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

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WHAT DO WE KNOW ABOUT THE TOPOLOGY?

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Number of nodes and location of them

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GLOBAL BITCOIN NODES DISTRIBUTION

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

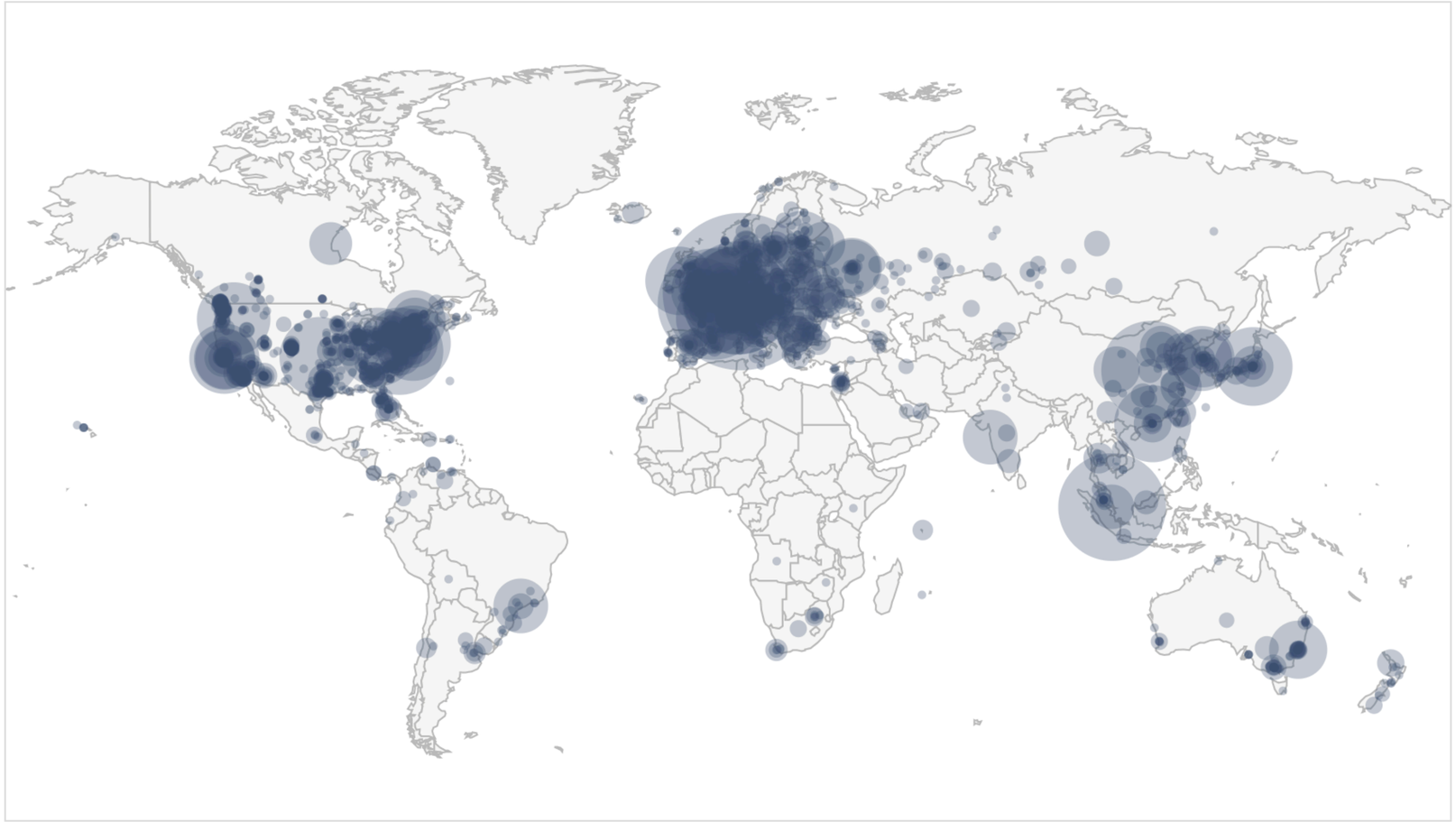
10365 NODES

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) »



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Top 10 countries with their respecti
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RANK	COUNTRY	NOD
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2	Germany	196
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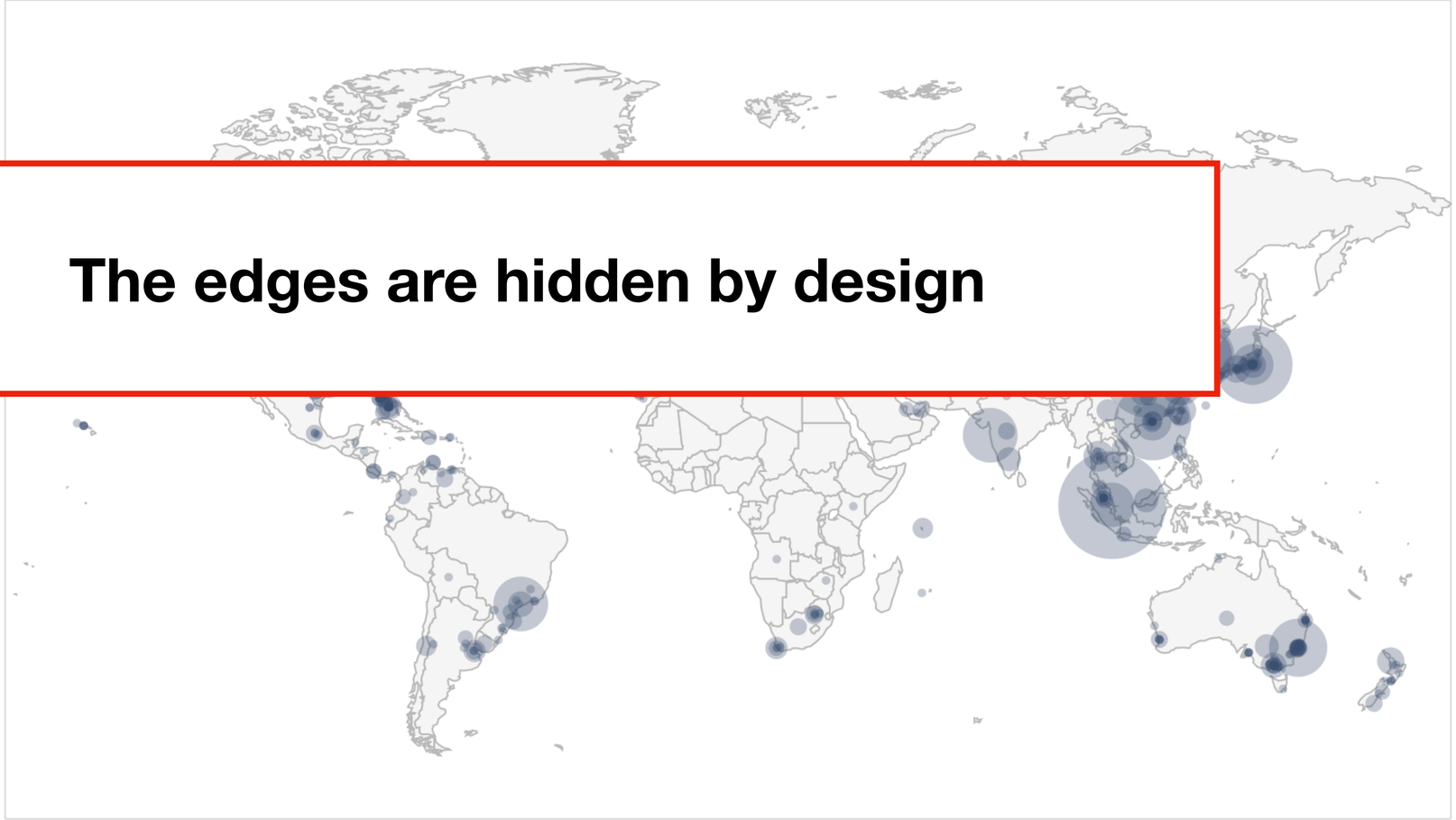


The edges are hidden by design

WHY HAVE A HIDDEN TOPOLOGY?

An open topology **could ease** different types of attacks:

- Transaction deanonymization
- Network based attacks (e.g: Eclipse attacks)

The **current approach** of the Bitcoin Core is to **keep it hidden**

WHY HAVE AN OPEN TOPOLOGY?

We know nothings about how the network really is:

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

Security by obscurity does not seem to proper way to go

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

BACKGROUND

Our inferring technique is based on **transaction propagation**

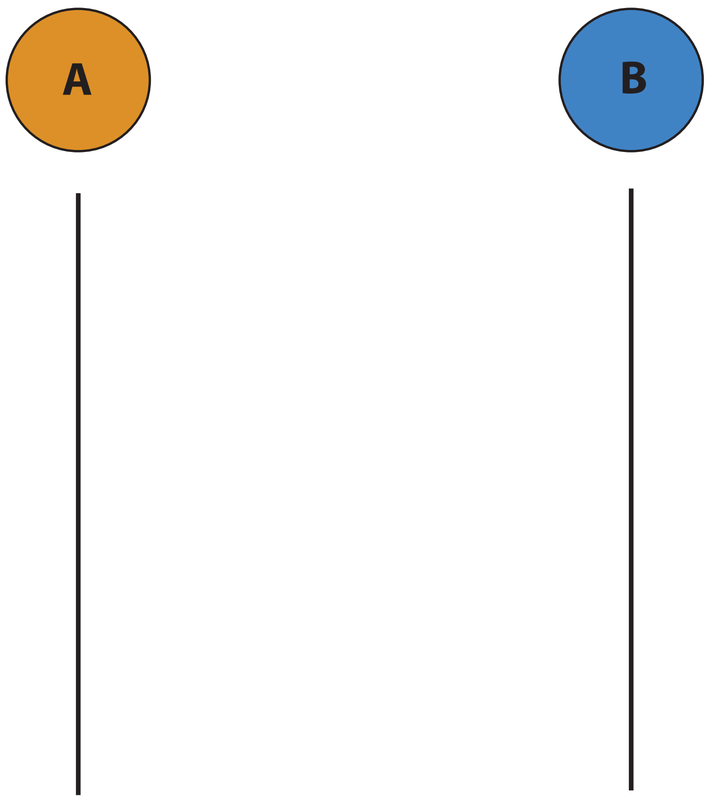
We take advantage of how transactions are handled by nodes:

- **orphans transactions**
- **double-spending transactions**

TRANSACTION PROPAGATION IN BITCOIN

Valid transaction are stored in **mempool**

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



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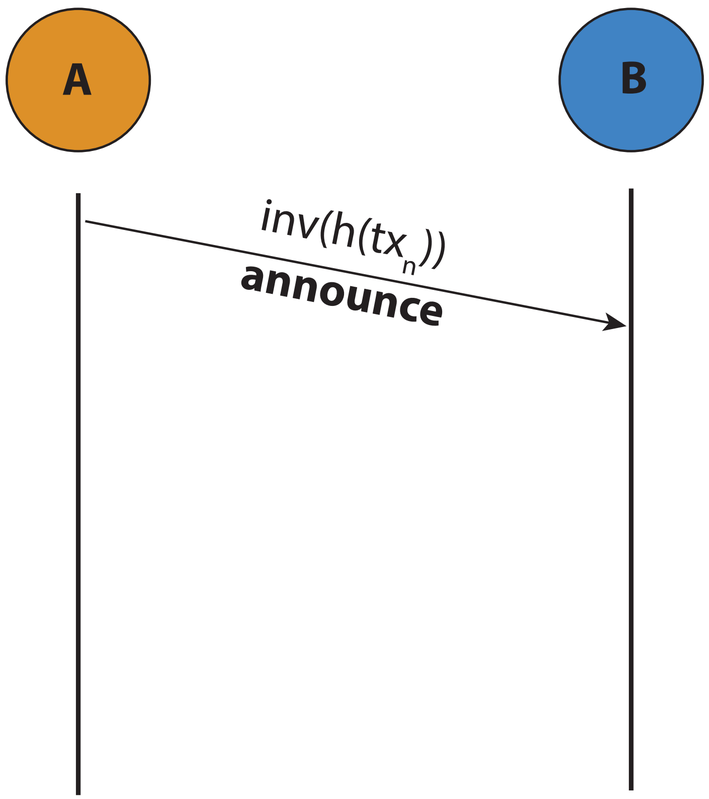

