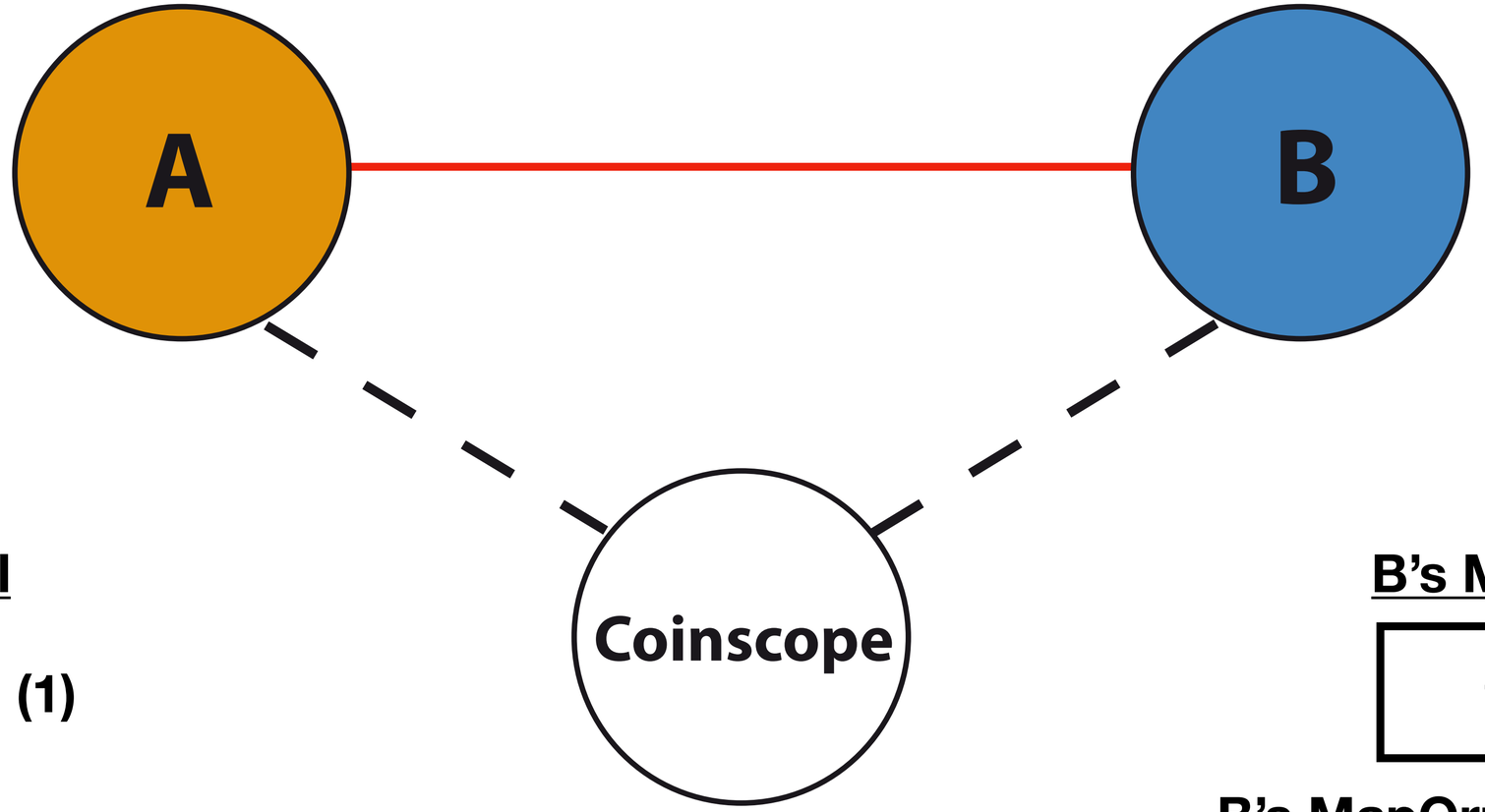
B's Mempool

txF (1)

B's MapOrphanTransactions

∅

POSITIVE INFERRING TECHNIQUE



A's Mempool

txP	(1)
txM	(2)

B's Mempool

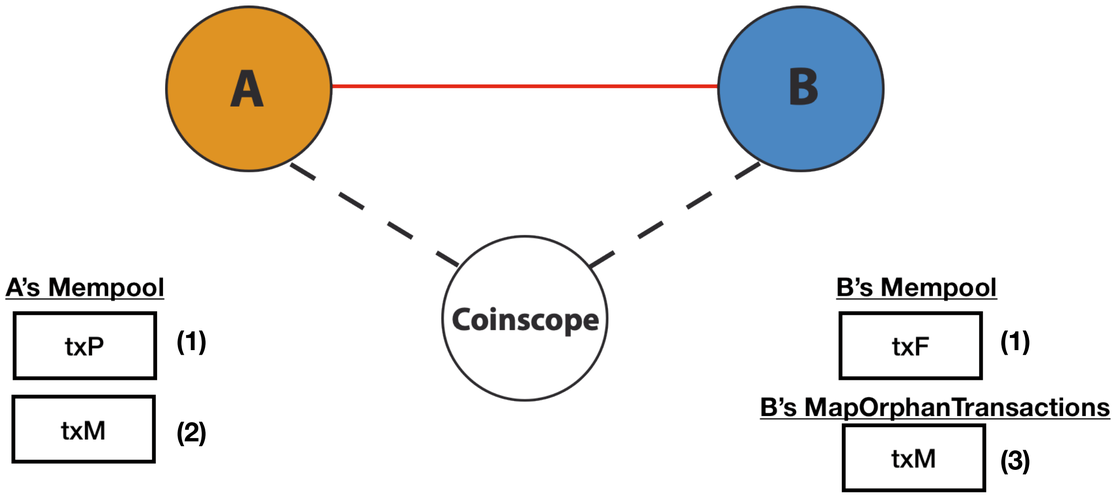
txF	(1)

B's MapOrphanTransactions

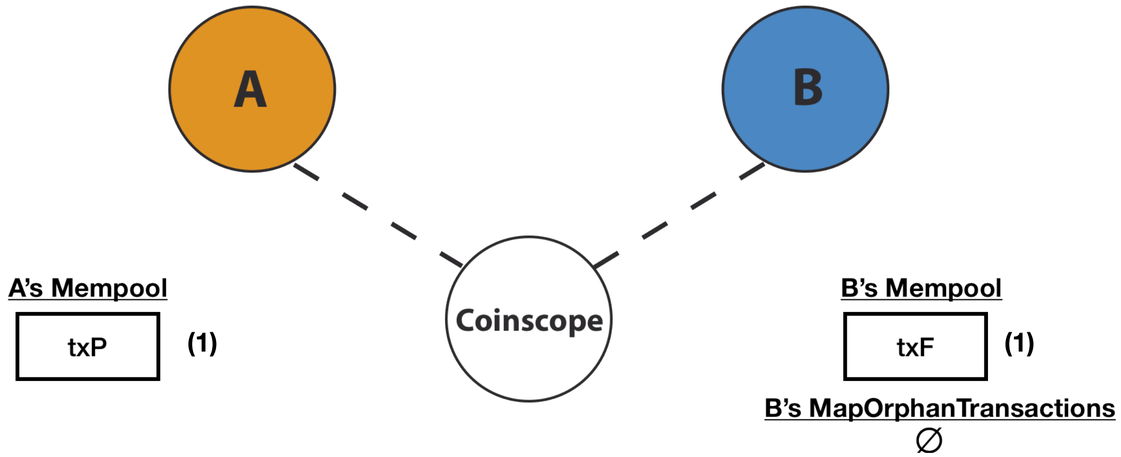
txM	(3)