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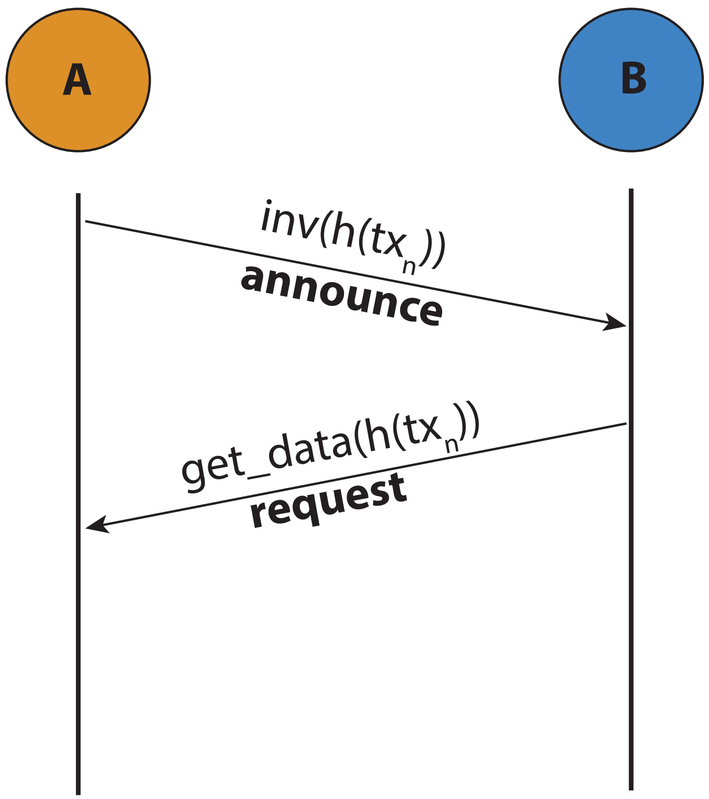

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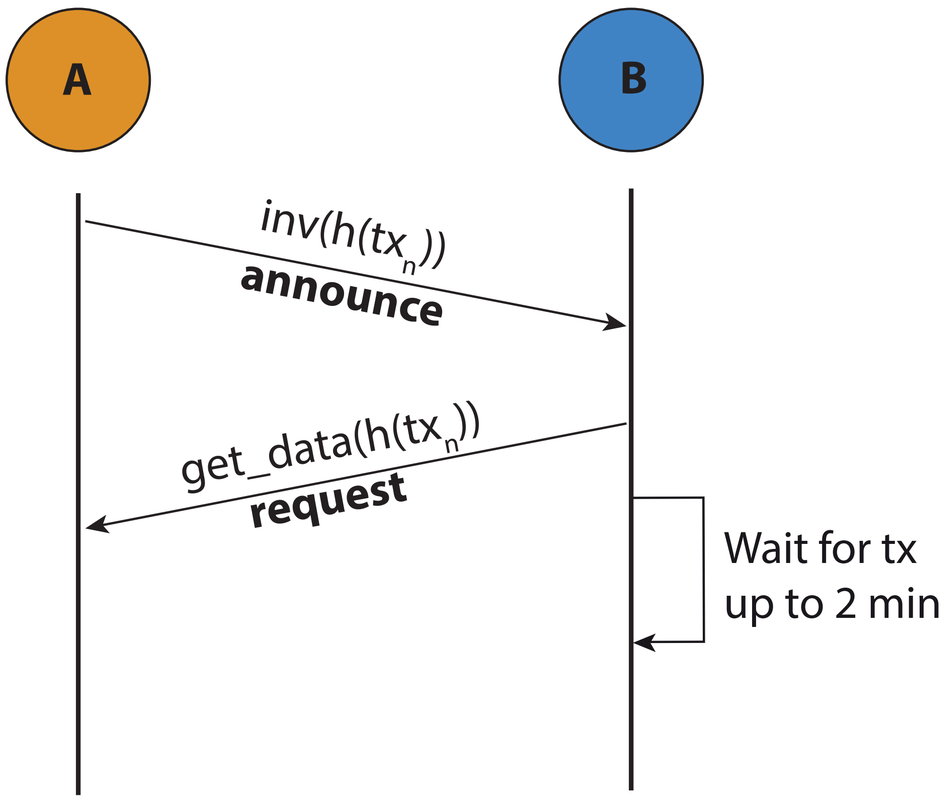

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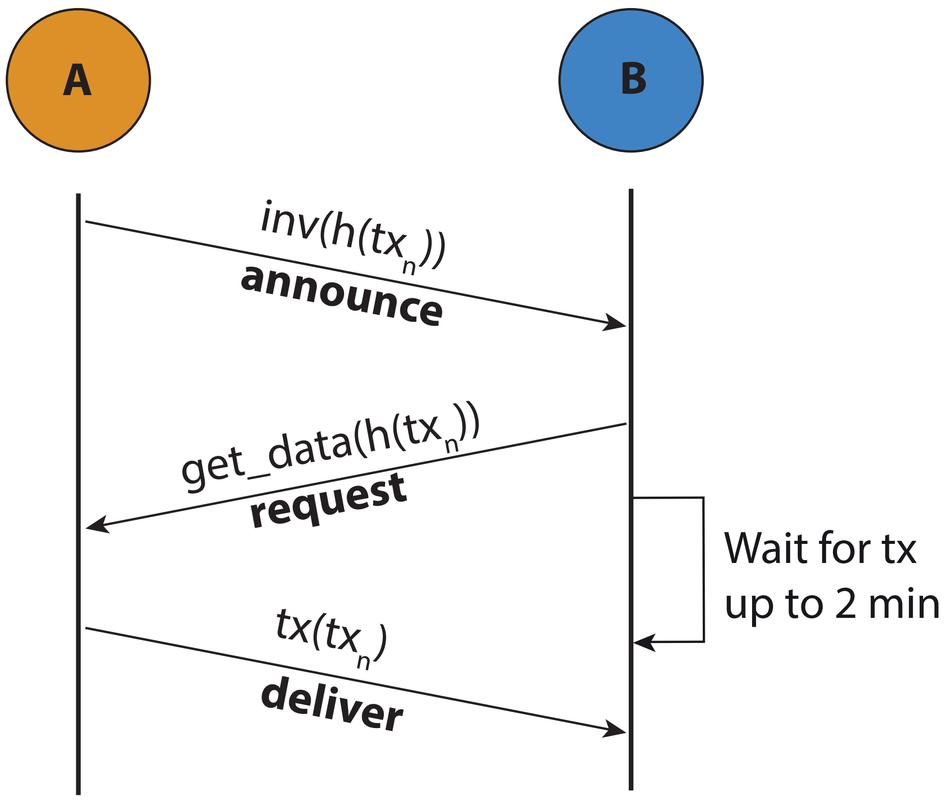
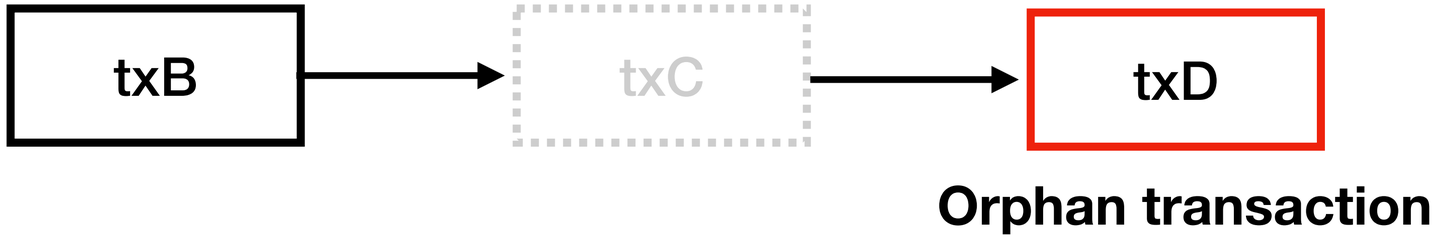


ORPHAN TRANSACTIONS

A transaction is orphan if **some of the referenced UTXOs are unknown**

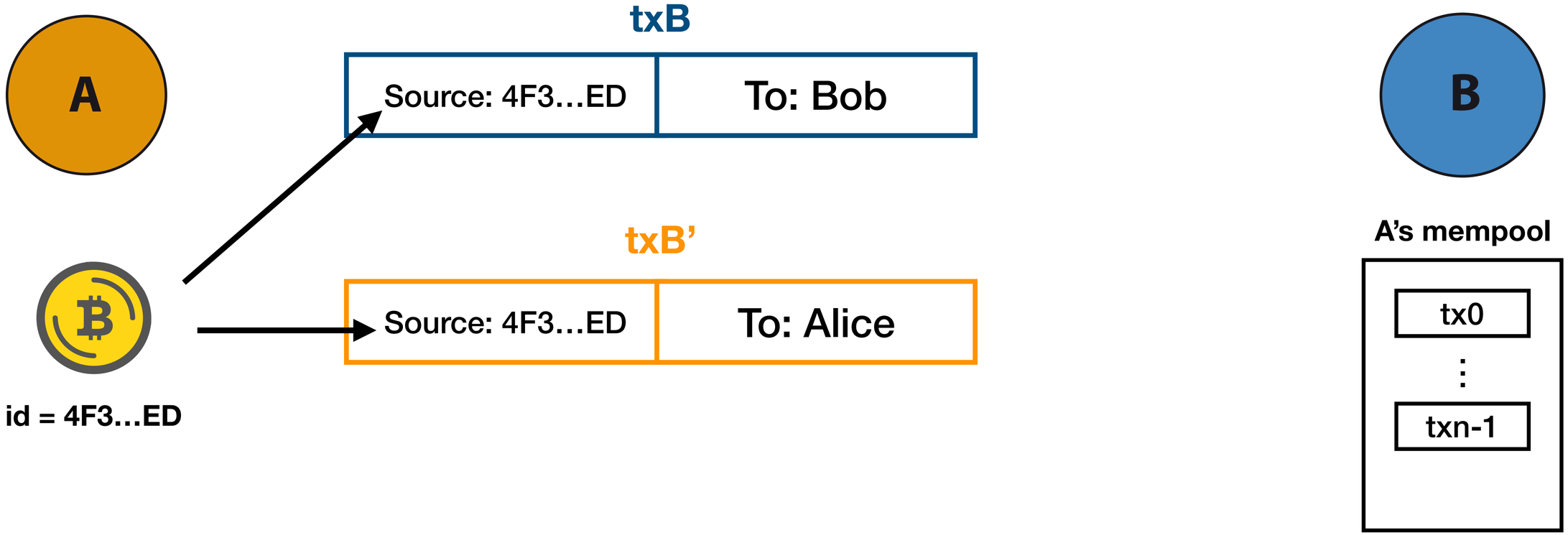


They can not be validated, so they are stored in a separated data structure known as **MapOrphanTransactions**

Transactions in MapOrphanTransactions are **NOT forwarded to any node**

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

DOUBLE-SPENDING TRANSACTIONS



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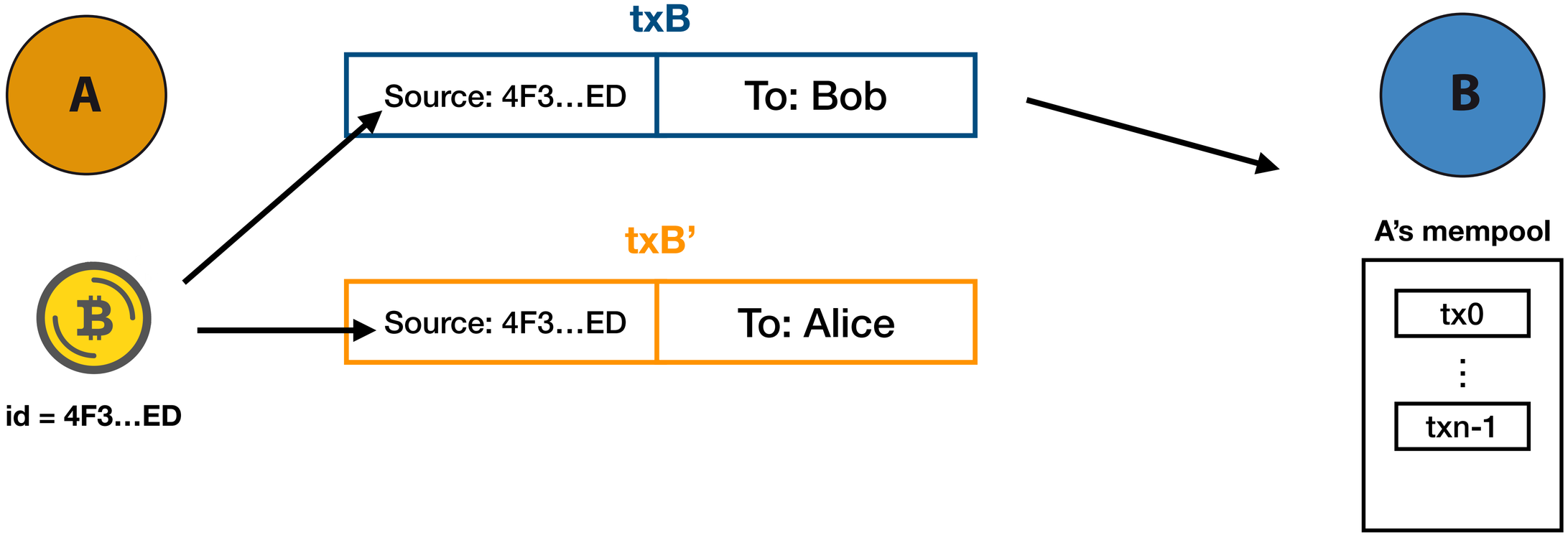

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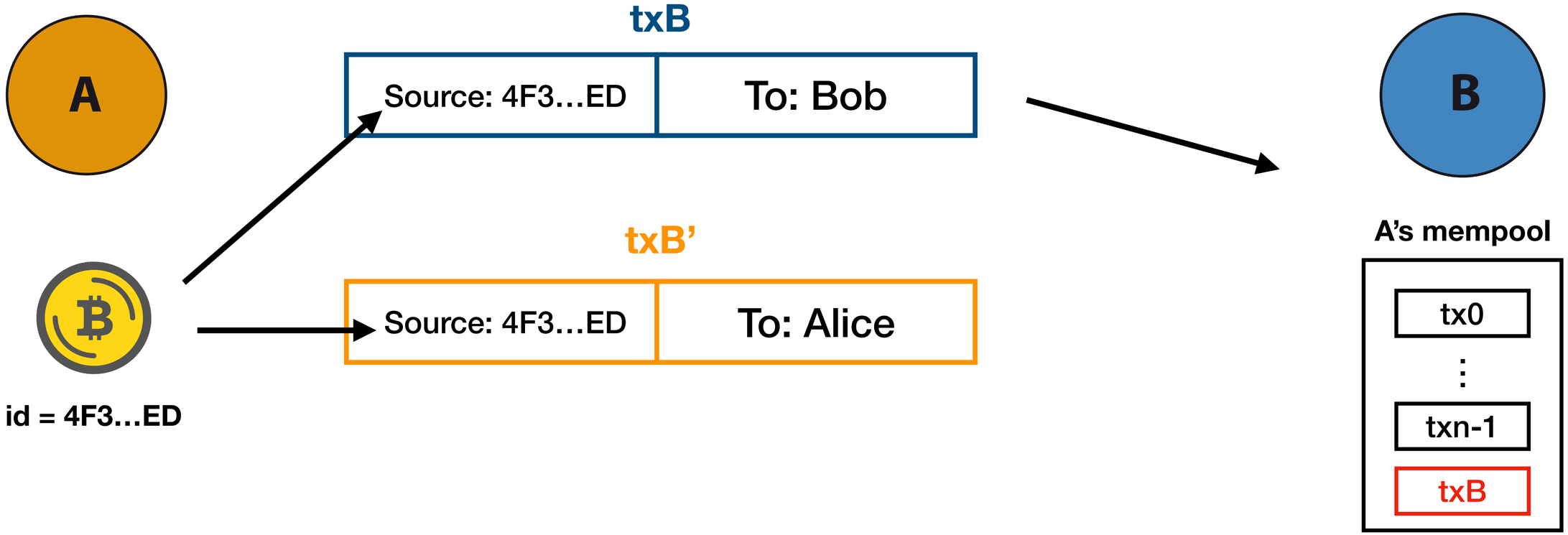

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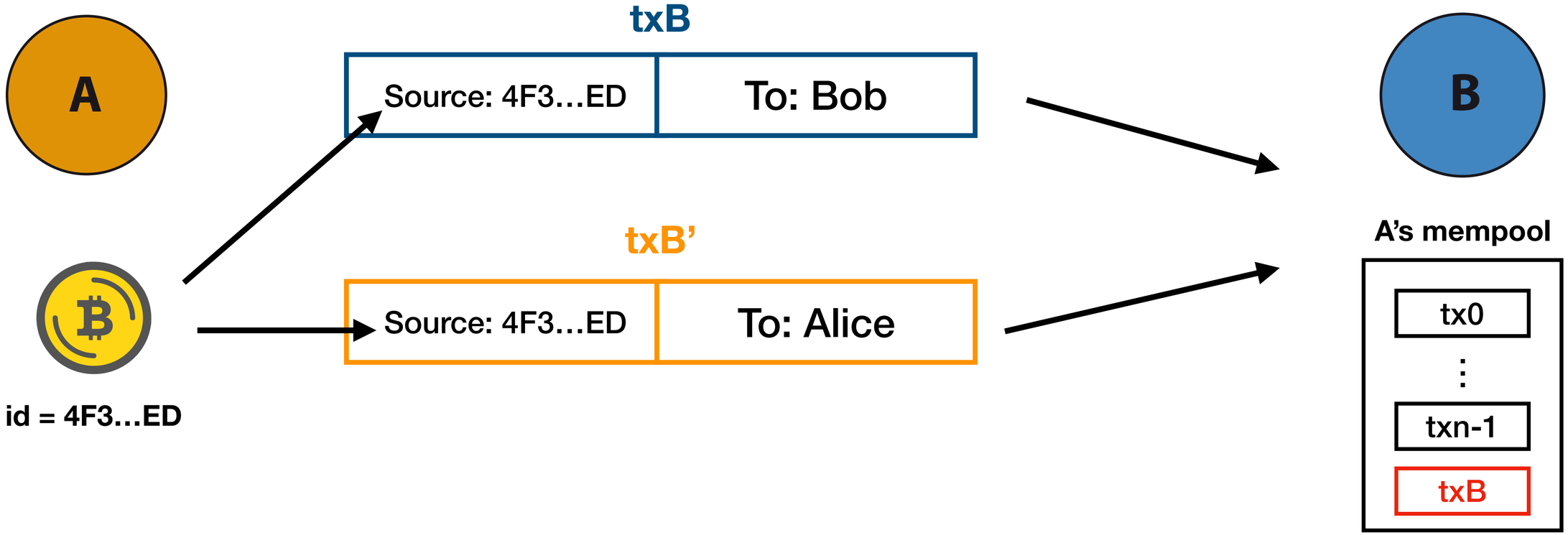

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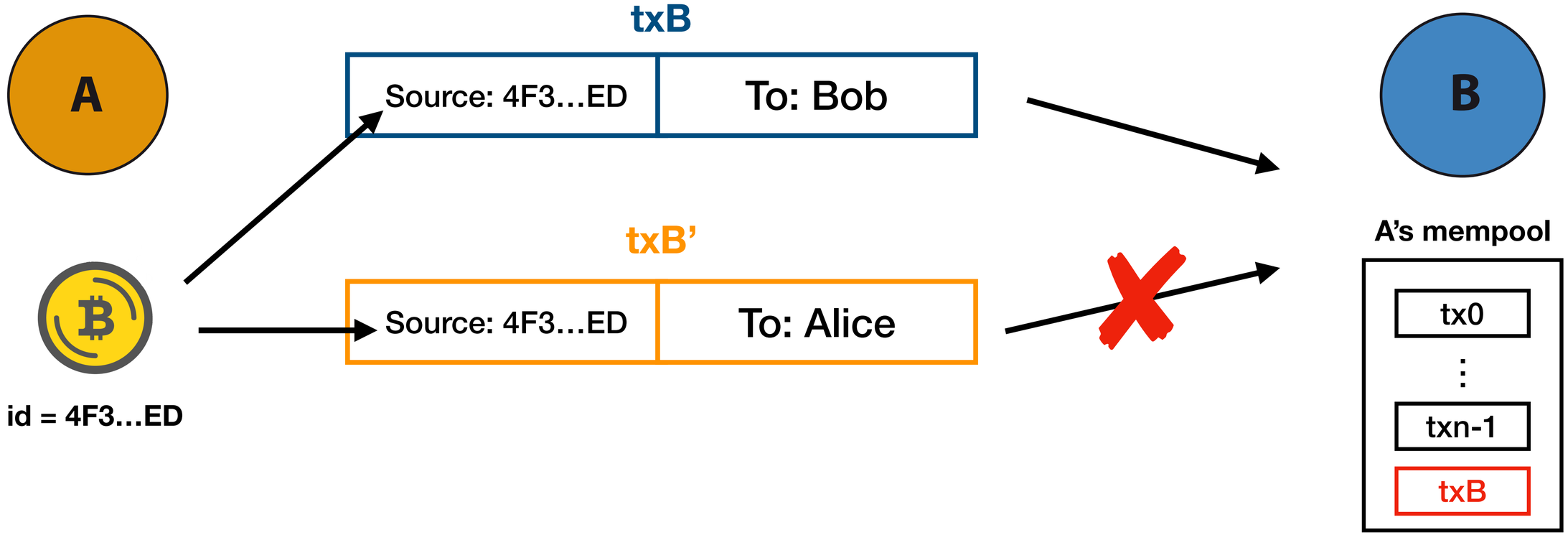

A BASIC TOPOLOGY INFERRING TECHNIQUE

Two nodes

Three transactions

Observation tool
(like coinscope)

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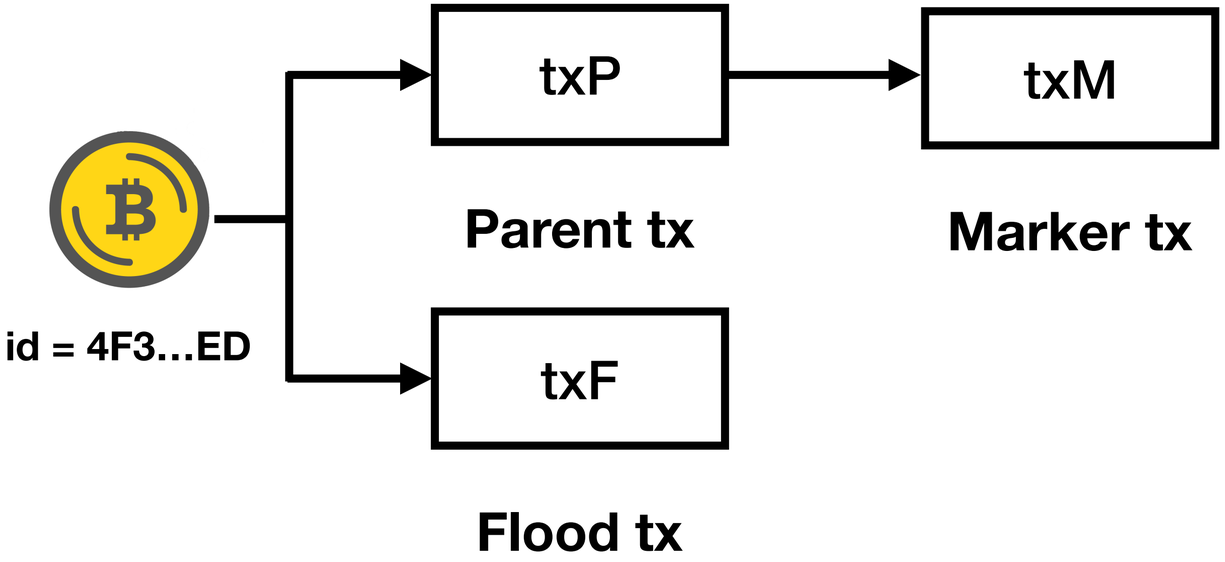

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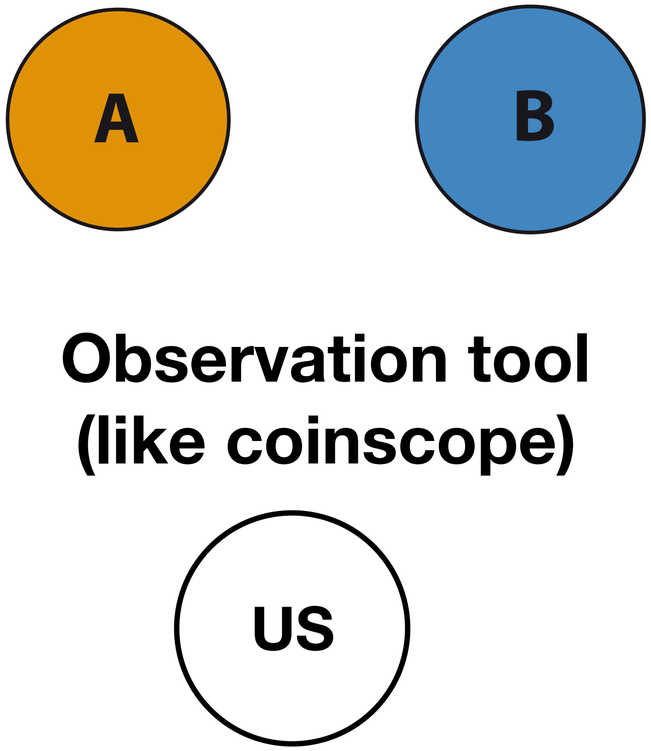

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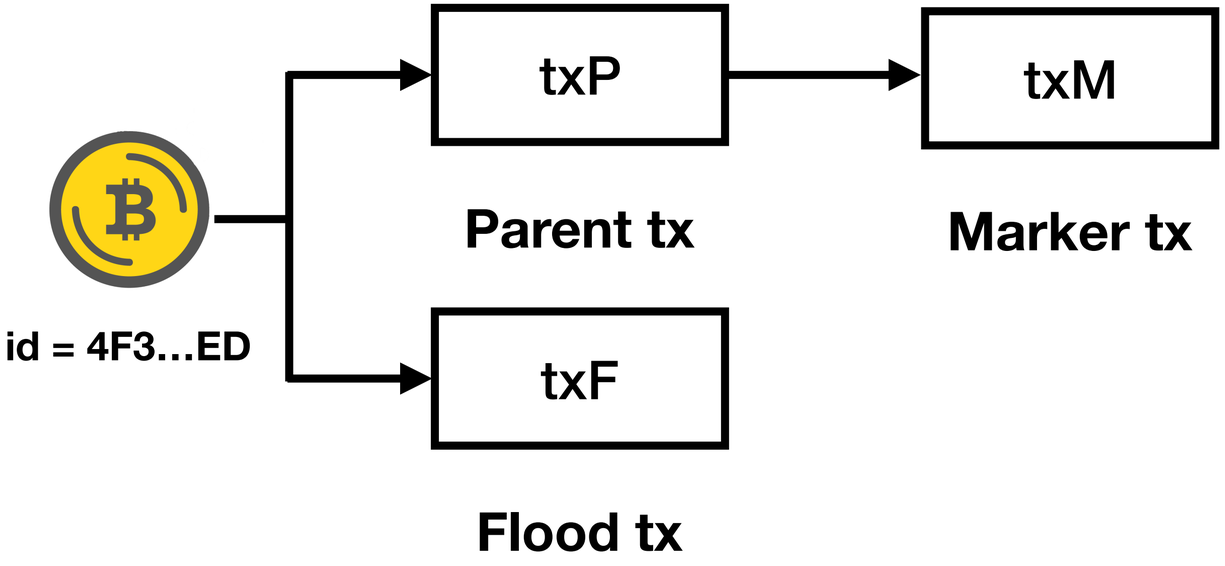