A BASIC TOPOLOGY INFERRING TECHNIQUE

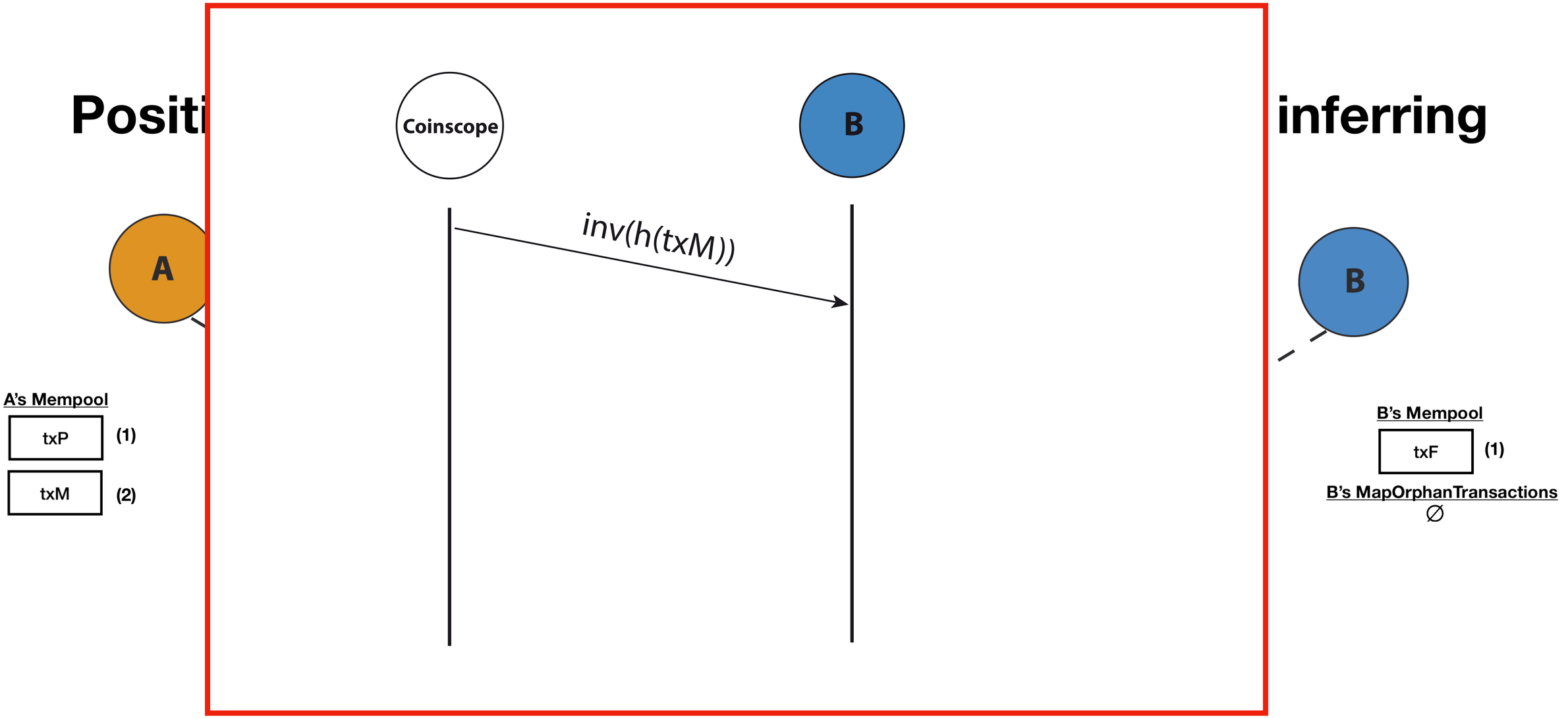
Positive edge inferring



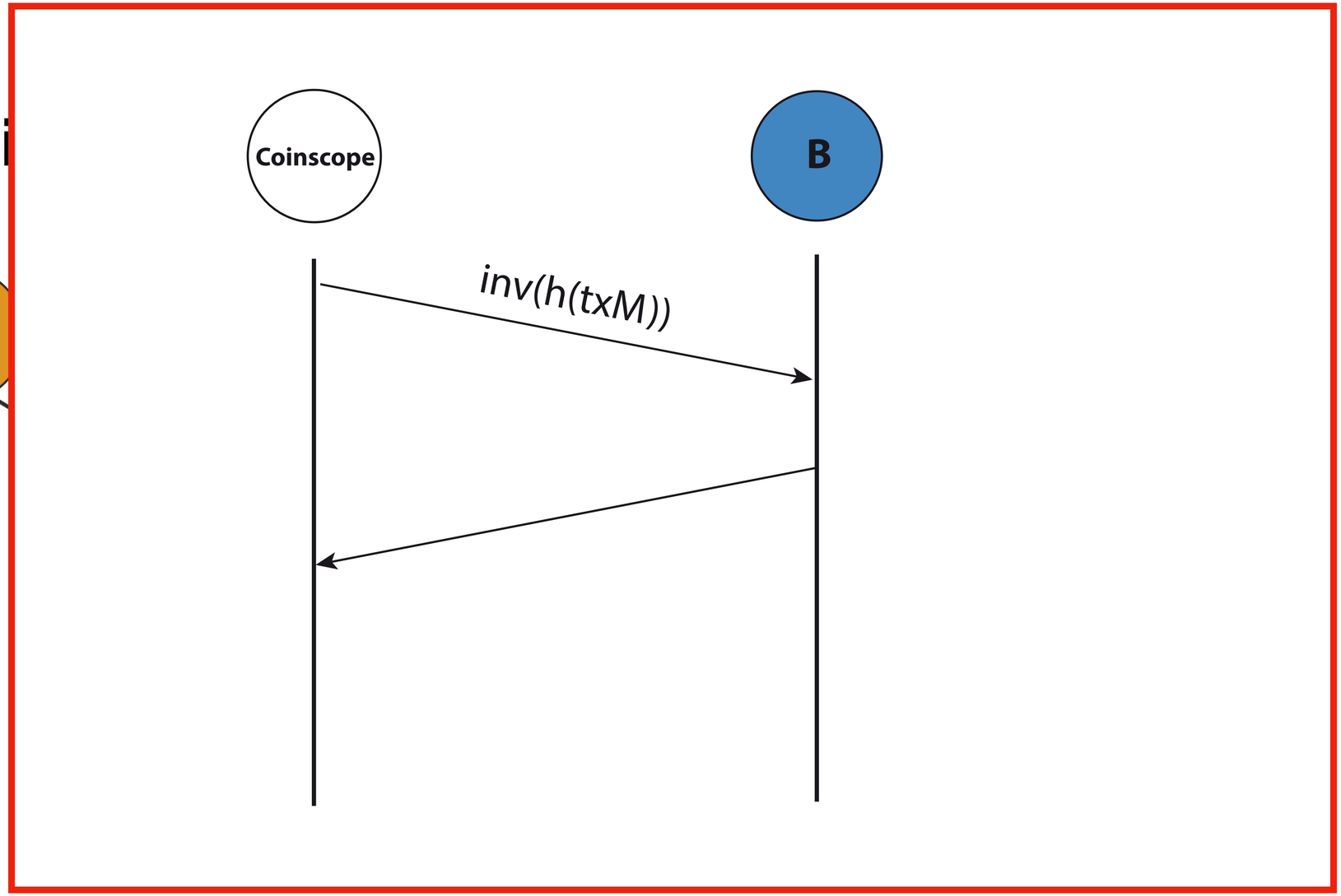
Negative edge inferring



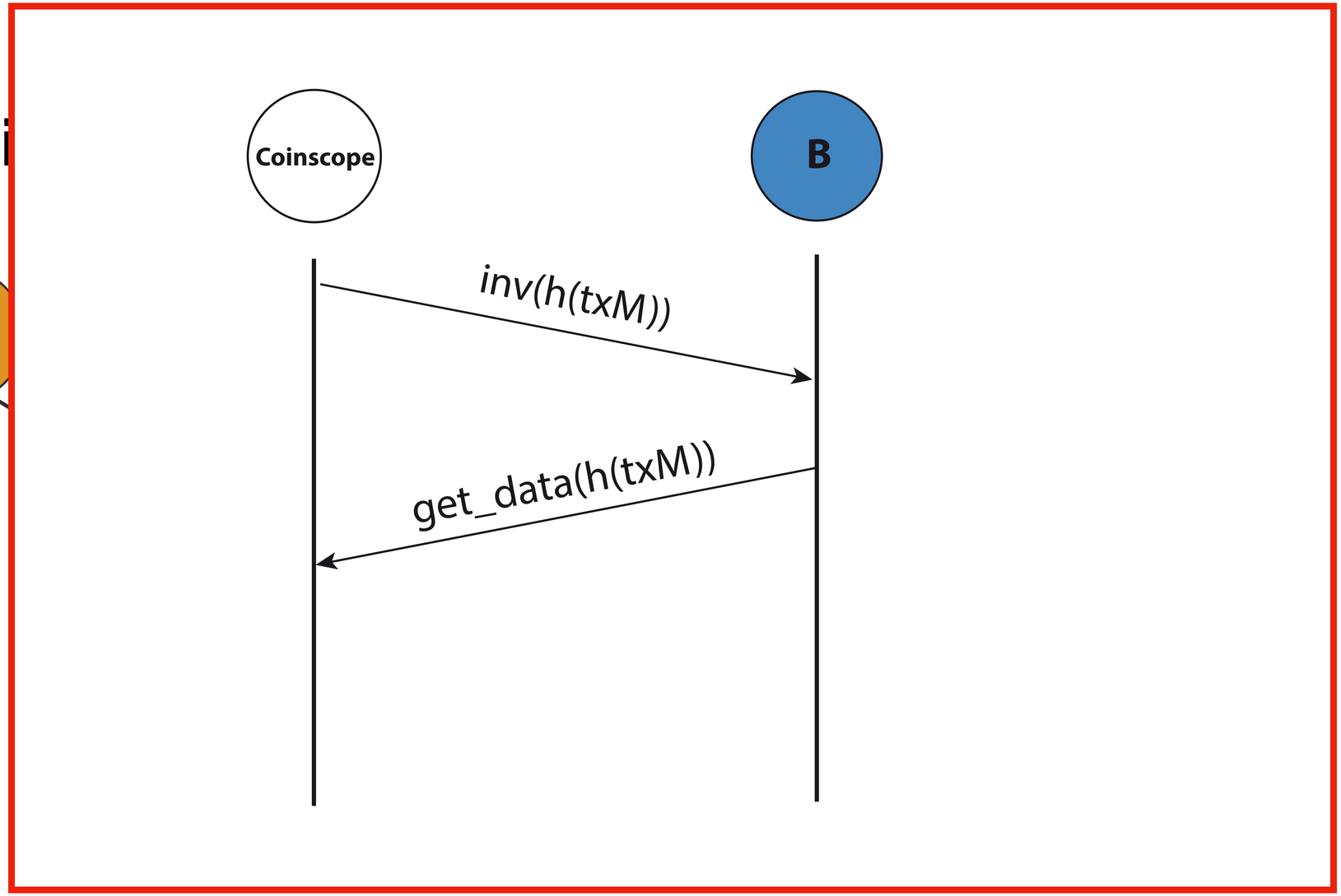
A BASIC TOPOLOGY INFERRING TECHNIQUE



A BASIC TOPOLOGY INFERRING TECHNIQUE



A BASIC TOPOLOGY INFERRING TECHNIQUE



Positi

inferring

A

A's Mempool

txP (1)

txM (2)

B

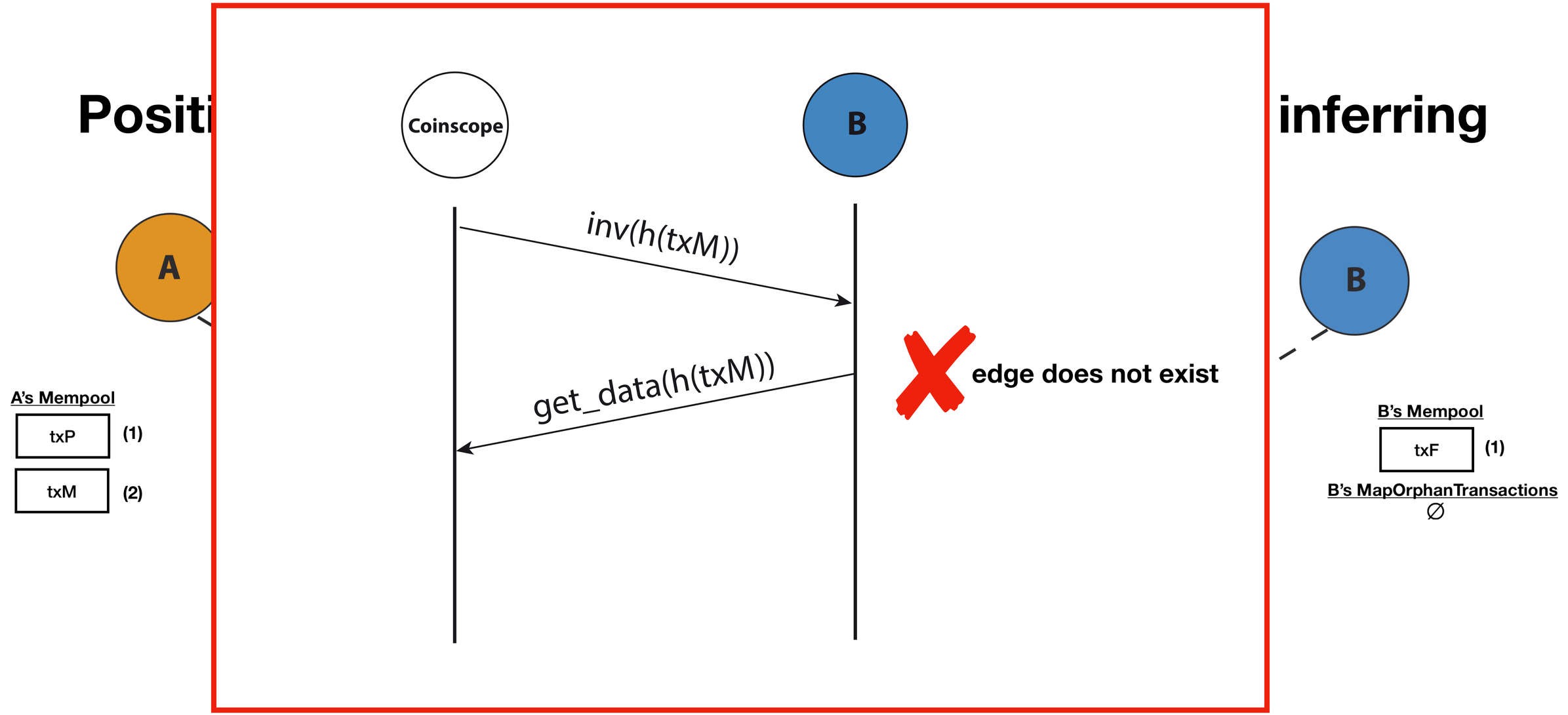
B's Mempool

txF (1)