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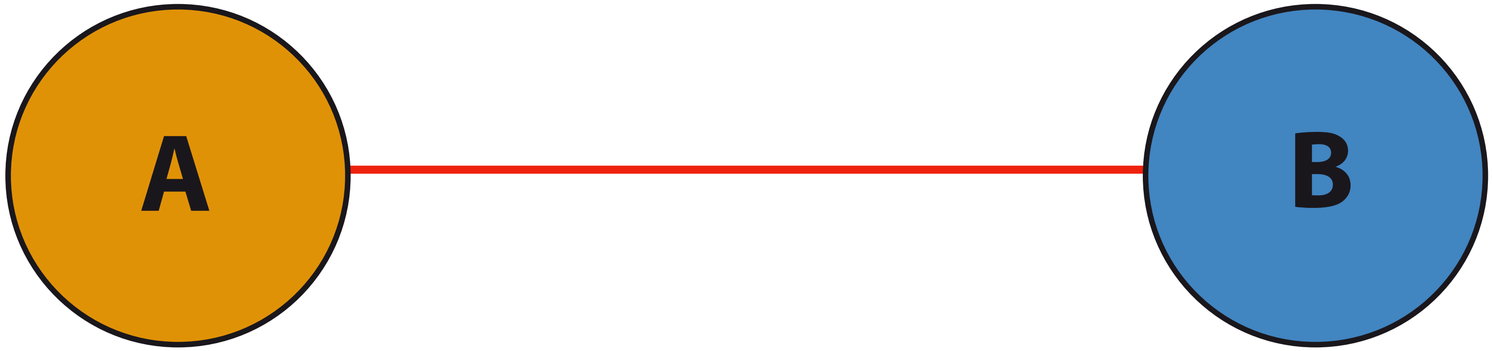

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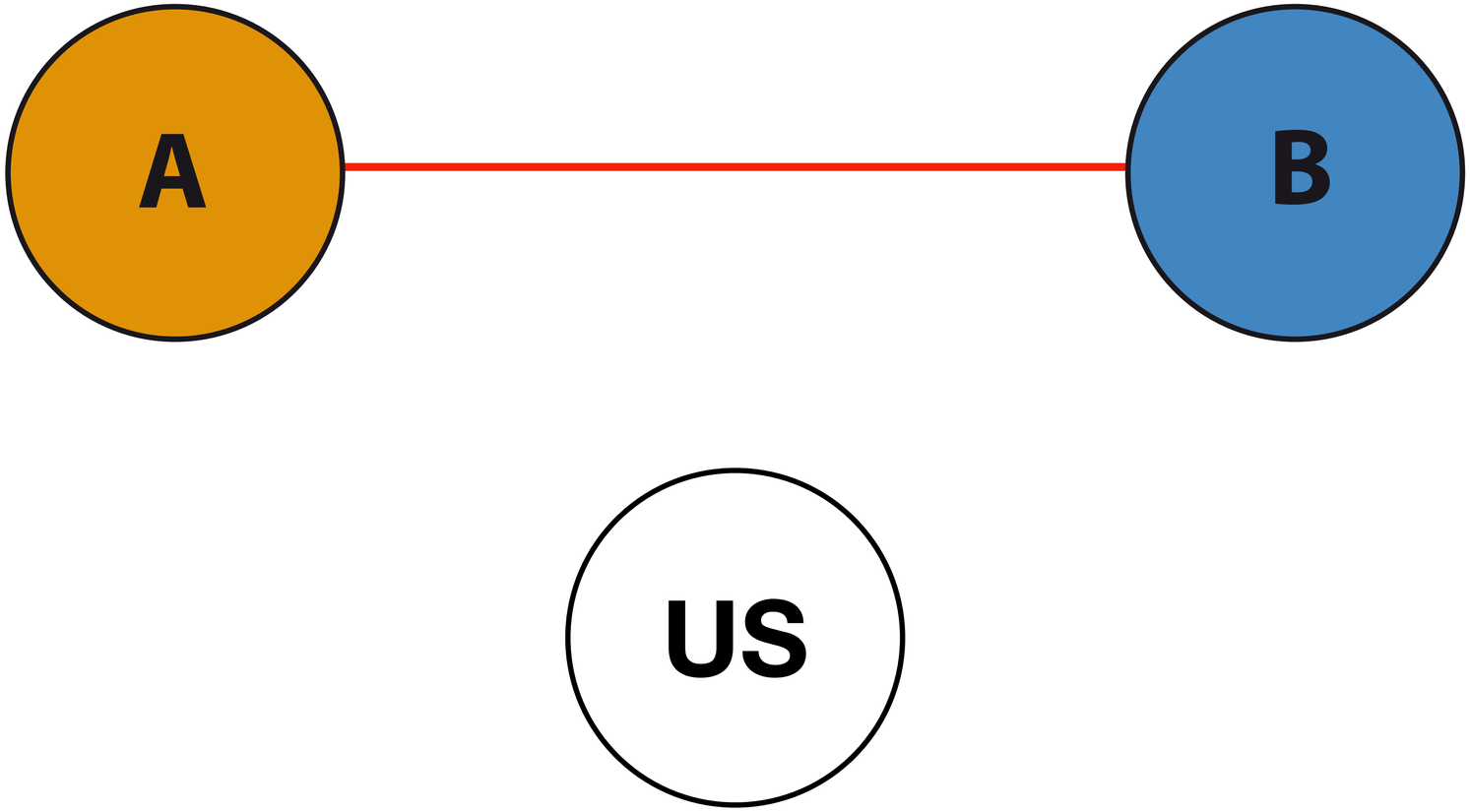

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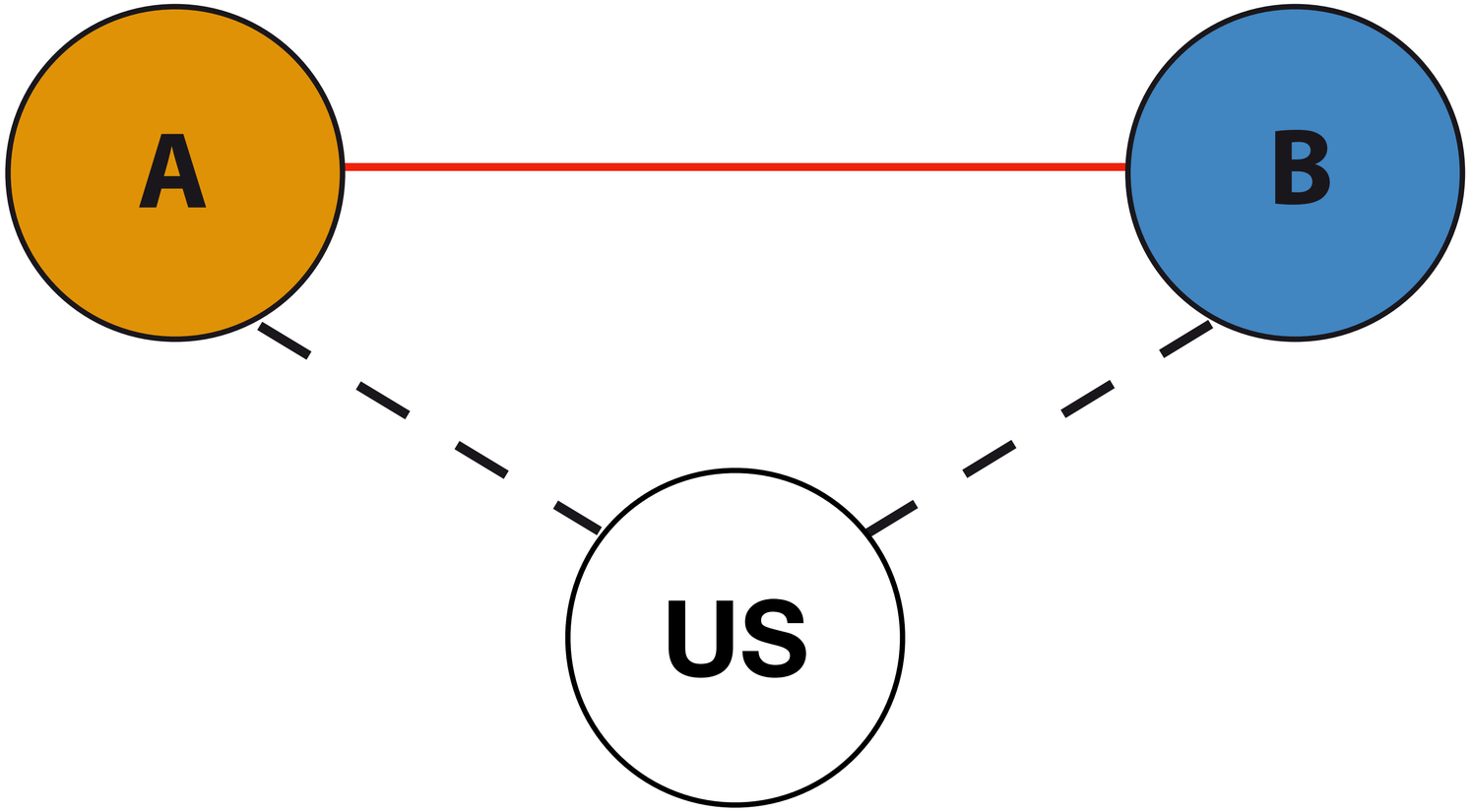

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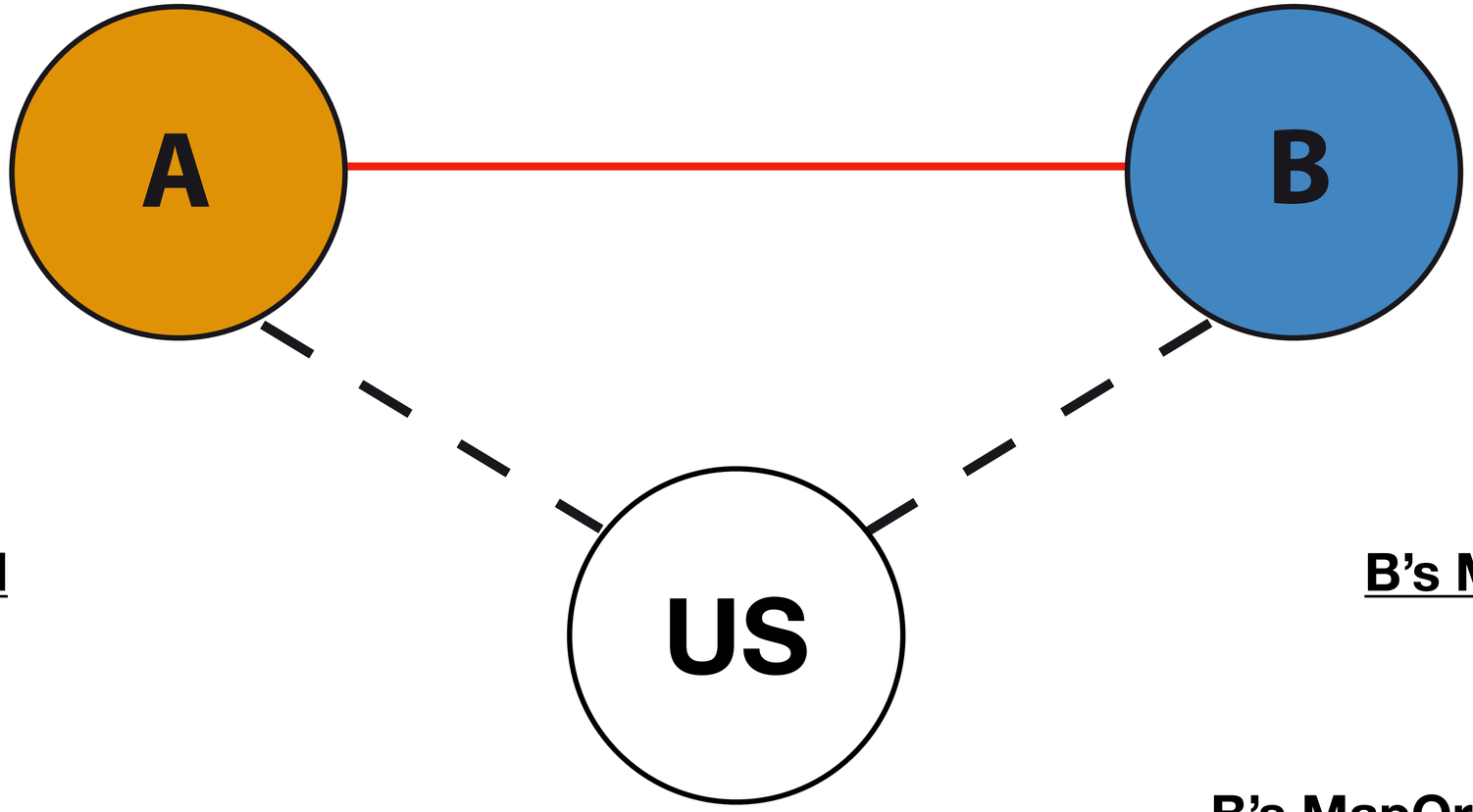