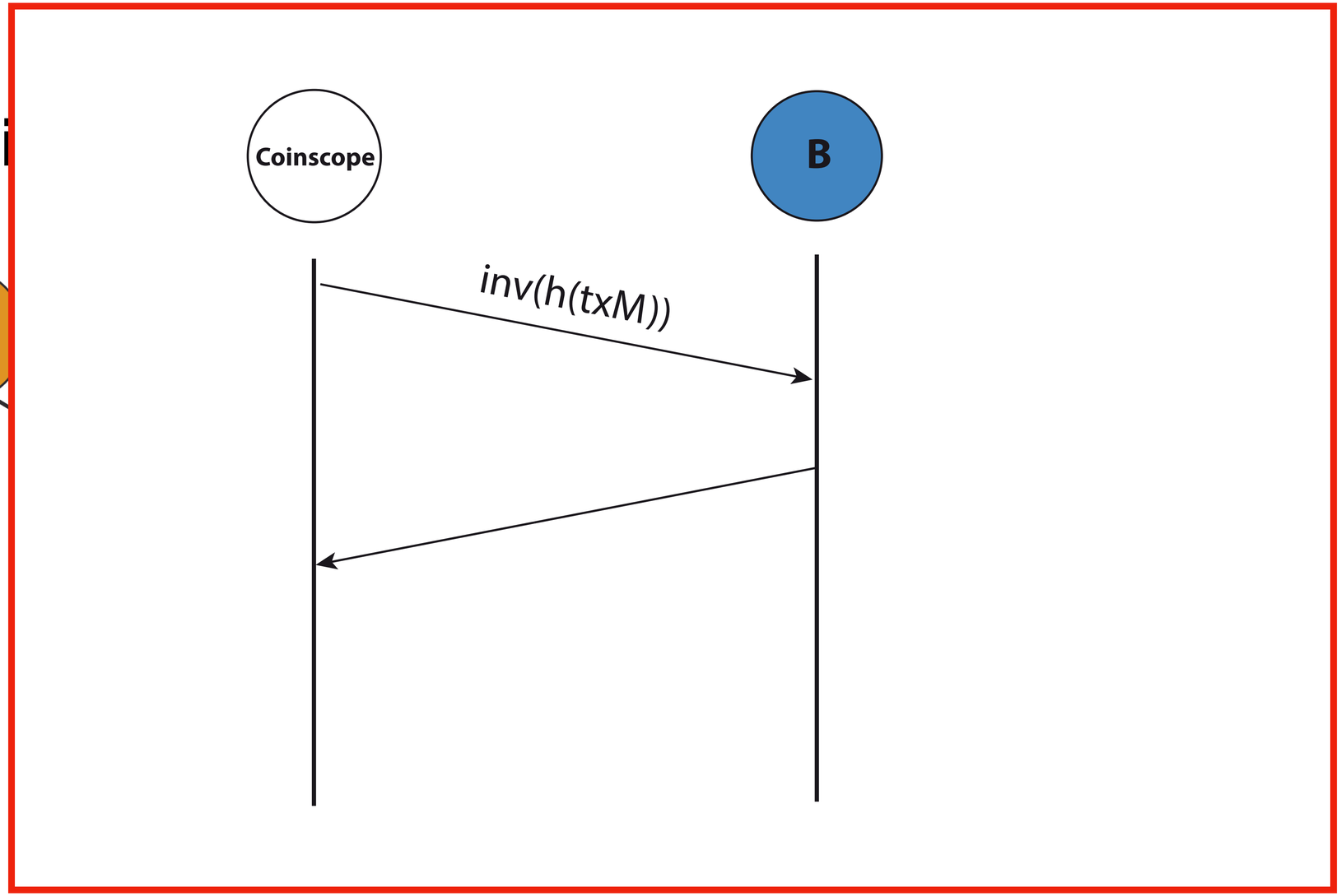
B's MapOrphanTransactions

∅

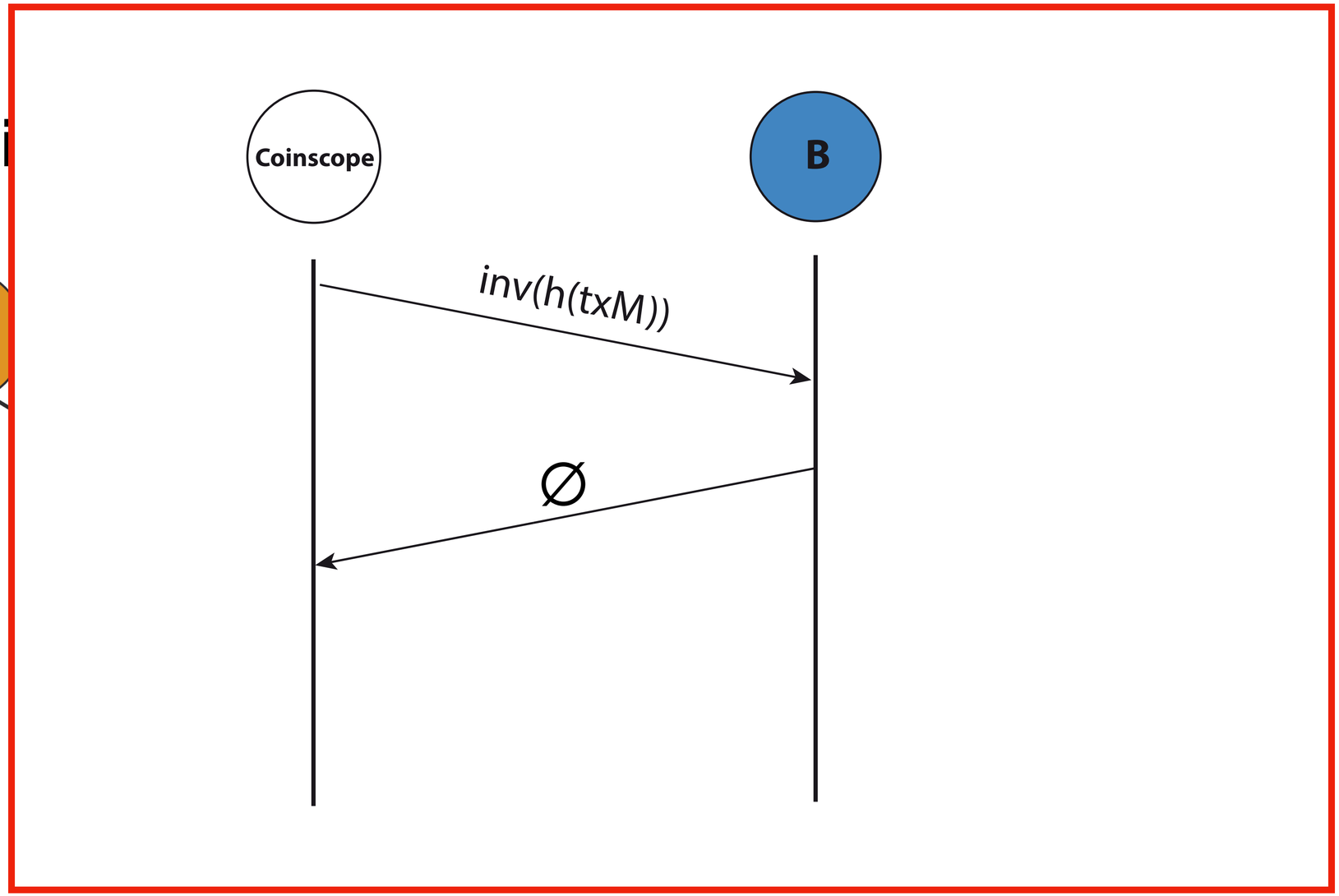
A BASIC TOPOLOGY INFERRING TECHNIQUE



A BASIC TOPOLOGY INFERRING TECHNIQUE



A BASIC TOPOLOGY INFERRING TECHNIQUE



Positi

inferring

A

A's Mempool

txP (1)

txM (2)

B

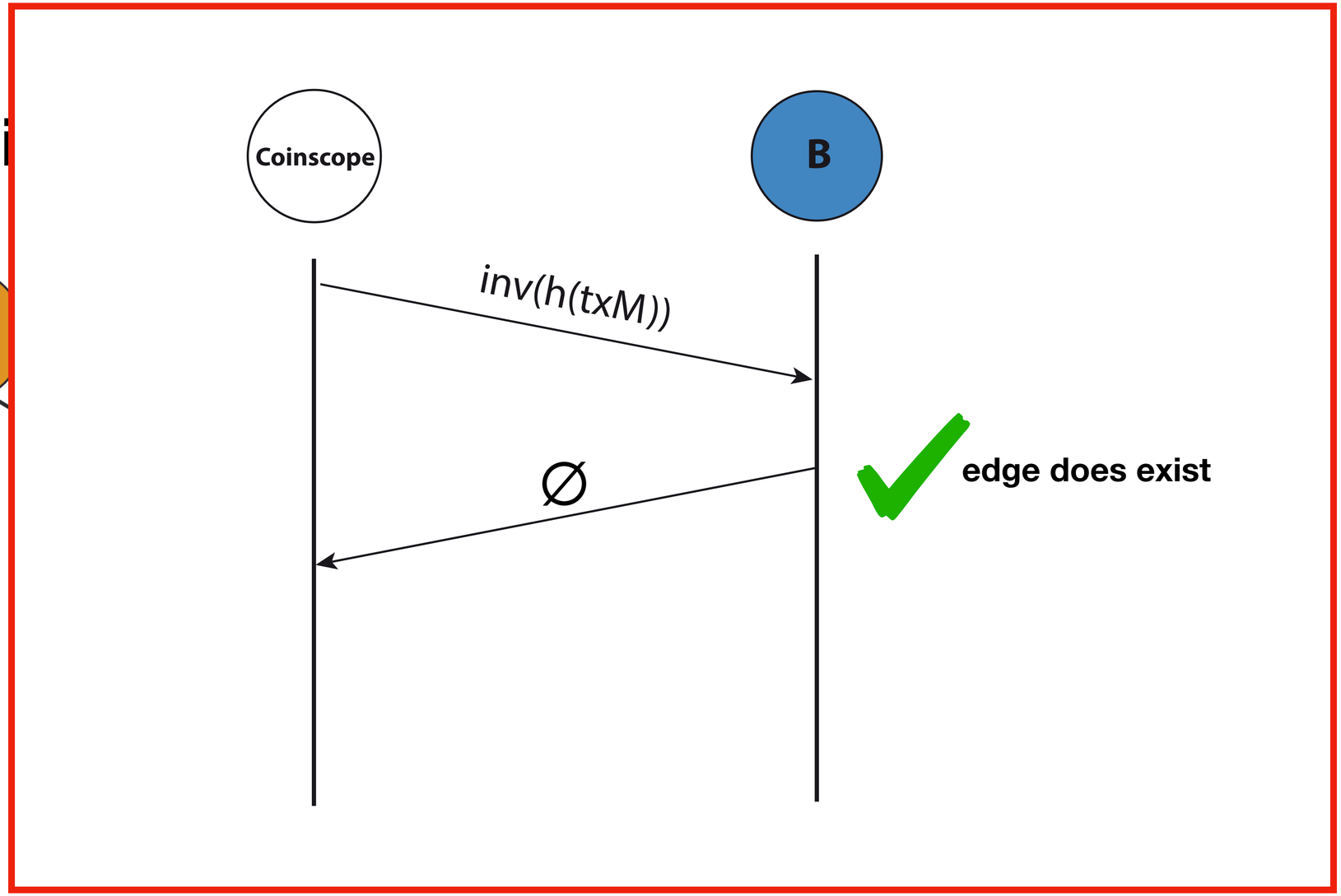
B's Mempool

txF (1)

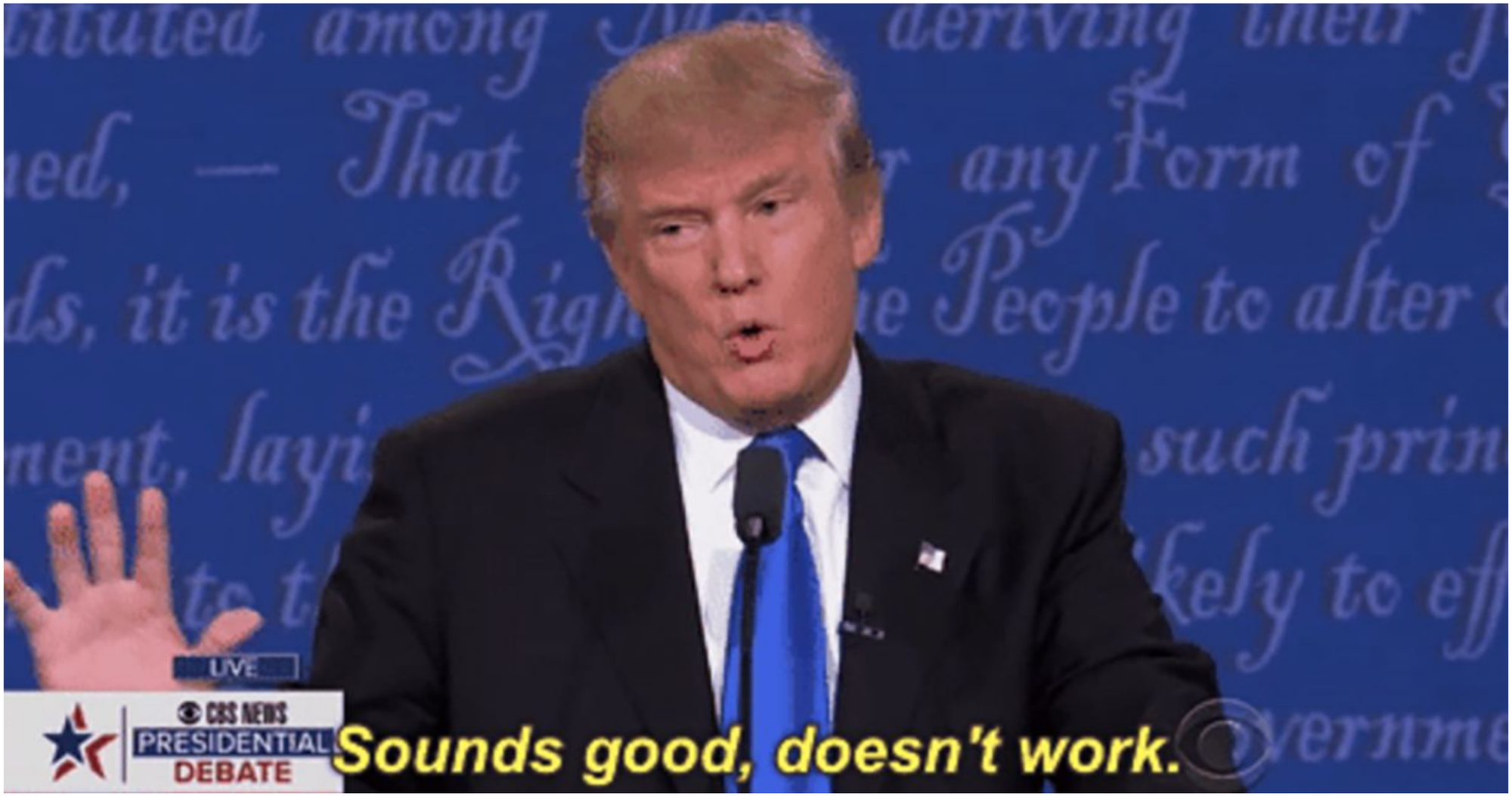
B's MapOrphanTransactions

∅

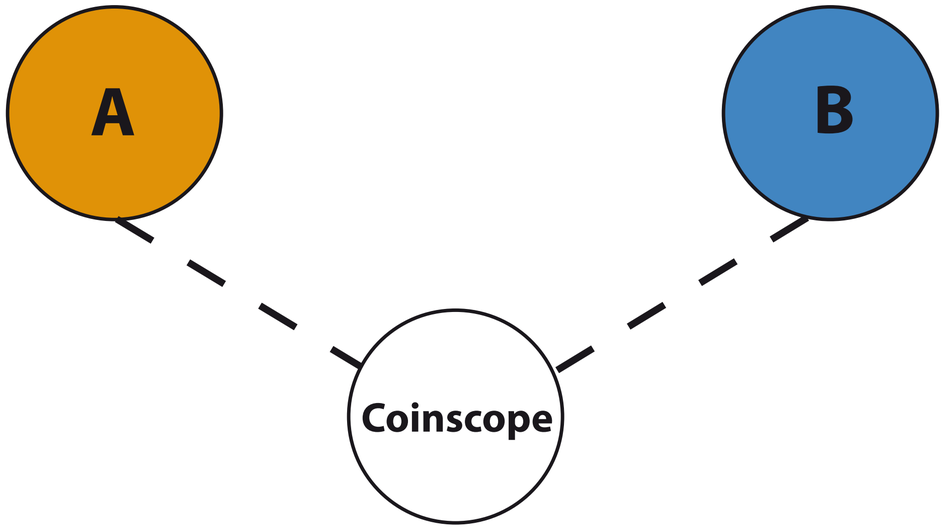
A BASIC TOPOLOGY INFERRING TECHNIQUE



ITS NOT THAT EASY

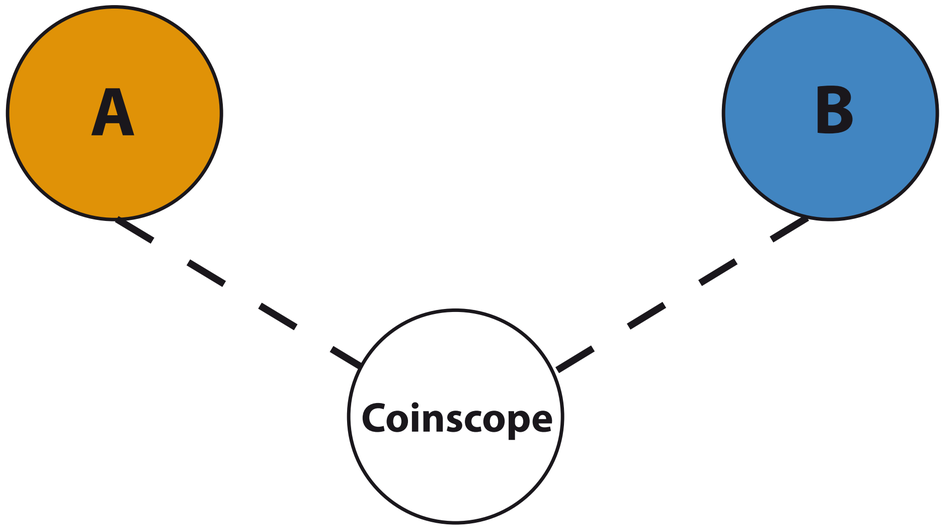


ITS NOT THAT EASY



ITS NOT THAT EASY

Long story short, if you add an additional node to the equation it will fail



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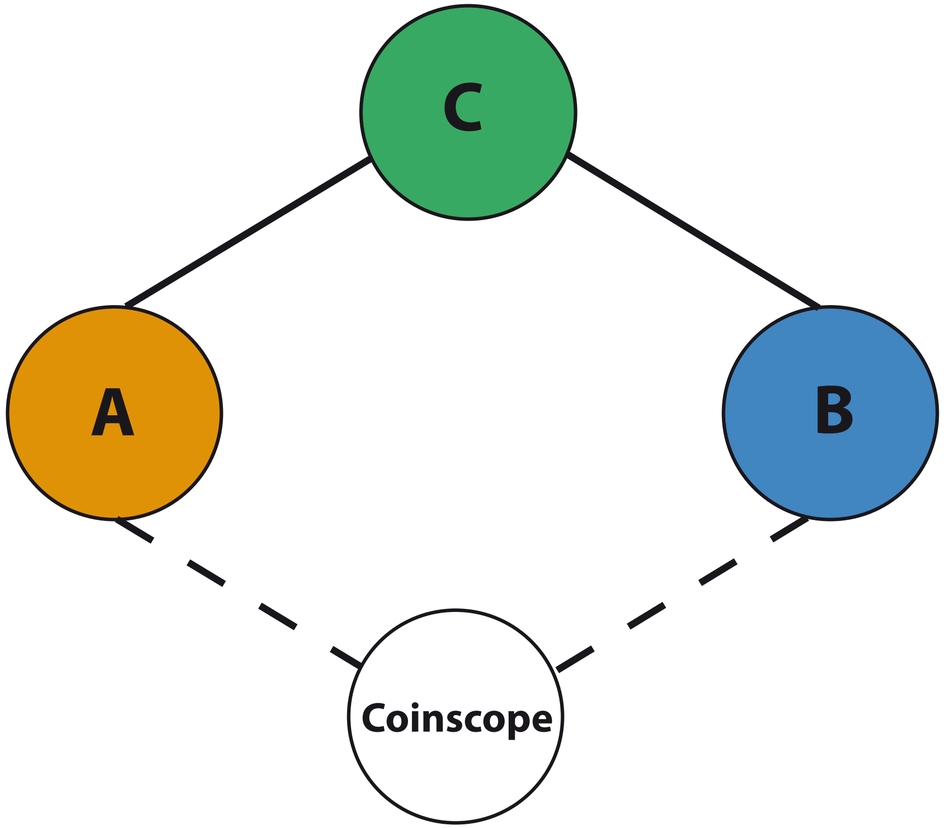

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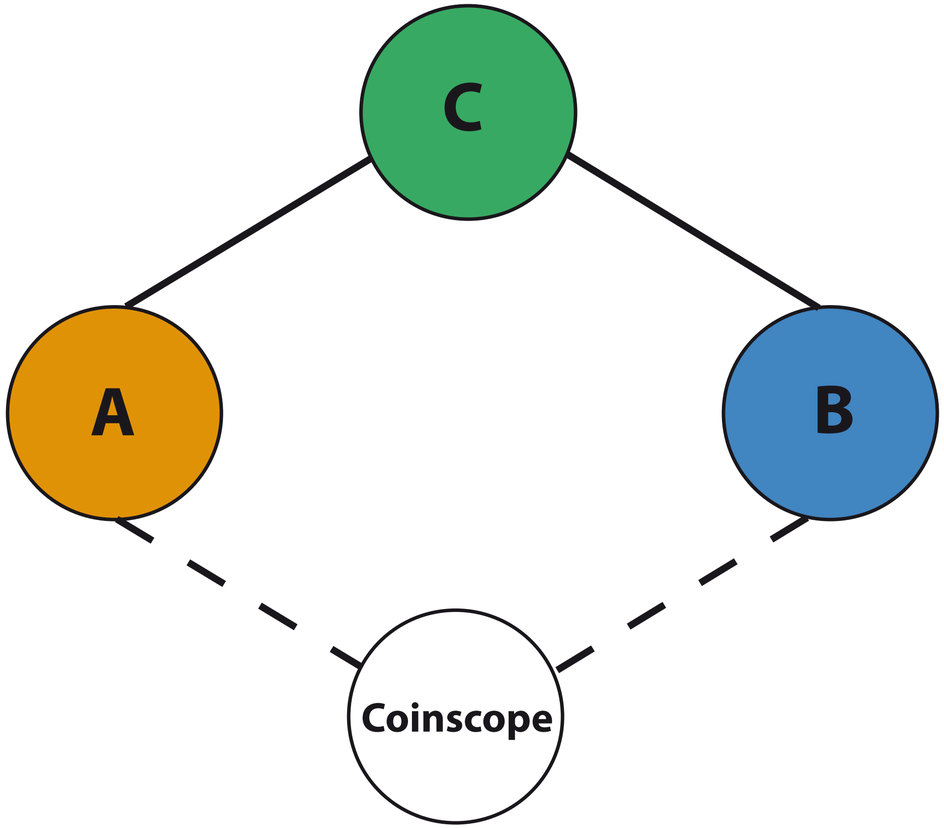


A's Mempool

∅

C's Mempool

∅

B's Mempool

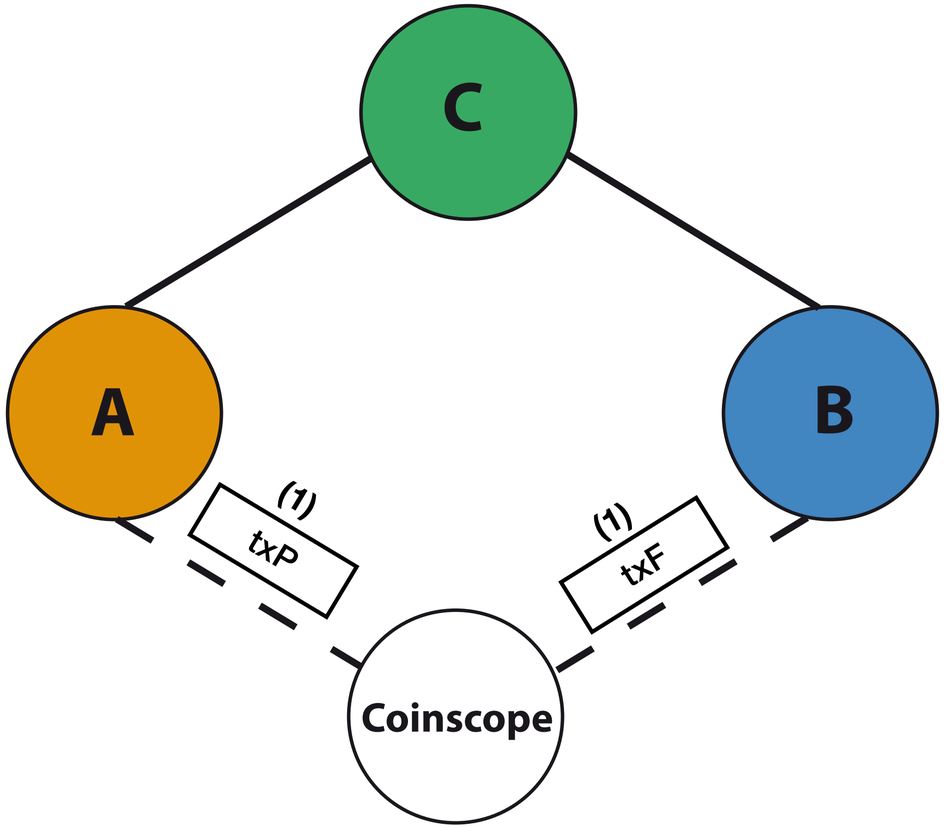
∅

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

Long story short, if you add an additional node to the equation it will fail



A's Mempool

∅

C's Mempool

∅

B's Mempool

∅

B's MapOrphanTransactions

∅

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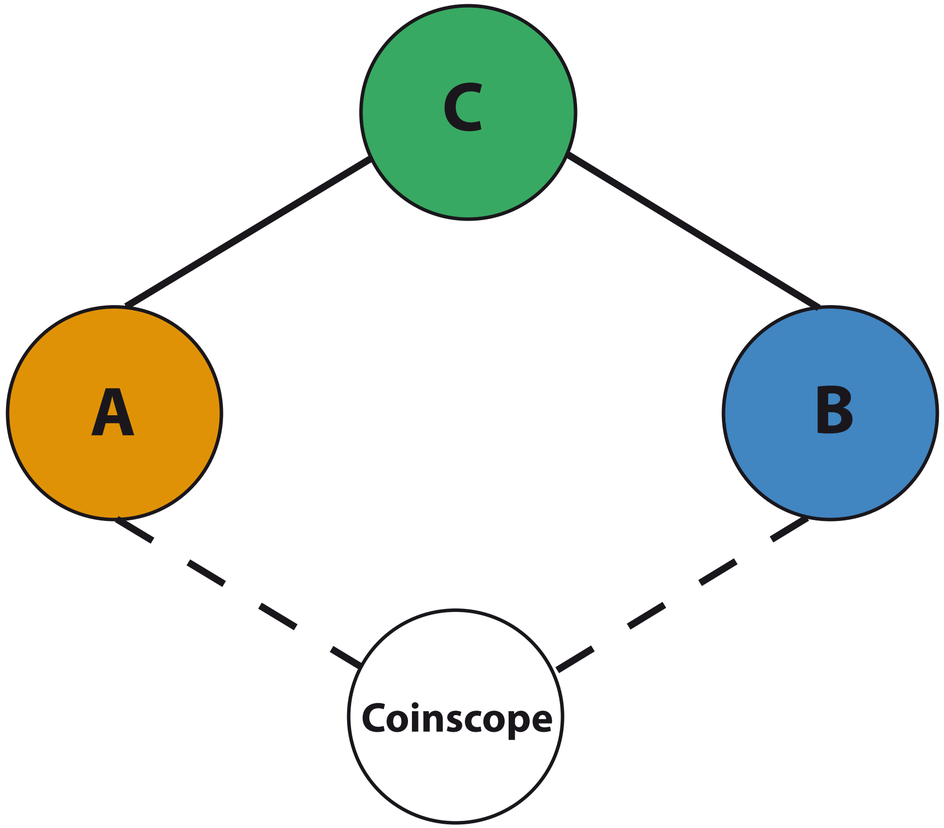

A's Mempool

∅

C's Mempool

∅

B's Mempool

∅

B's MapOrphanTransactions

∅

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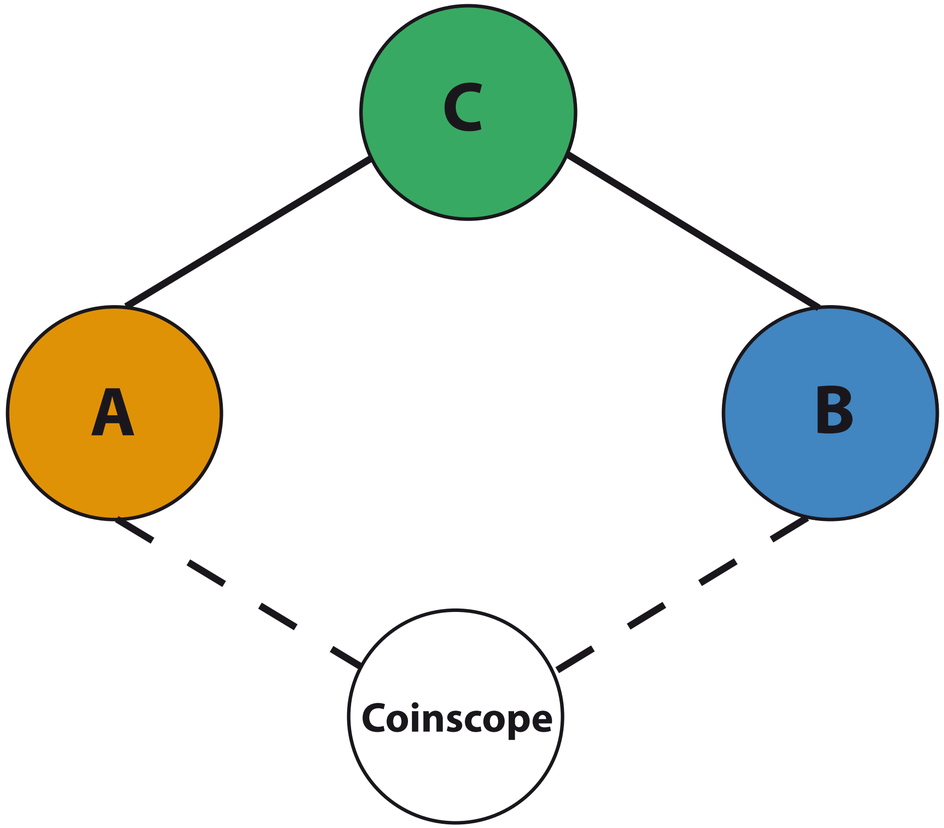
Long story short, if you add an additional node to the equation it will fail