A's Mempool

∅

B's Mempool

∅

B's MapOrphanTransactions

∅

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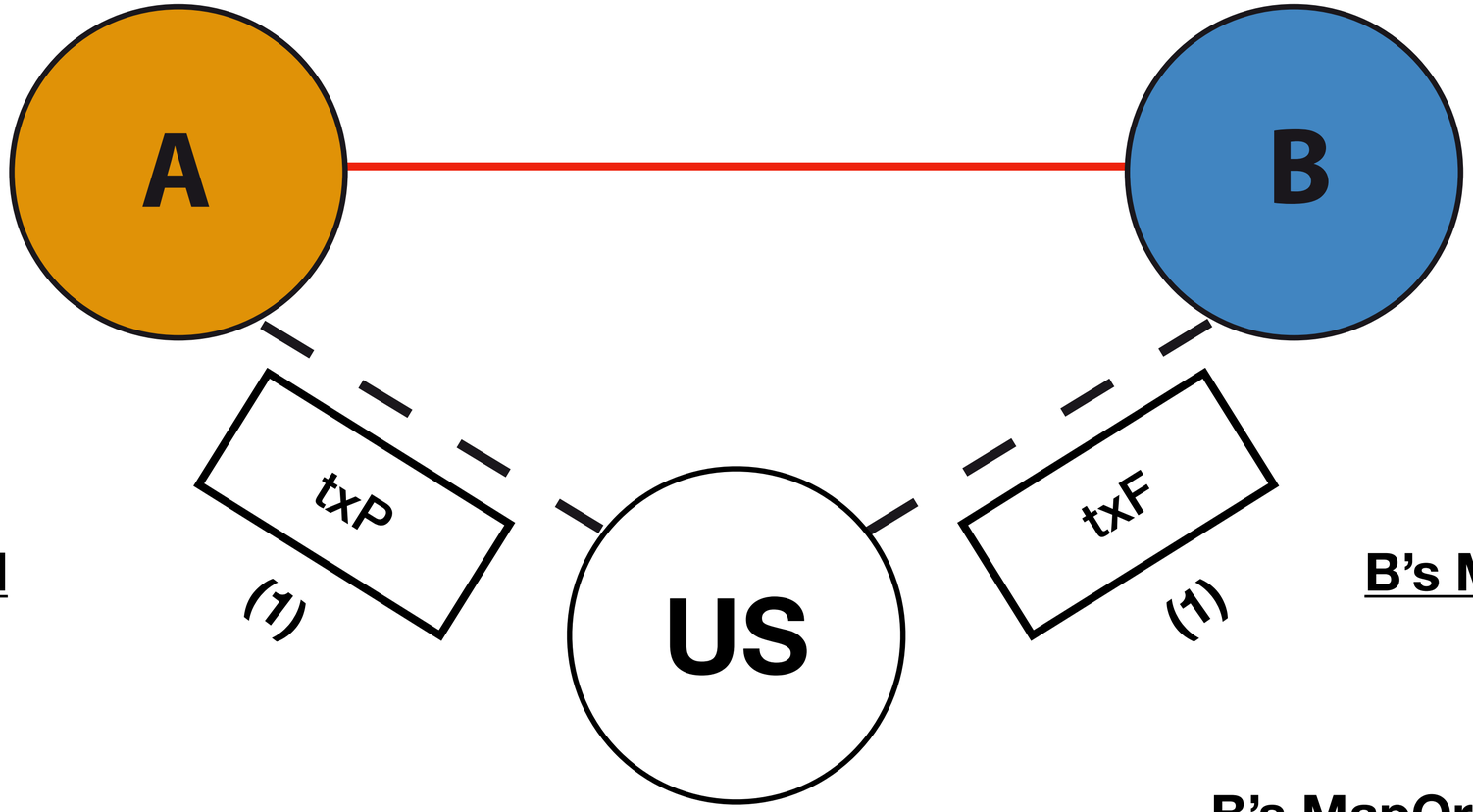

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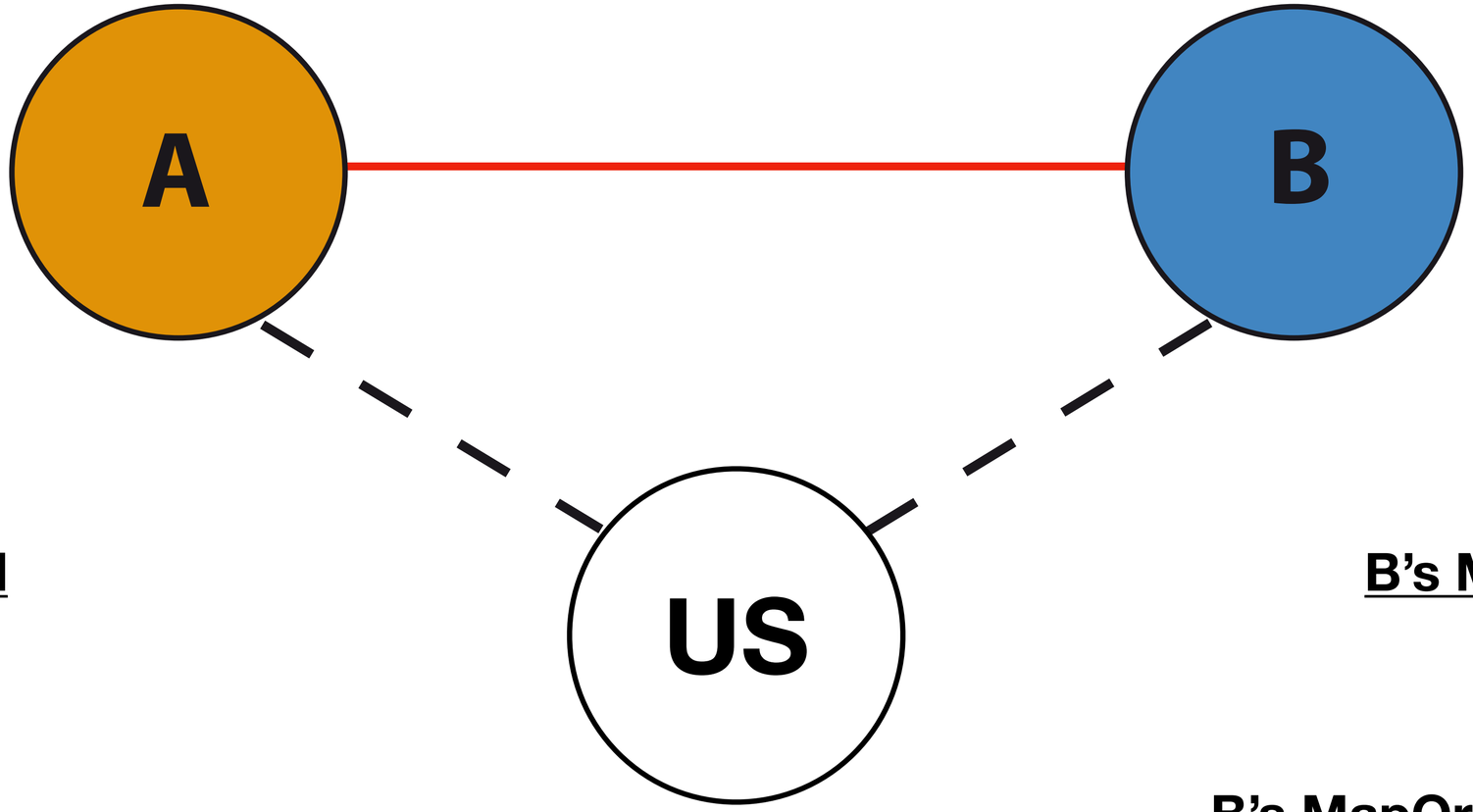

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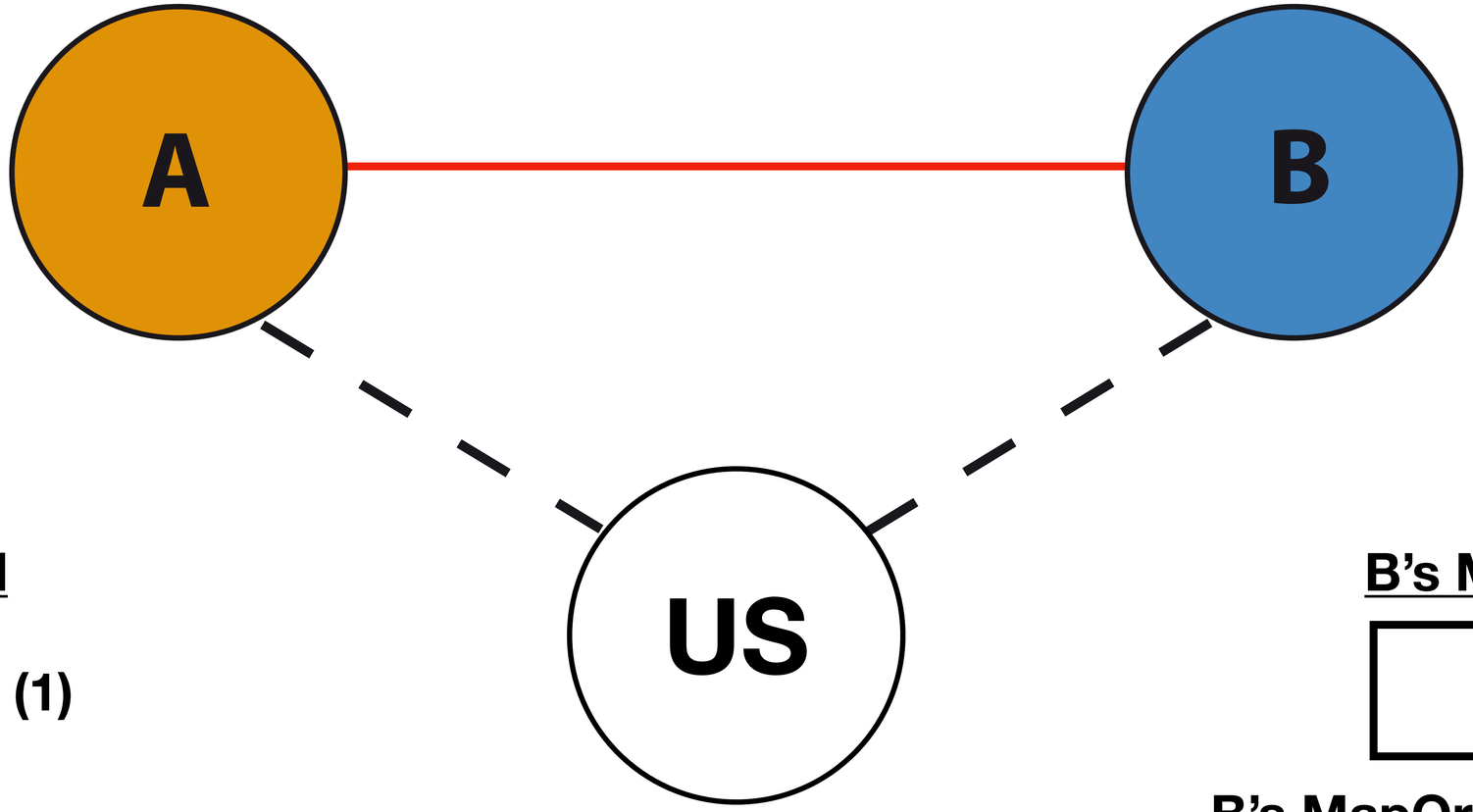

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txF	(1)