A's Mempool

txP (1)

C's Mempool

∅

B's Mempool

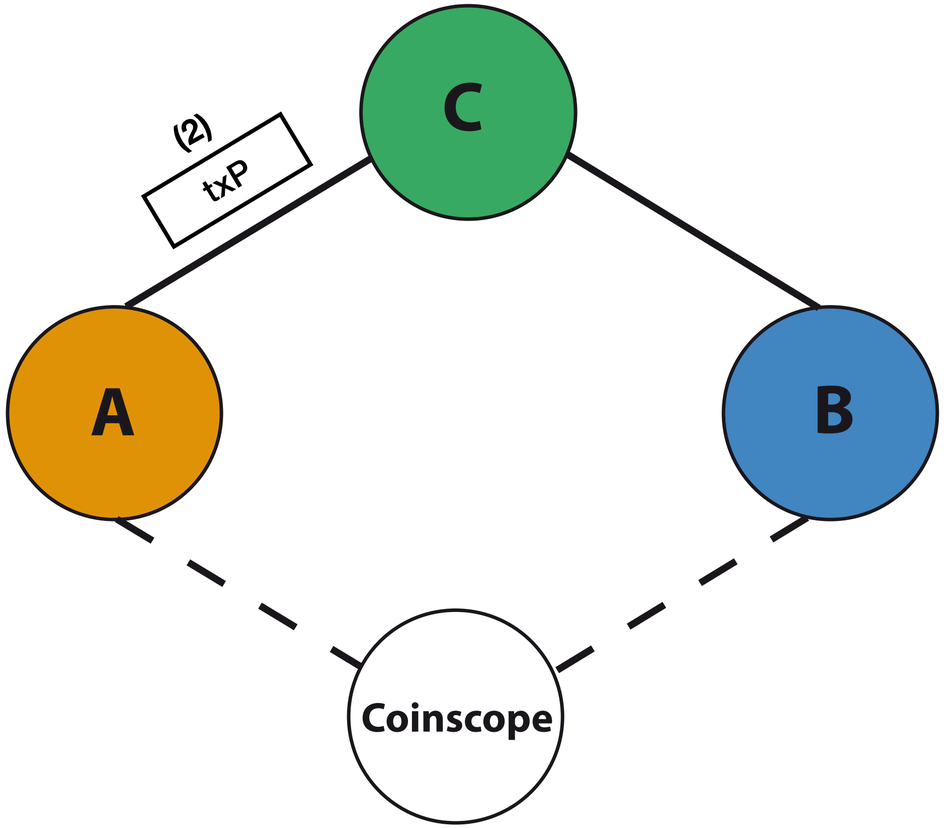
txF (1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

Long story short, if you add an additional node to the equation it will fail



A's Mempool

txP (1)

C's Mempool

∅

B's Mempool

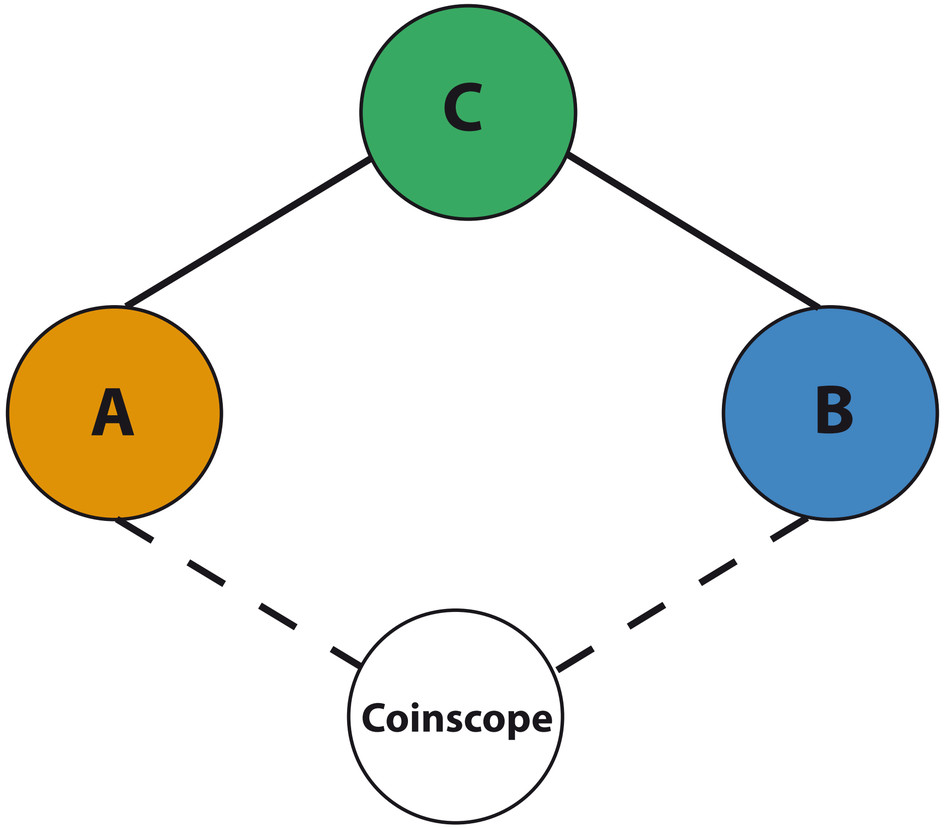
txF (1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

Long story short, if you add an additional node to the equation it will fail



A's Mempool

txP (1)

C's Mempool

∅

B's Mempool

txF (1)

B's MapOrphanTransactions

∅

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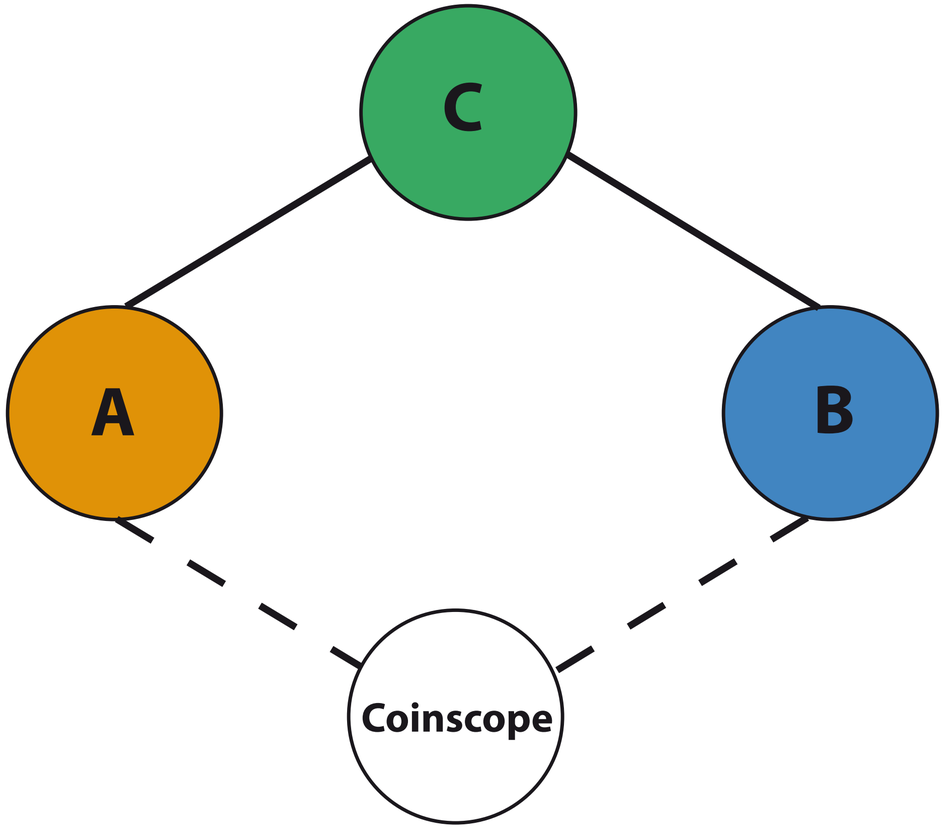


A's Mempool

txP (1)

C's Mempool

txP (2)

B's Mempool

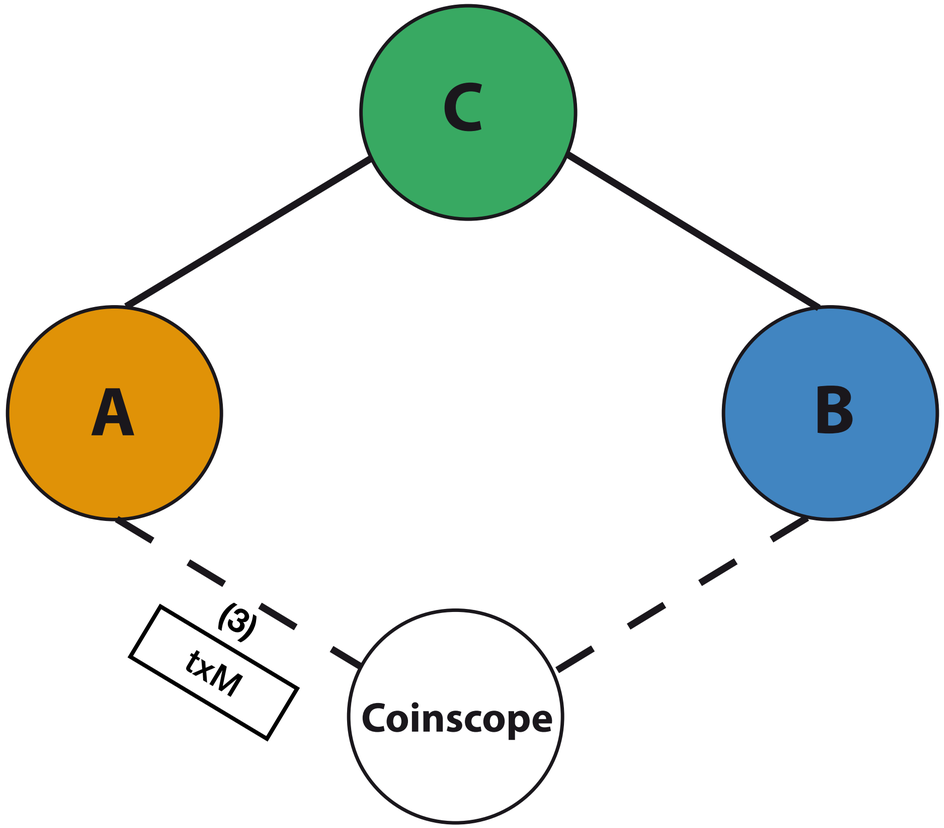
txF (1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

Long story short, if you add an additional node to the equation it will fail



A's Mempool

txP (1)

C's Mempool

txP (2)

B's Mempool

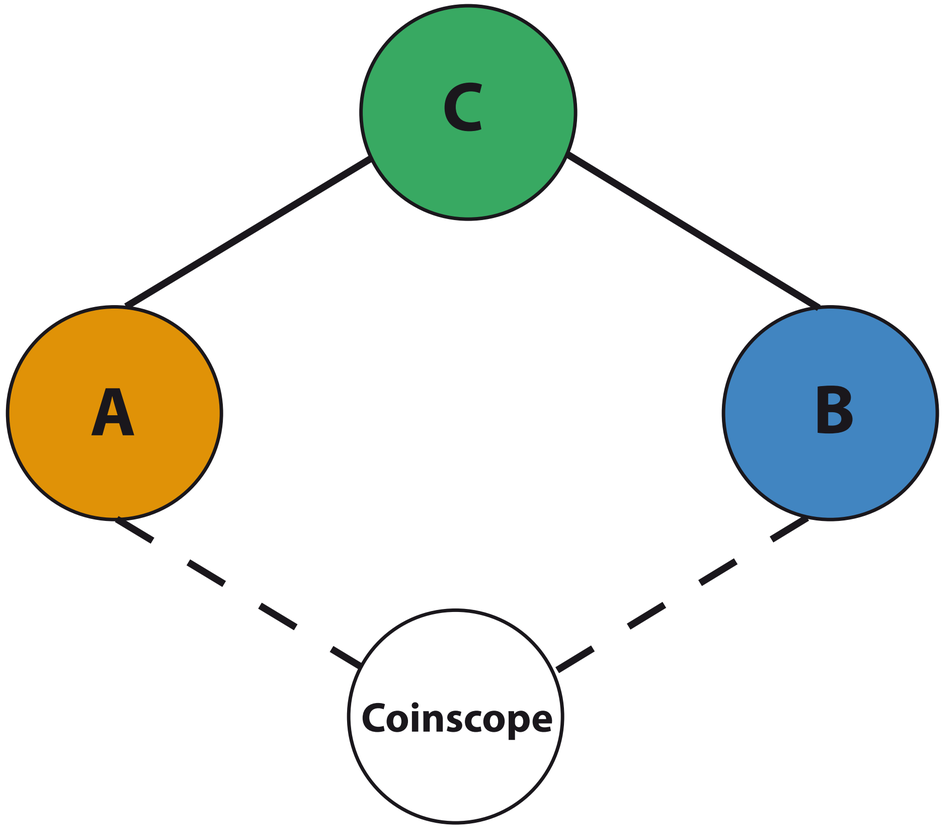
txF (1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

Long story short, if you add an additional node to the equation it will fail



A's Mempool

txP (1)

C's Mempool

txP (2)