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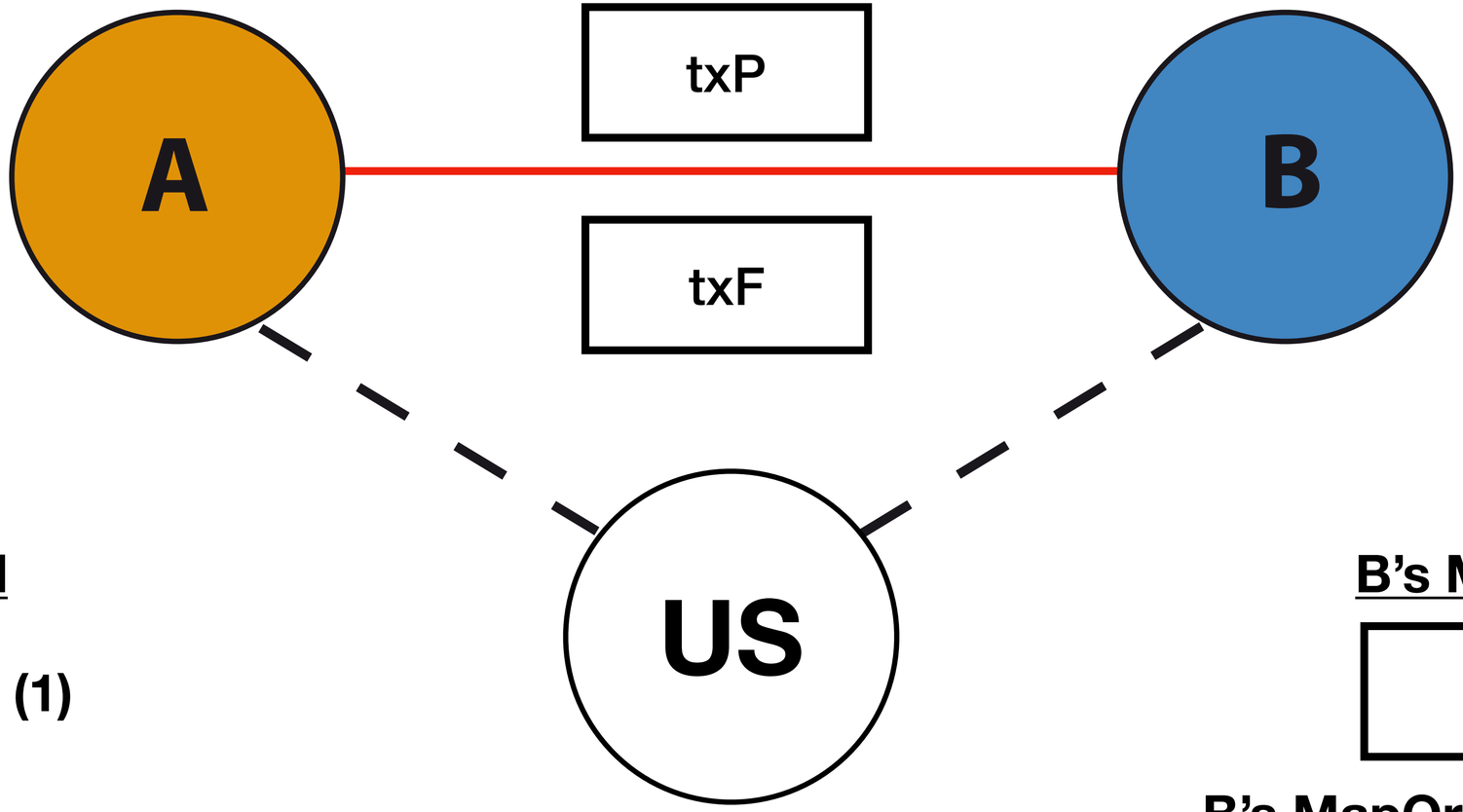

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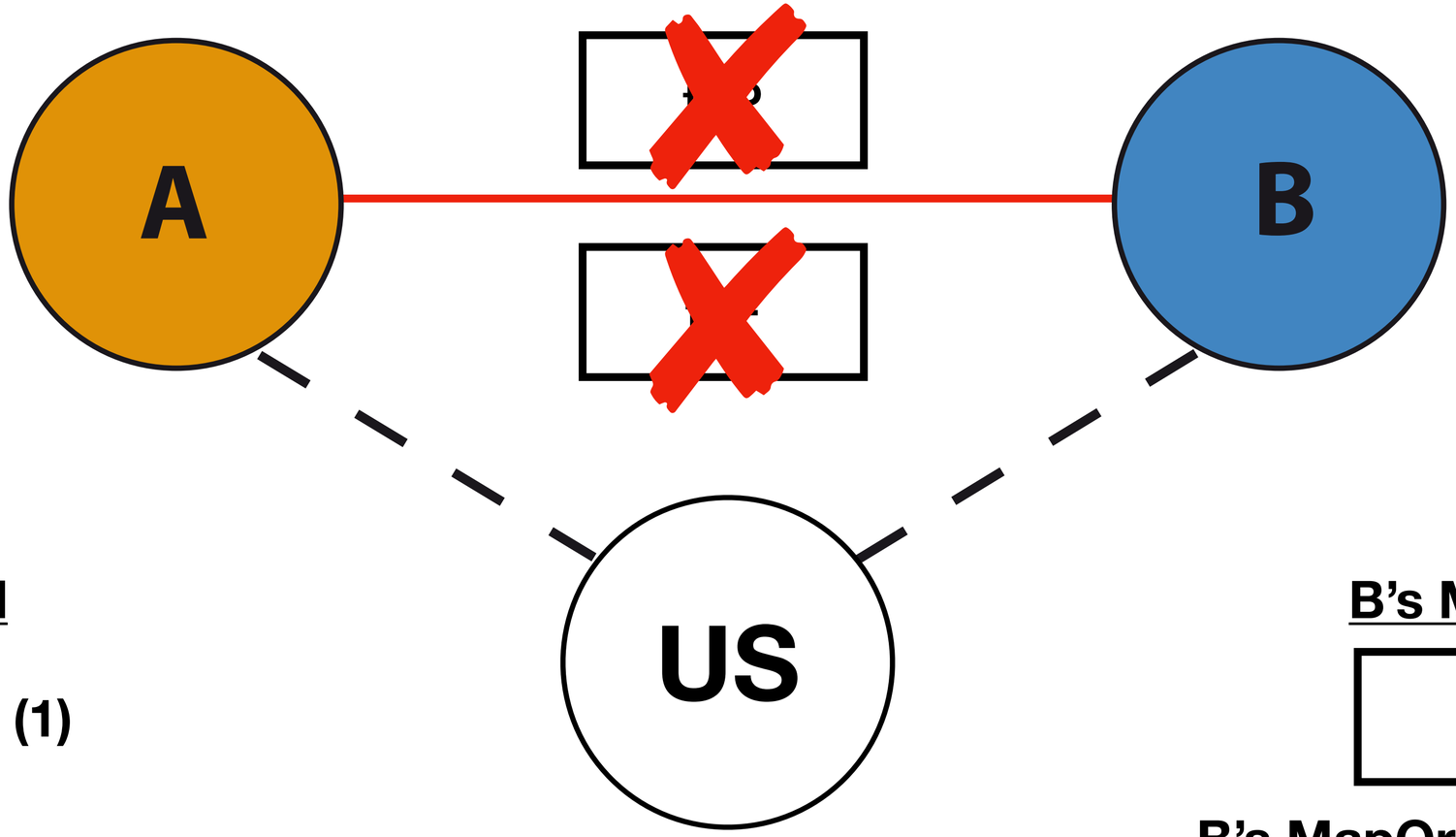

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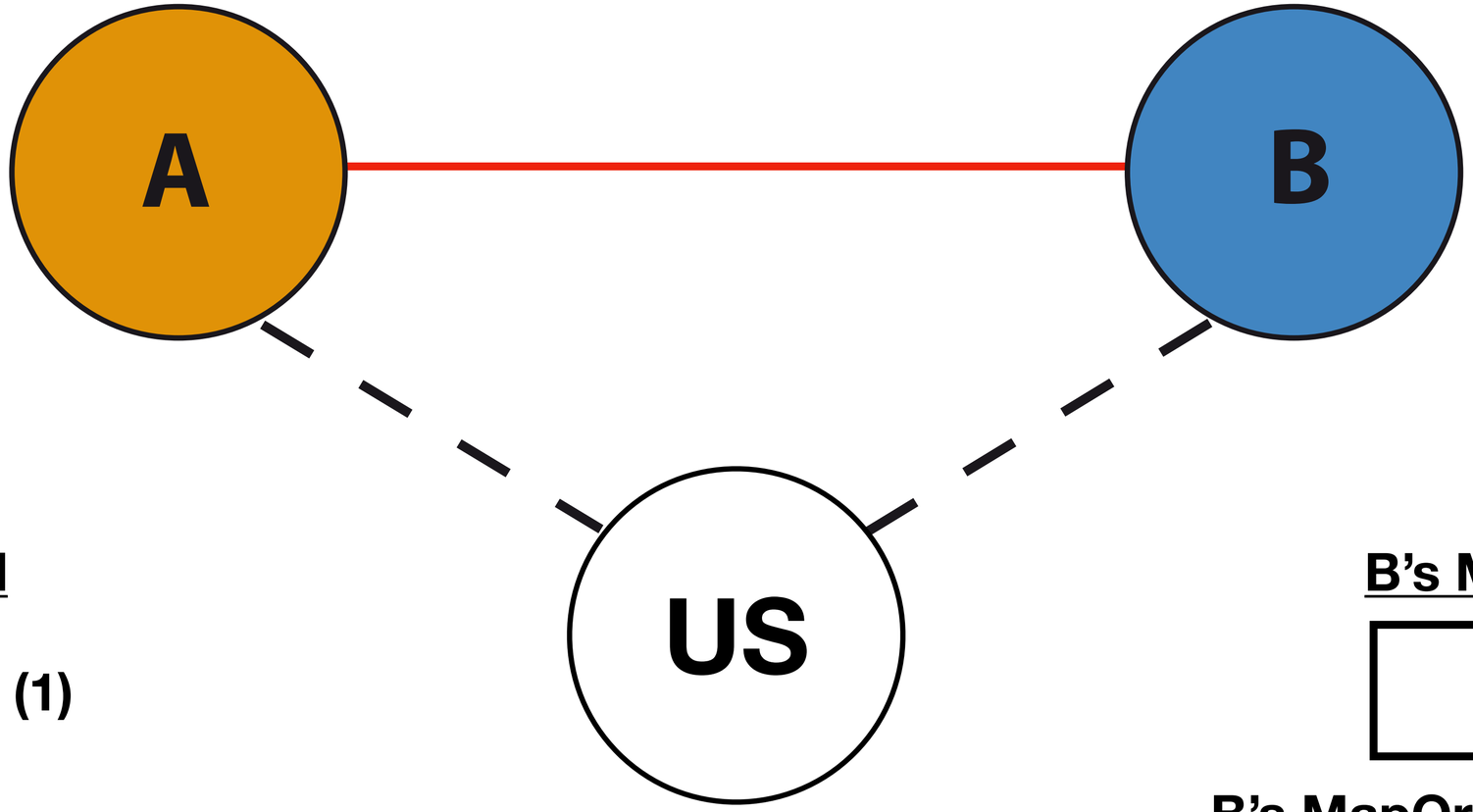

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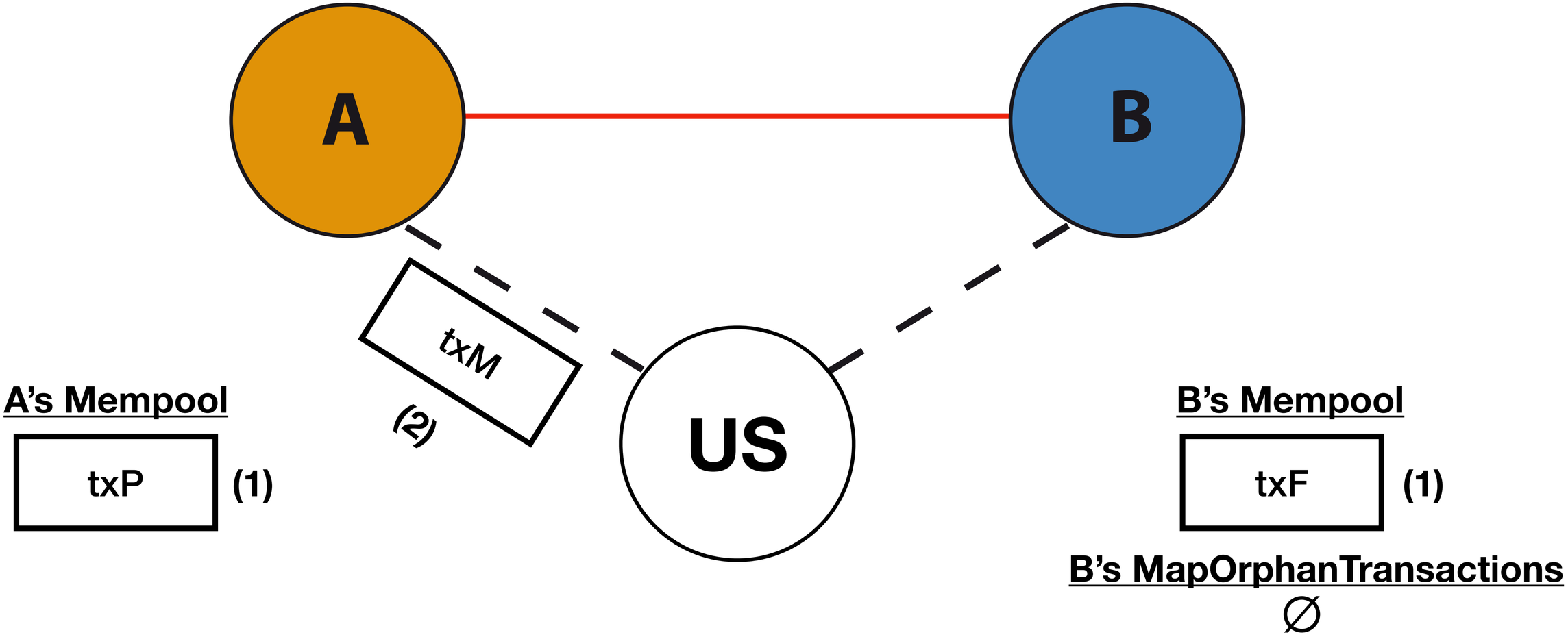