B's Mempool

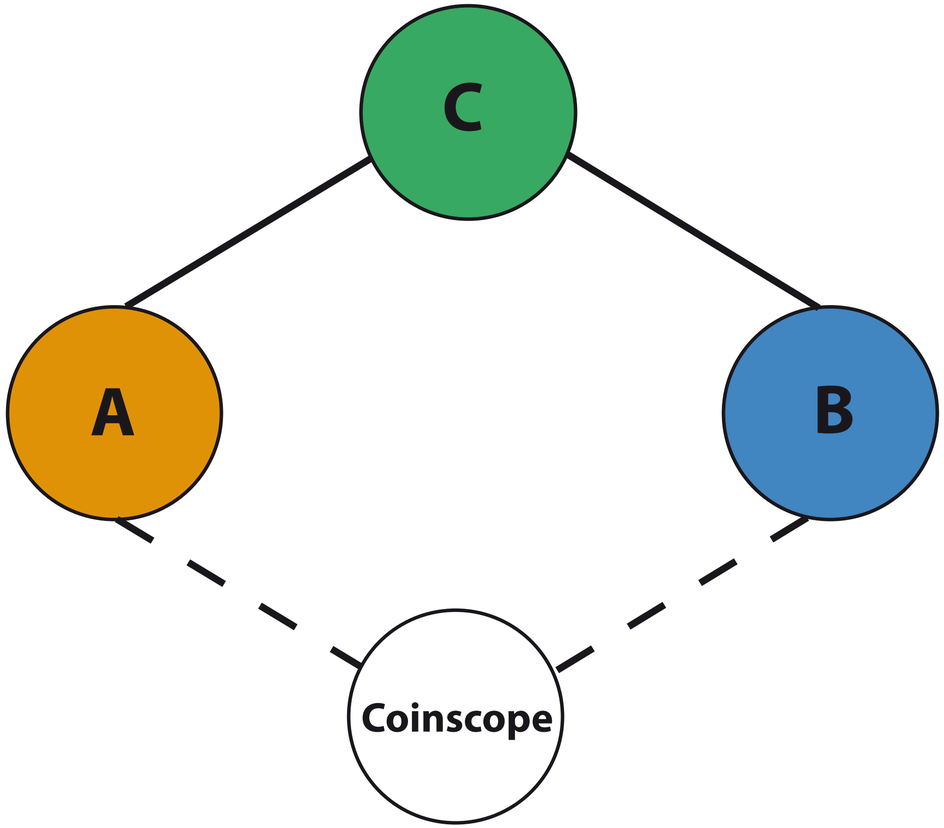
txF (1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

Long story short, if you add an additional node to the equation it will fail



A's Mempool

txP (1)

txM (3)

C's Mempool

txP (2)

B's Mempool

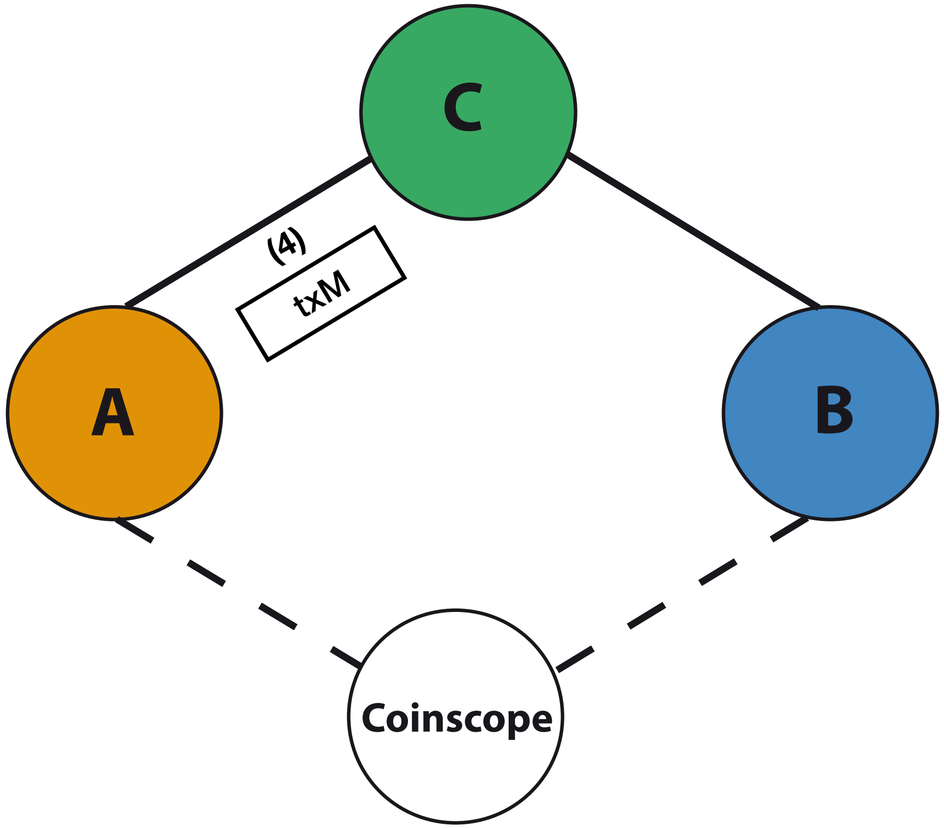
txF (1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

Long story short, if you add an additional node to the equation it will fail



A's Mempool

txP (1)

txM (3)

C's Mempool

txP (2)

B's Mempool

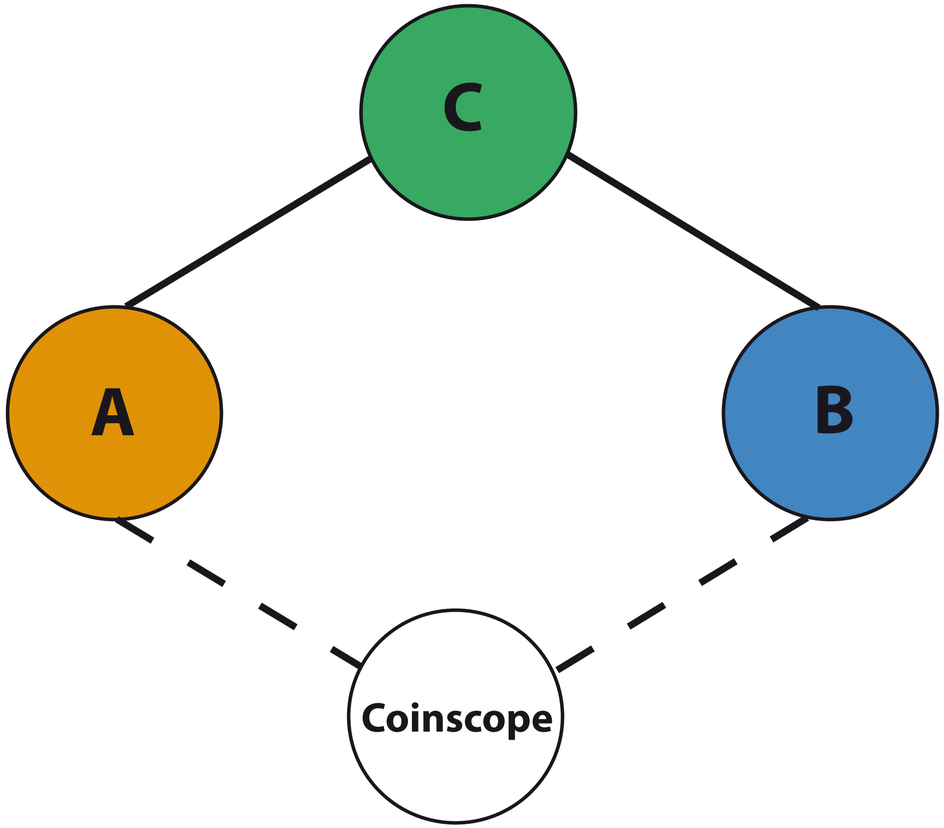
txF (1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

Long story short, if you add an additional node to the equation it will fail



A's Mempool

txP (1)

txM (3)

C's Mempool

txP (2)

B's Mempool

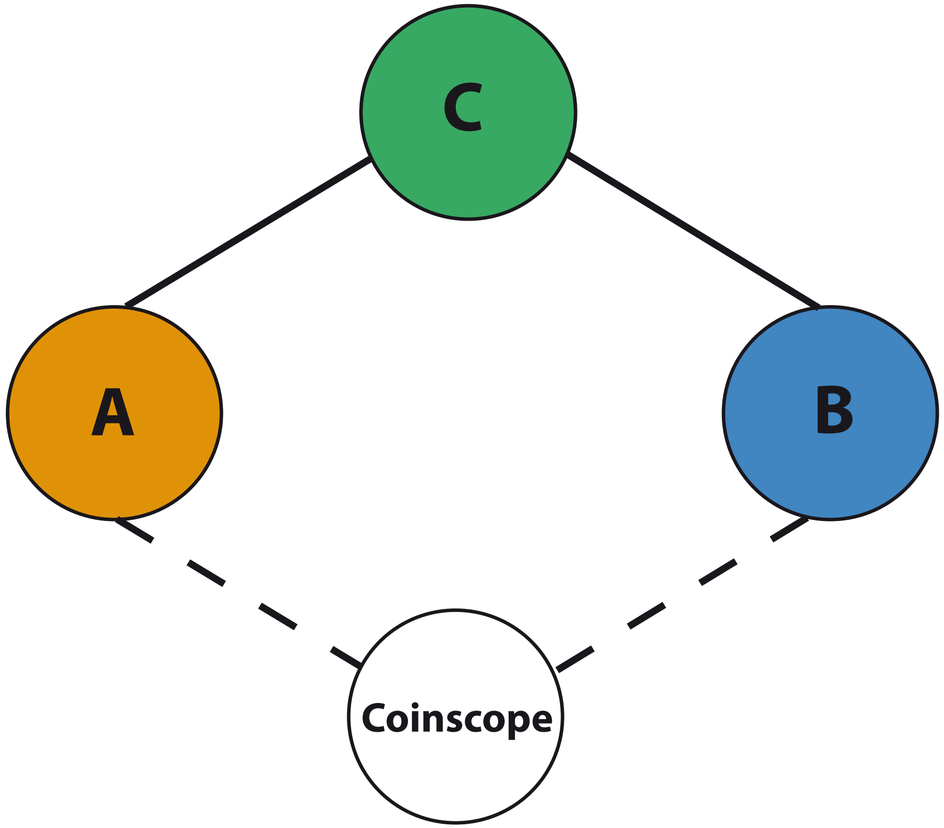
txF (1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

Long story short, if you add an additional node to the equation it will fail



A's Mempool

txP	(1)
txM	(3)

C's Mempool

txP	(2)
txM	(4)

B's Mempool

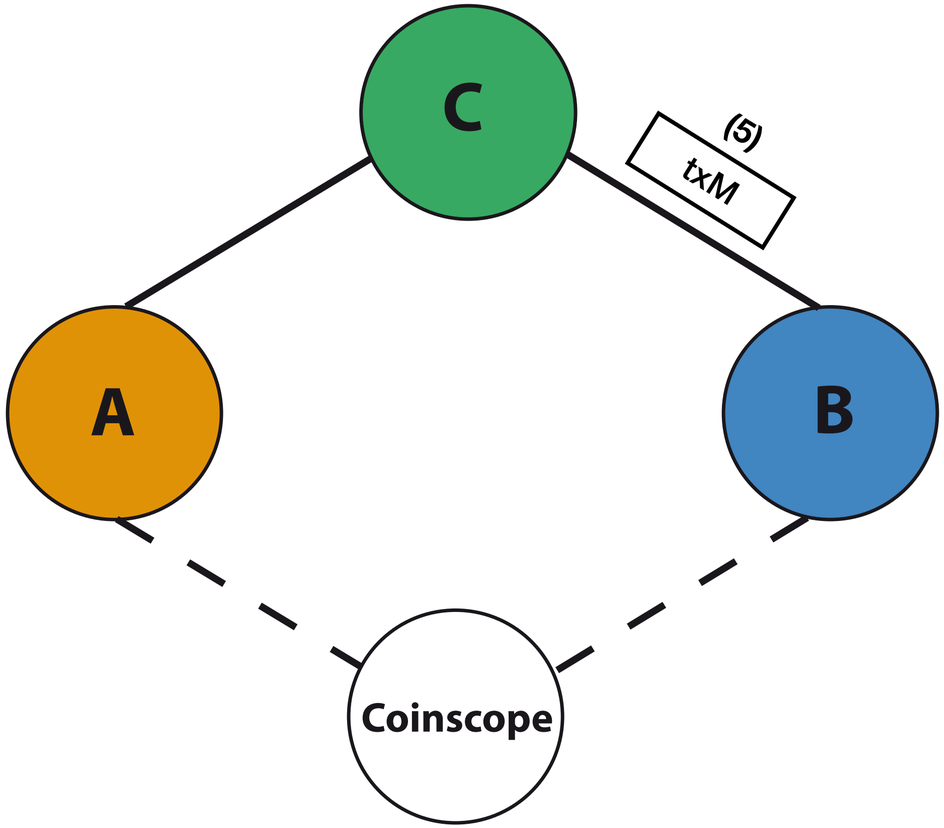
txF	(1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

Long story short, if you add an additional node to the equation it will fail



A's Mempool

txP	(1)
txM	(3)

C's Mempool

txP	(2)
txM	(4)