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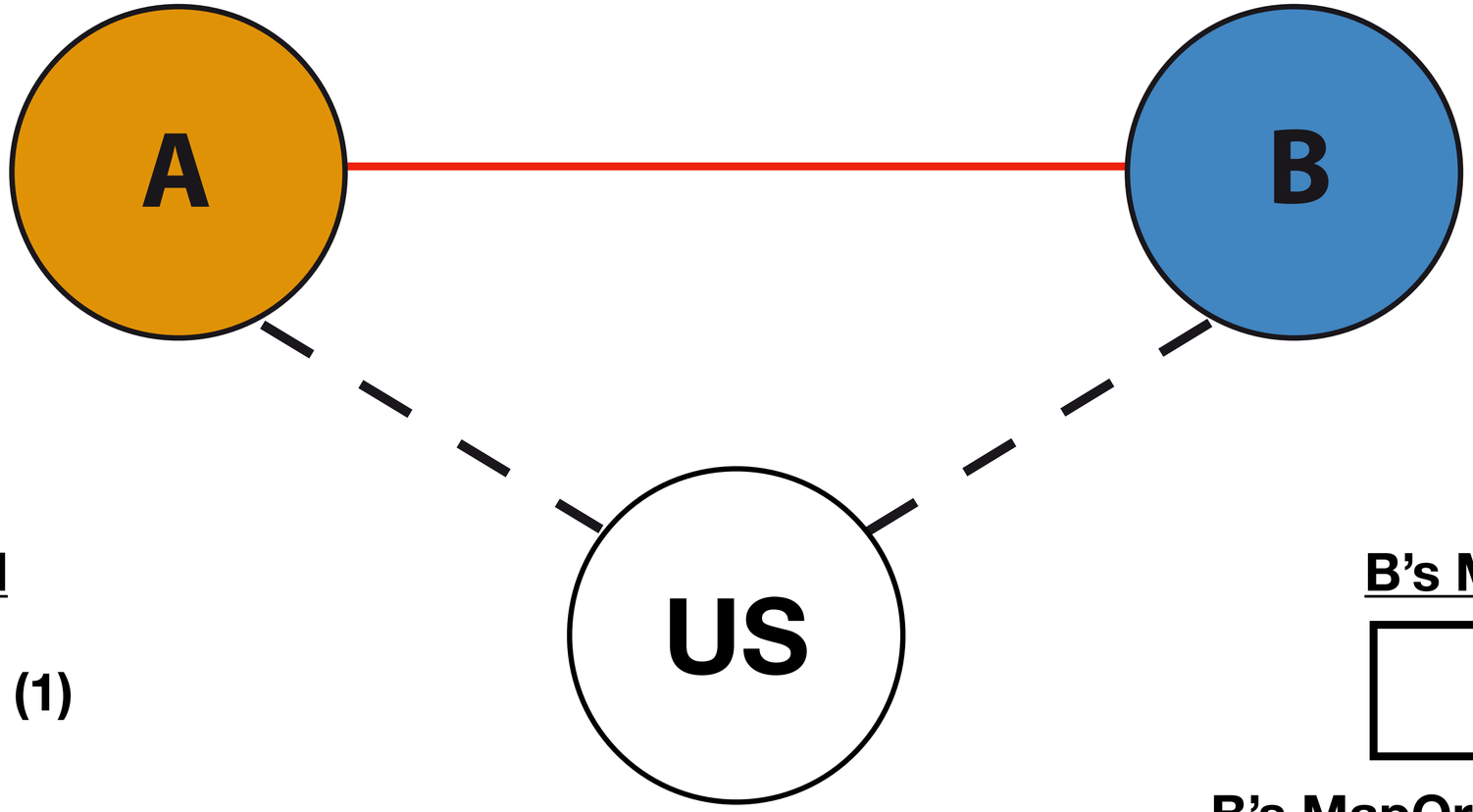

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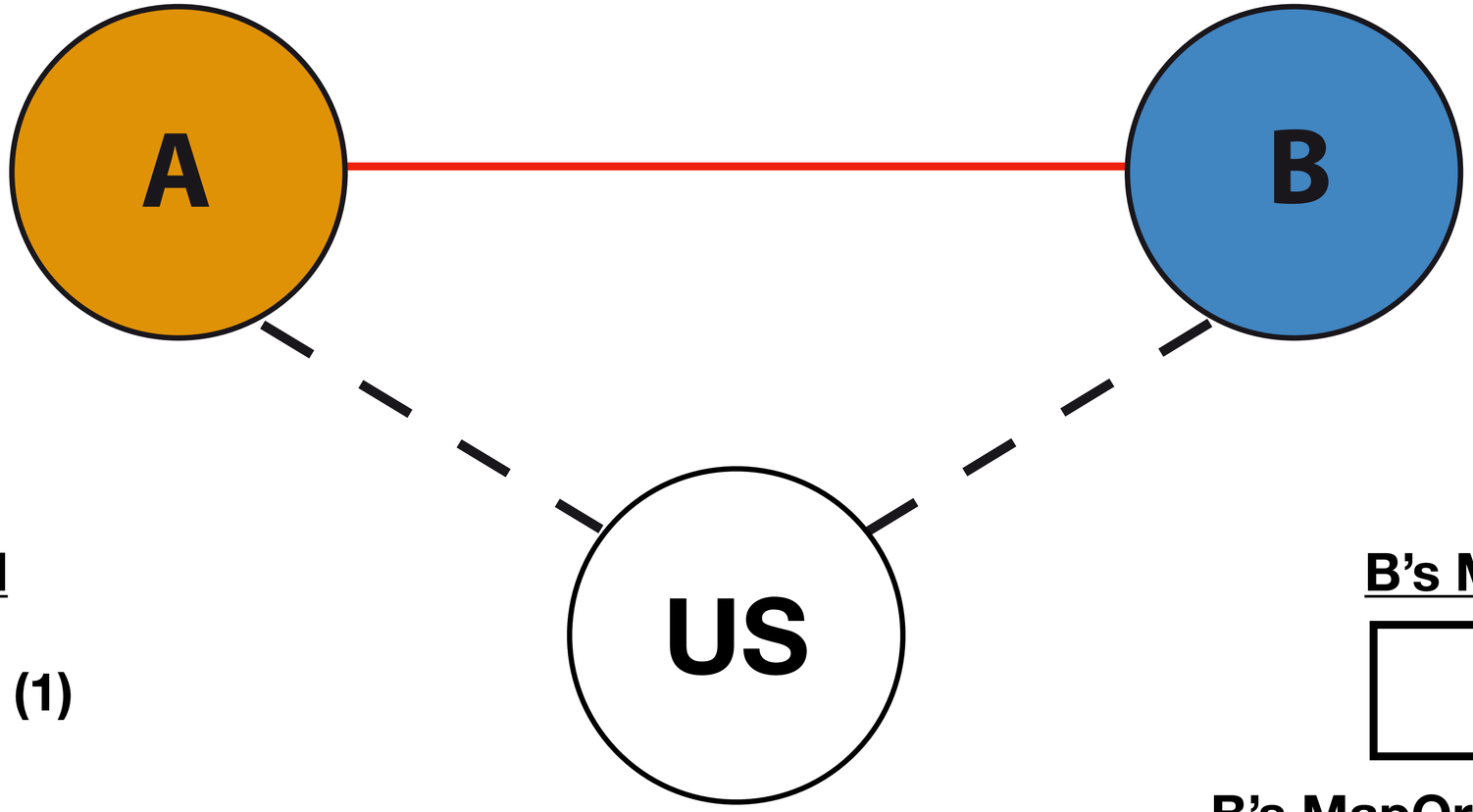

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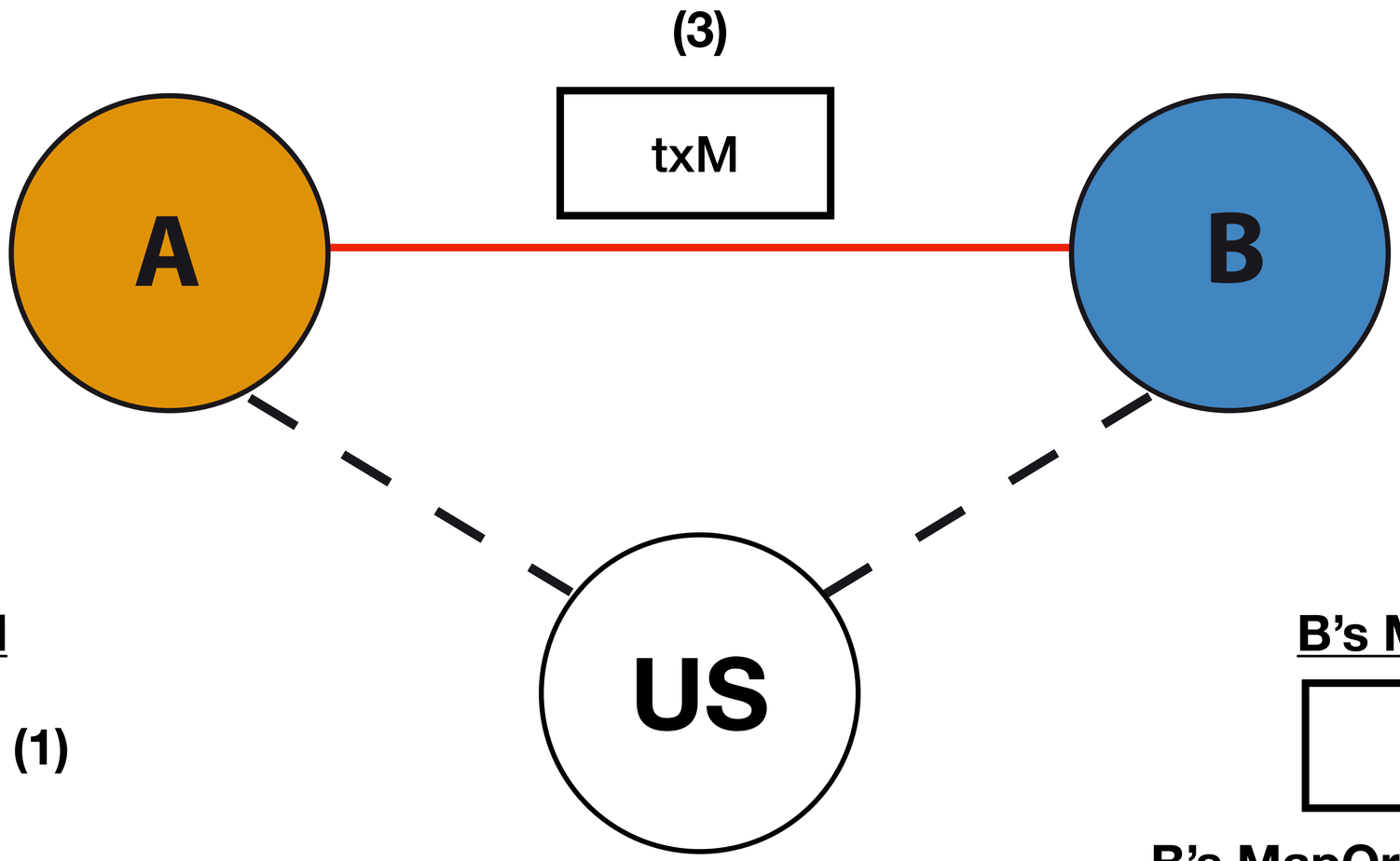

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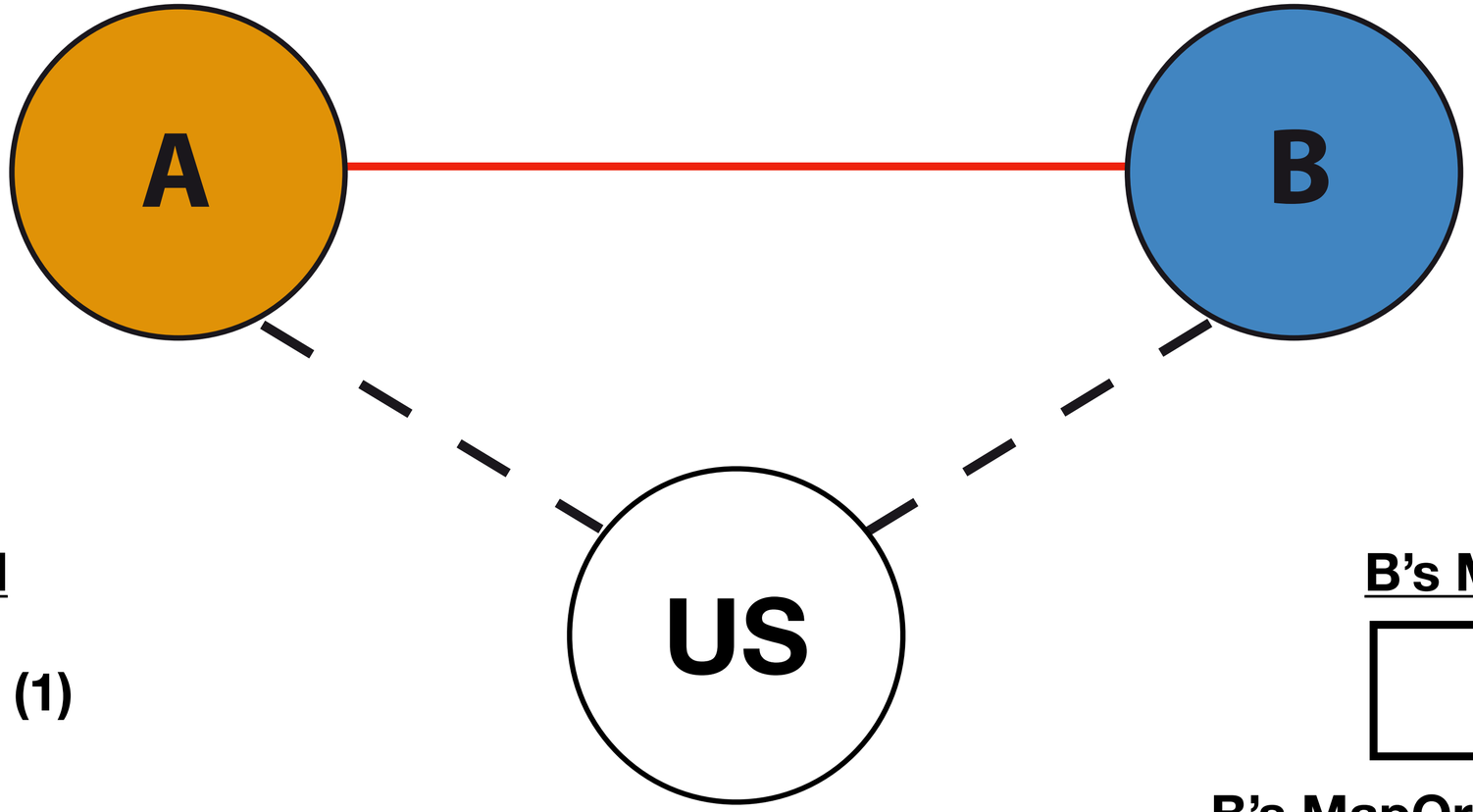