B's Mempool

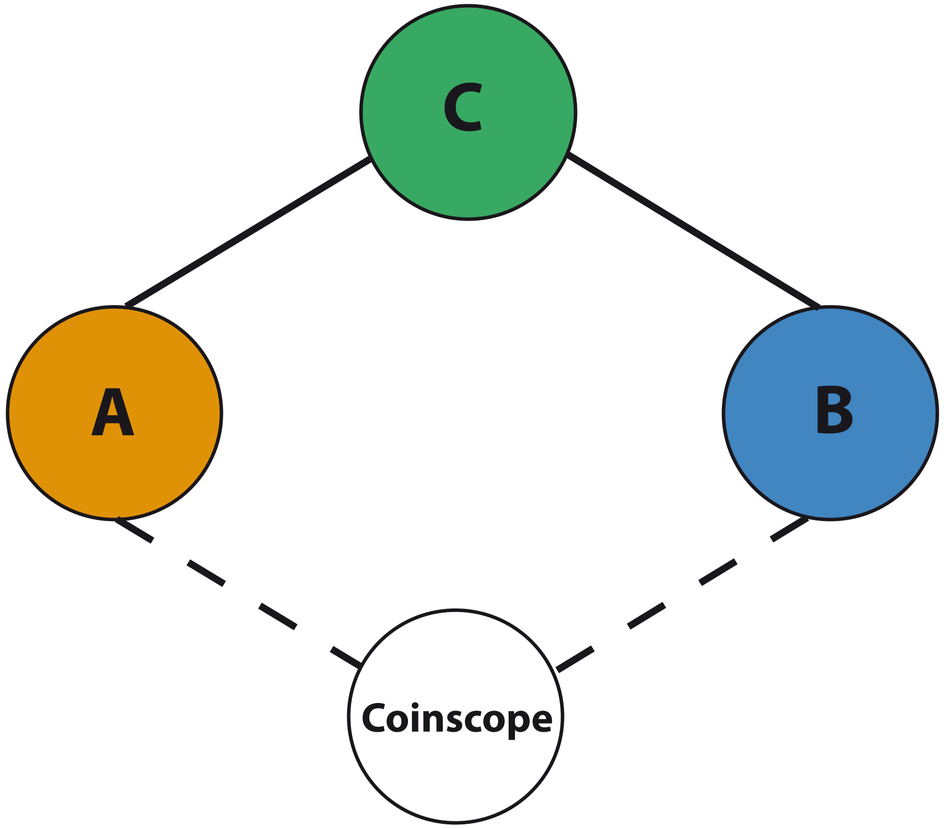
txF	(1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

Long story short, if you add an additional node to the equation it will fail



A's Mempool

txP	(1)
txM	(3)

C's Mempool

txP	(2)
txM	(4)

B's Mempool

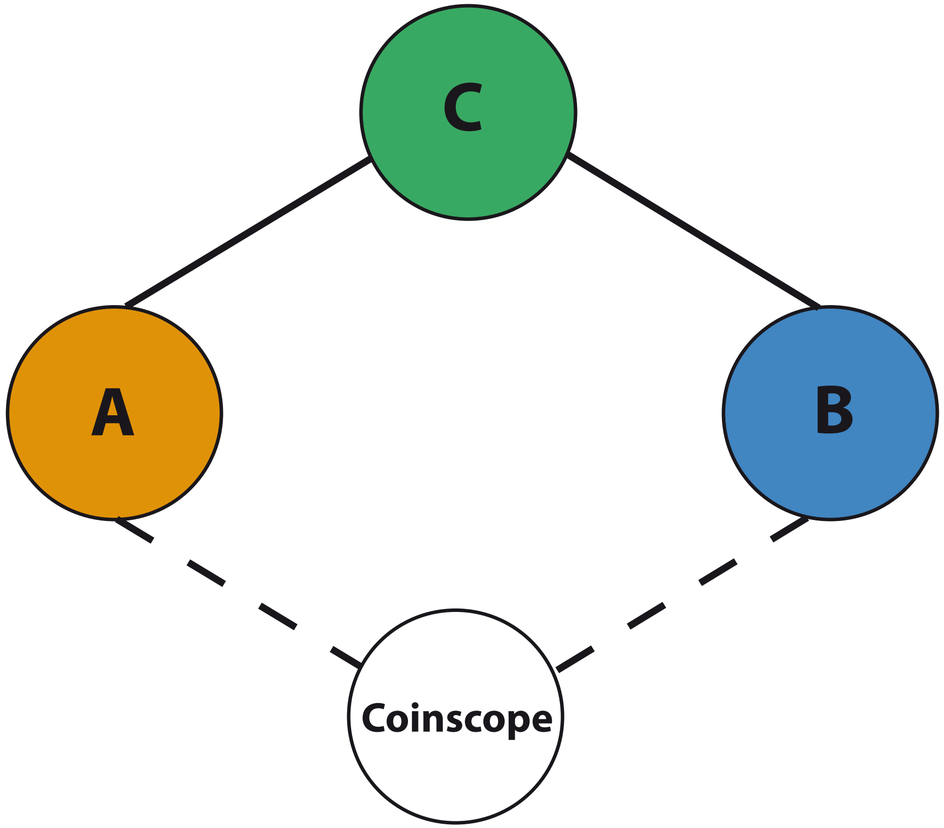
txF	(1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

Long story short, if you add an additional node to the equation it will fail



A's Mempool

txP (1)

txM (3)

C's Mempool

txP (2)

txM (4)

B's Mempool

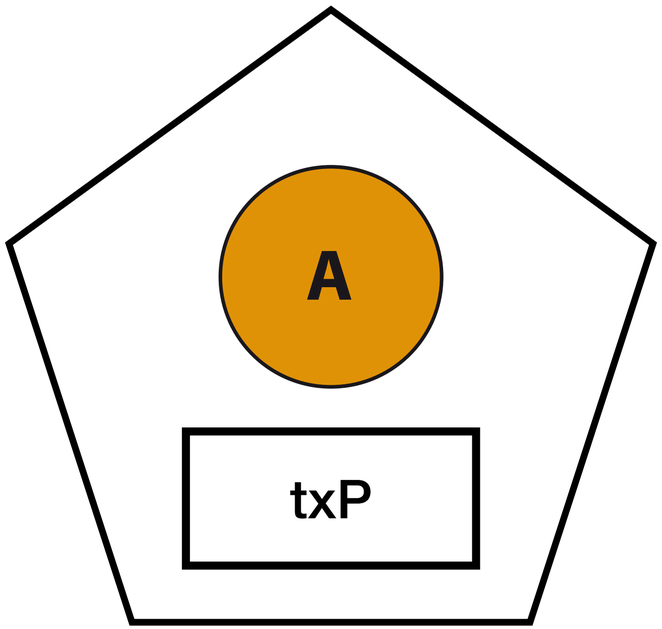
txF (1)

B's MapOrphanTransactions

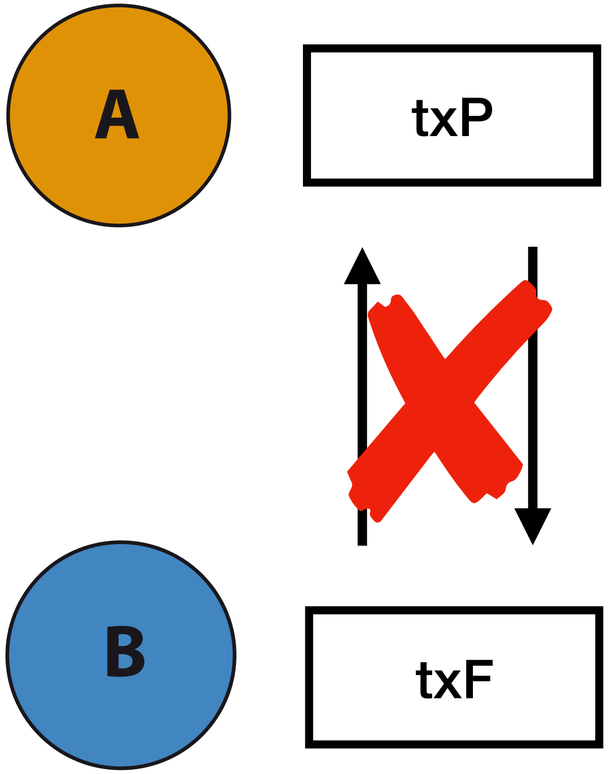
txM (5)

MAKE THIS WORK IN A REAL NETWORK

Isolation



Synchronicity



Scalability

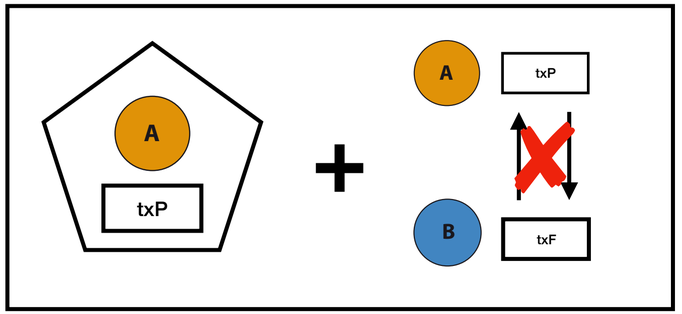
$$\approx 3n\ txs$$

$$\approx 2\sqrt{n}\ txs$$

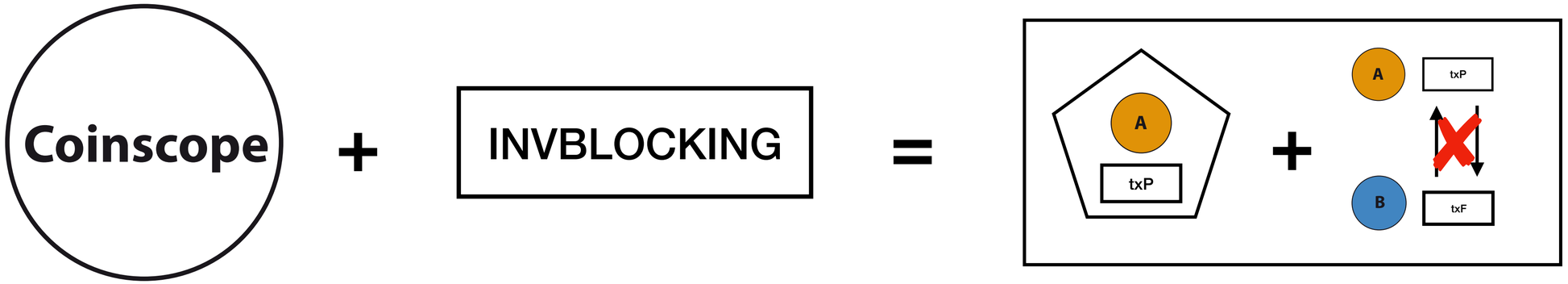
$$n = \#nodes$$

ACHIEVING ISOLATION AND SYNCHRONICITY

Coinscope + INVBLOCKING =

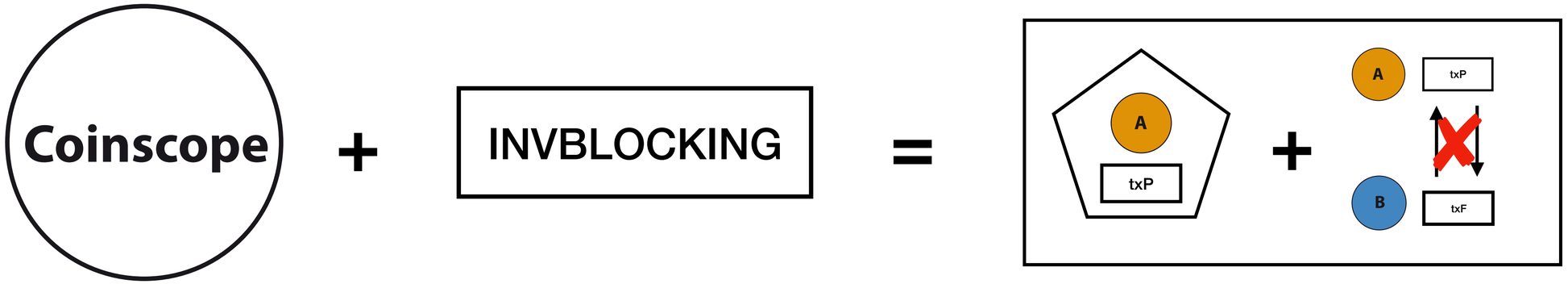


ACHIEVING ISOLATION AND SYNCHRONICITY



INVBLOCKING

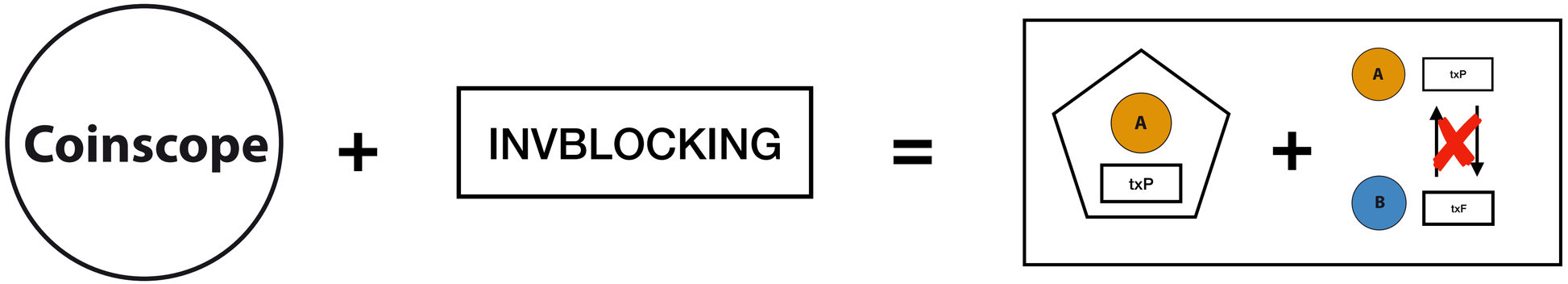
ACHIEVING ISOLATION AND SYNCHRONICITY



INVBLOCKING

- Send **INV** messages with **txP** and **txF** to the whole network

ACHIEVING ISOLATION AND SYNCHRONICITY



INVBLOCKING

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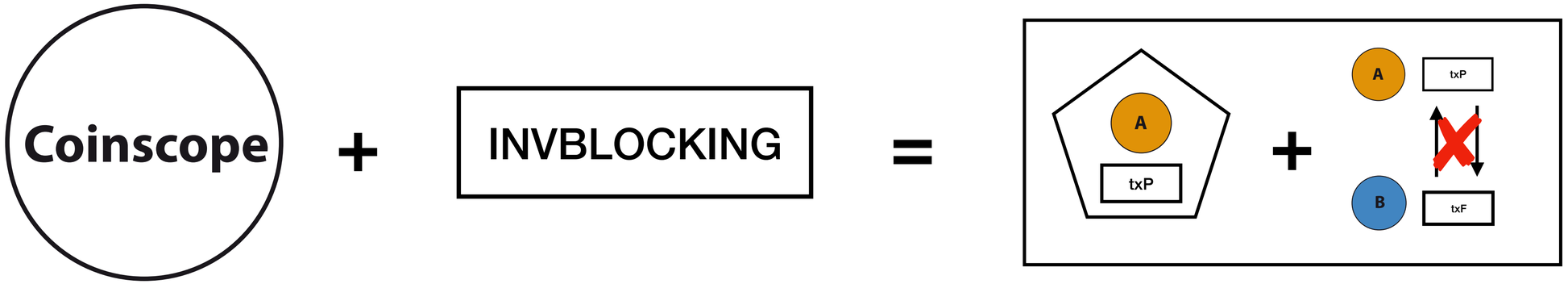
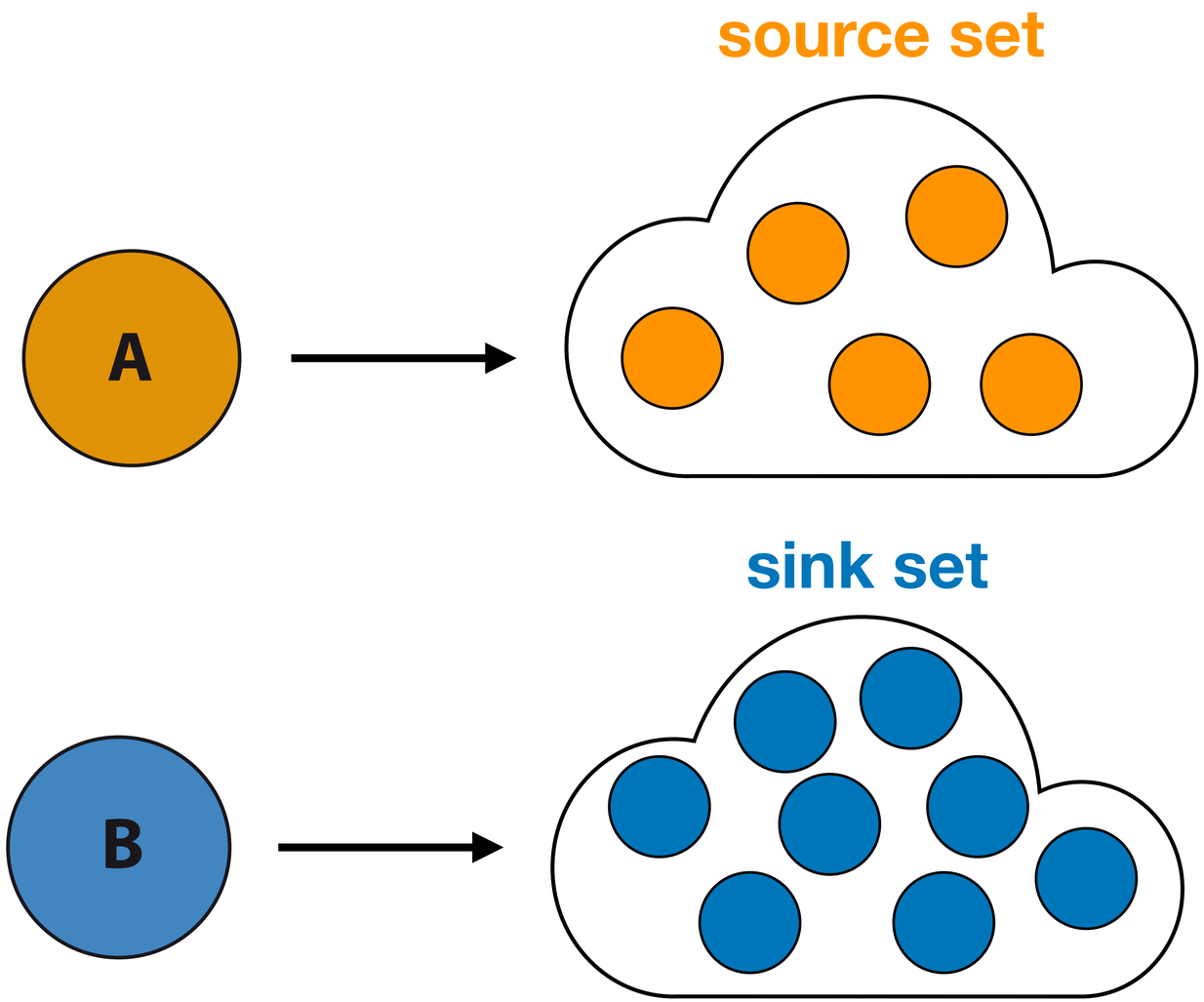
ACHIEVING ISOLATION AND SYNCHRONICITY



INVBLOCKING

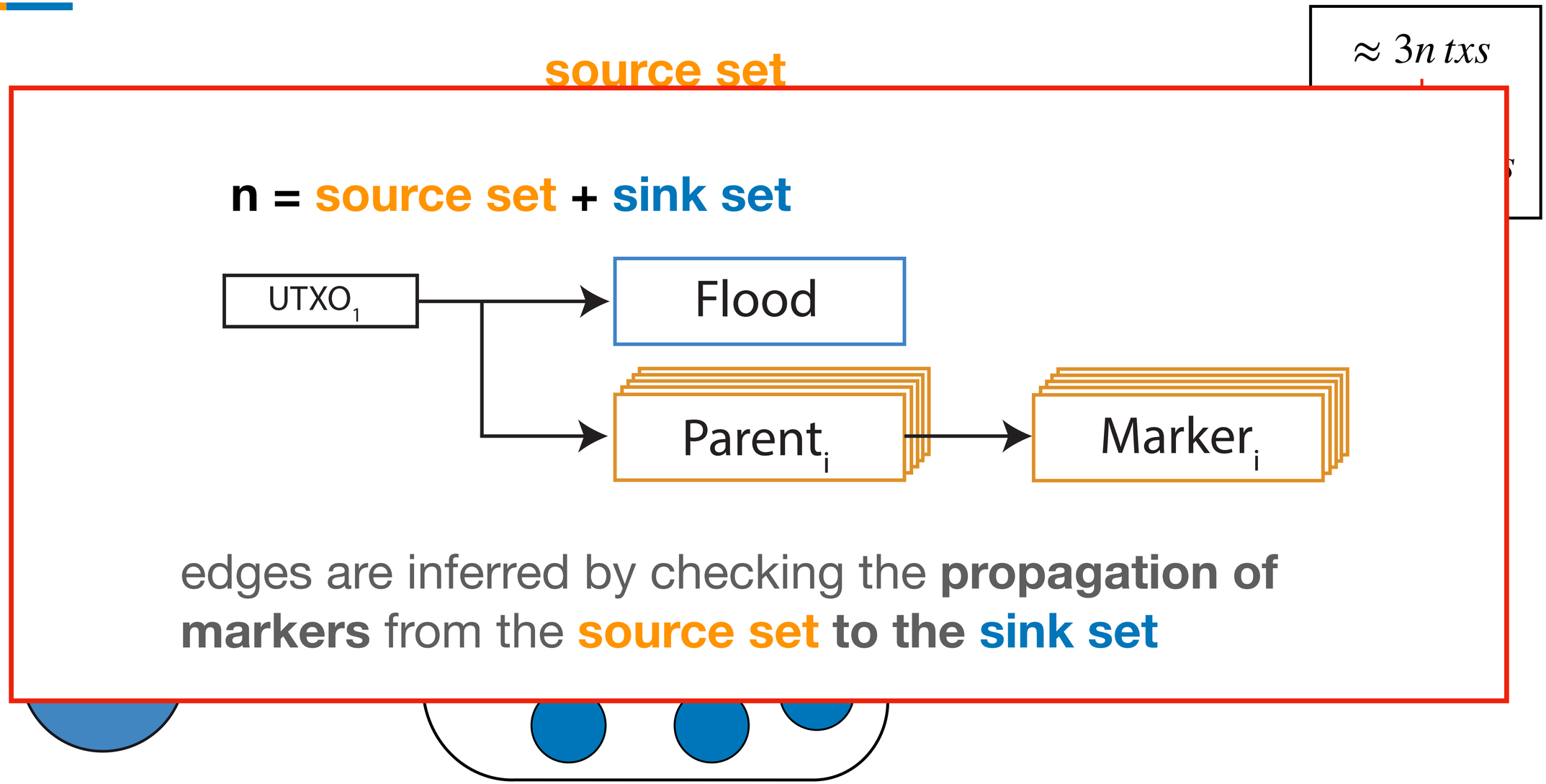
- Send **INV** messages with **txP** and **txF** to the whole network
- Nodes will **ask us** about **txP** and **txF**
- We **withhold** the information effectively **blocking the propagation of txP and txF**

ACHIEVING SCALABILITY



$$\approx 3n\ txs$$
$$\downarrow$$
$$\approx 2\sqrt{n}\ txs$$

ACHIEVING SCALABILITY



ACHIEVING SCALABILITY (CONT)

To satisfy the **scalability property**, we are inferring several edges at the same time

We need to make sure that the MapOrphanTransactions pool **have enough room** to store all our orphans

Otherwise **false negatives** could occur

ACHIEVING SCALABILITY (CONT)

To satisfy the **scalability property**, we are inferring several edges at the same time

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Otherwise **false negatives** could occur

Refer to the paper for details about the orphan pool handling

TXPROBE - PROTOCOL OVERVIEW

- **Choose** source and sink sets
- **Create** Parents, Markers and Flood transactions
- **INVBLOCK** the network
- **Send** transactions
- **Request** markers back

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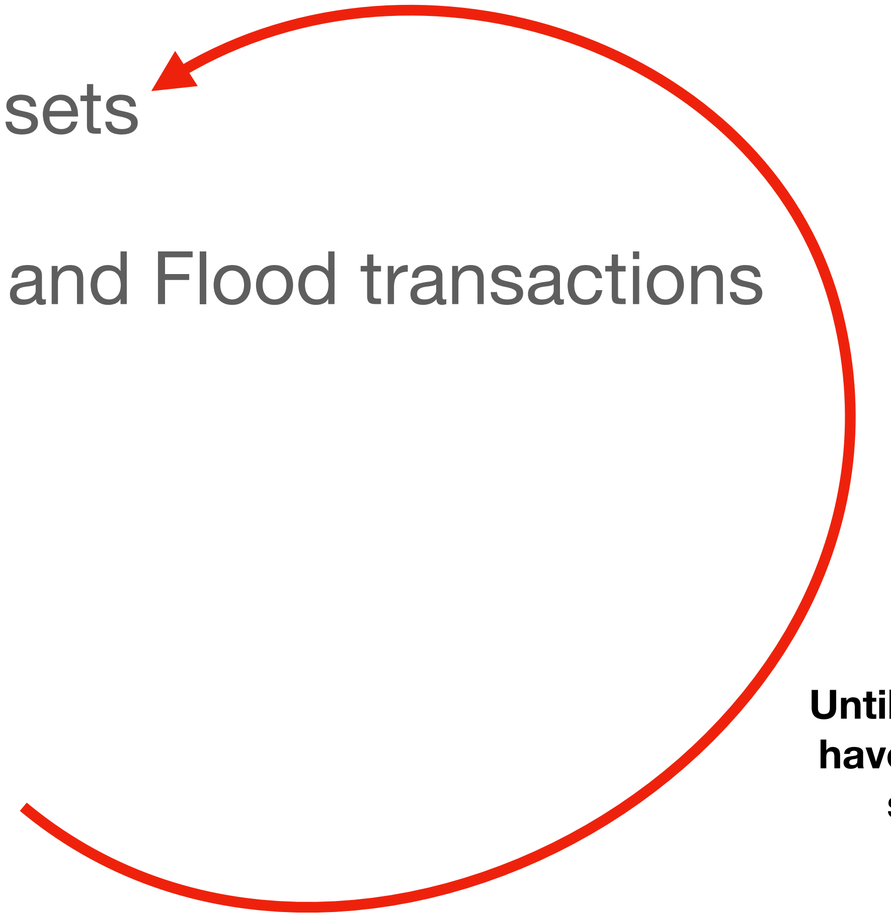

Until every pair of nodes have been in a different set al least once

TXPROBE - DATA VALIDATION

- We run 5 Bitcoin Core nodes as **ground truth**
- Nodes are included as part os the source set
- We define our precision / recall by checking how well can we infer the ground truth nodes connections

TXPROBE - COSTS

For a network like **Bitcoin mainnet:**

nodes ≈ 10000

time ≈ 8.25 hours

cost = 573210-764280 satoshi (5 sat/byte) ≈ **$(20-30)**

We can actually do better, add some notes about this

WHY TESTNET AND NO MAINNET?

- TxProbe is rather invasive: it empties the **MapOrphanTransactions pool** of all nodes in the network every round
- We could not measure the implication that such behavior may have had on the **propagation of regular transactions**
- The technique **could** have also **be seen as an attack** to the network