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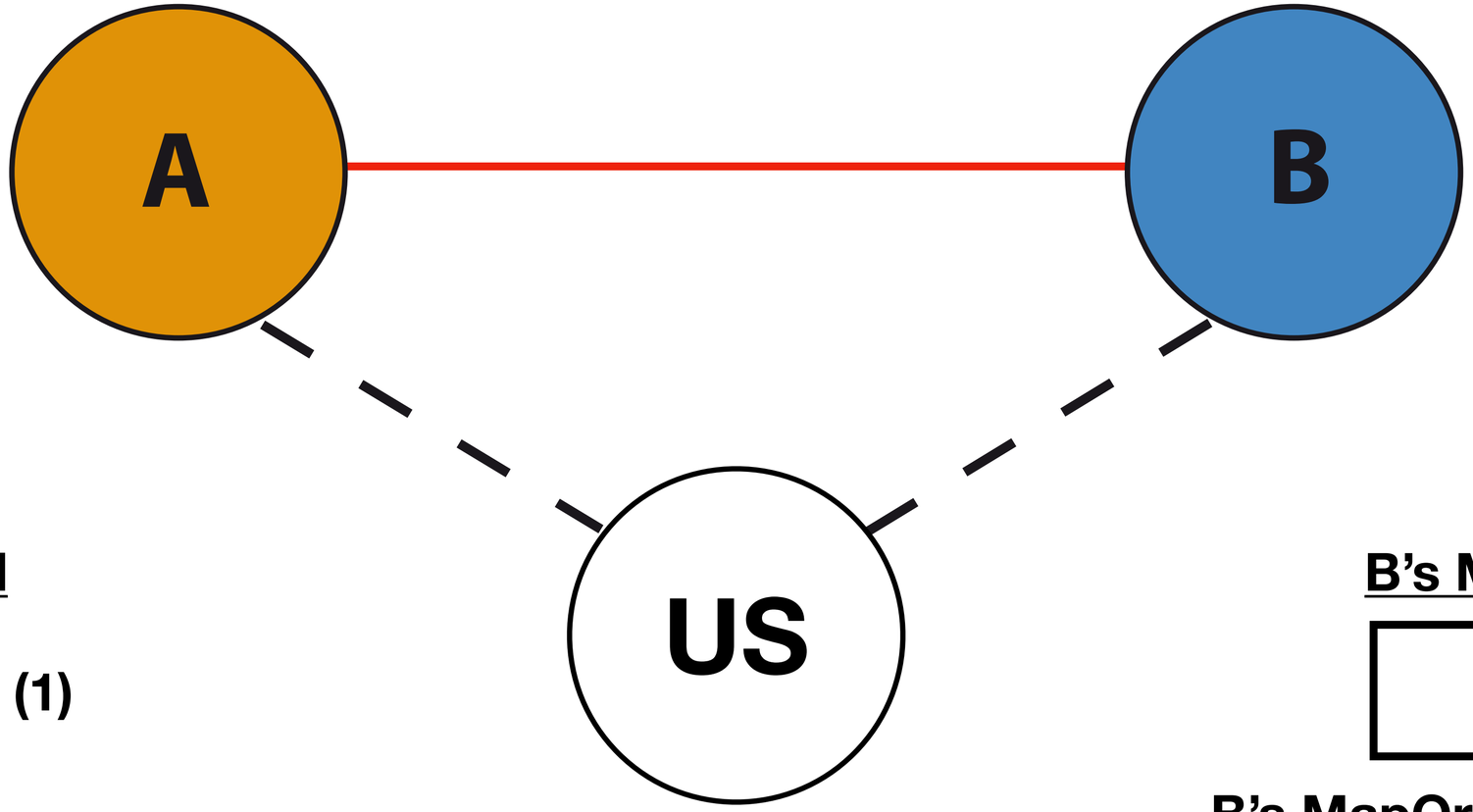

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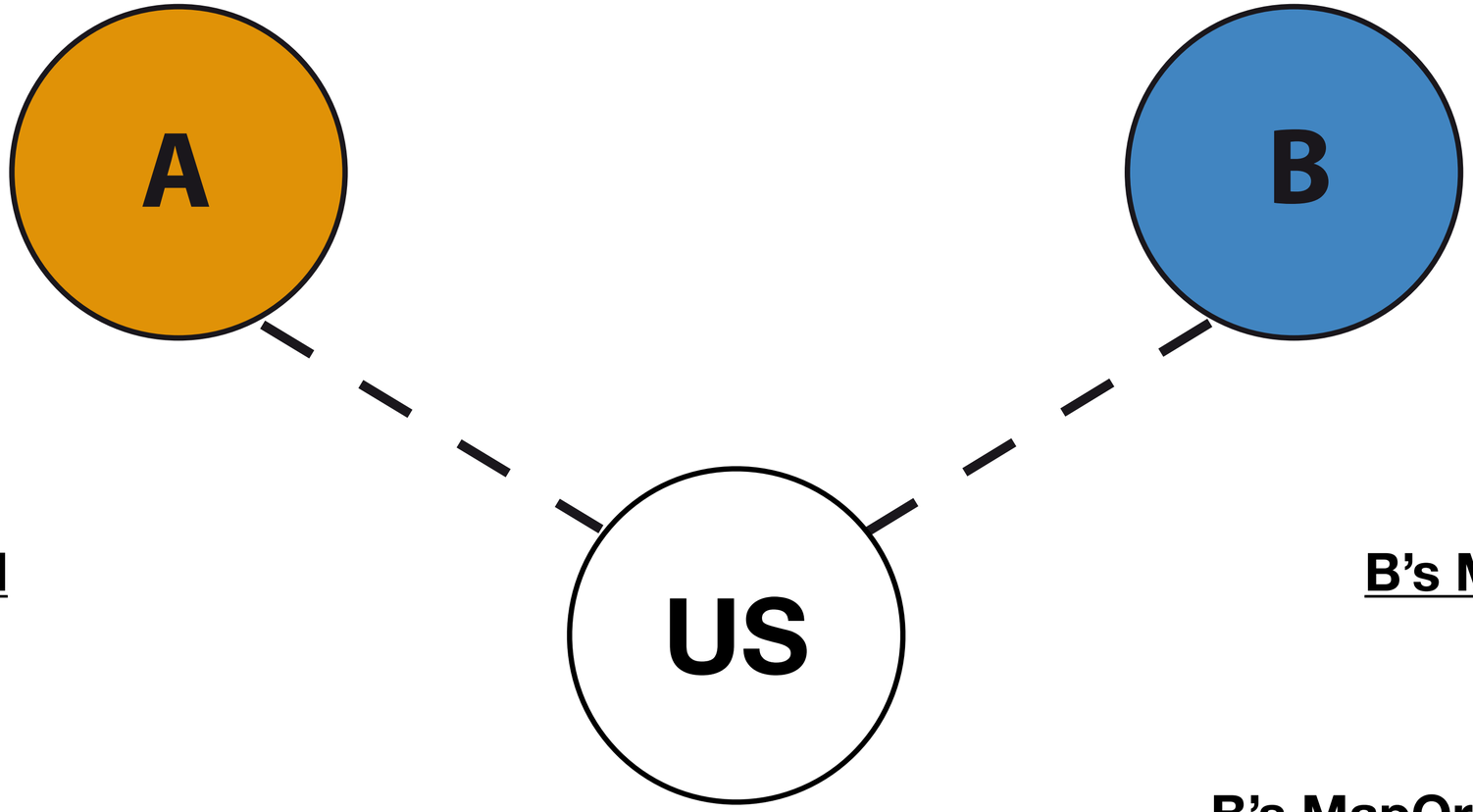
txM (3)

NEGATIVE INFERRING TECHNIQUE



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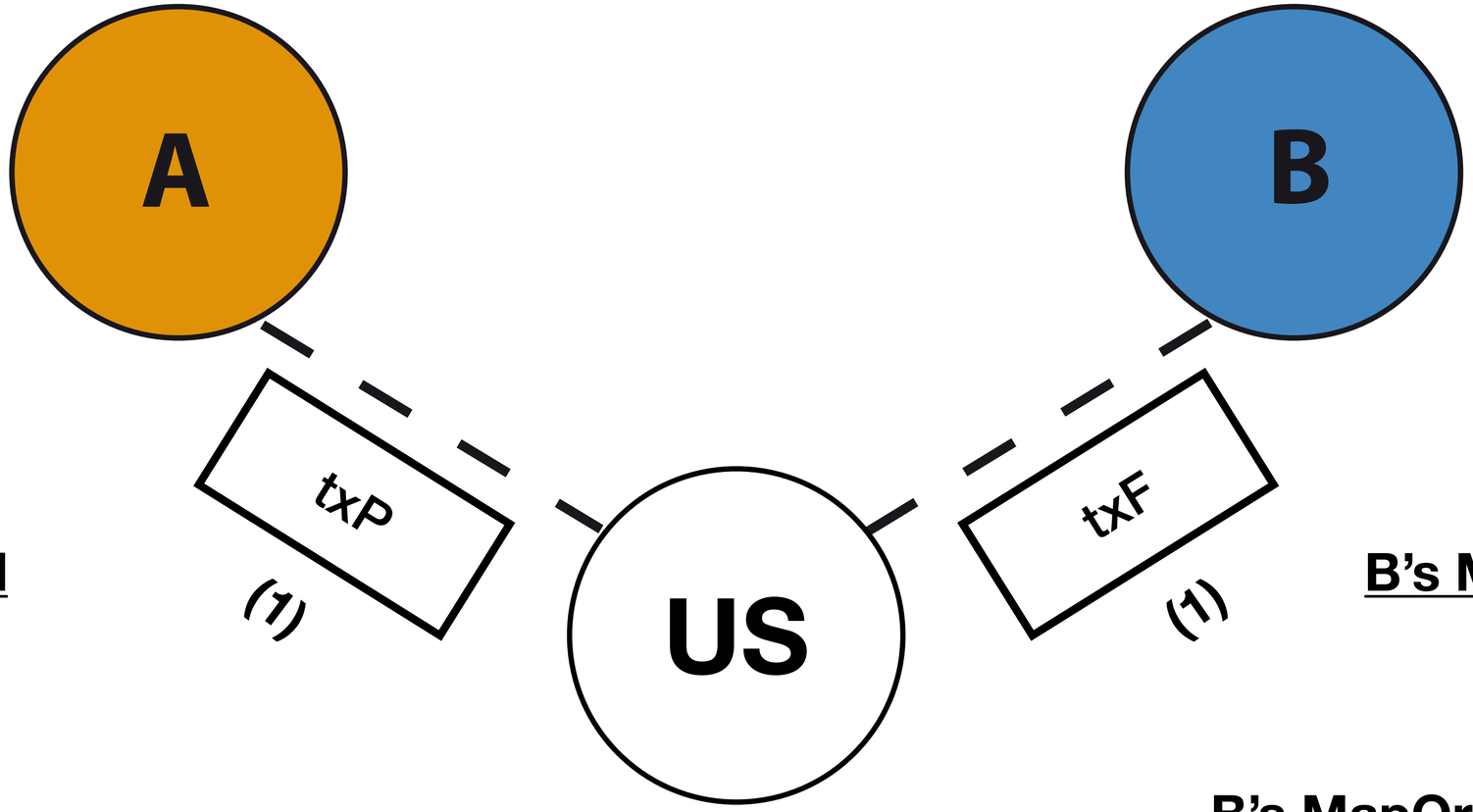

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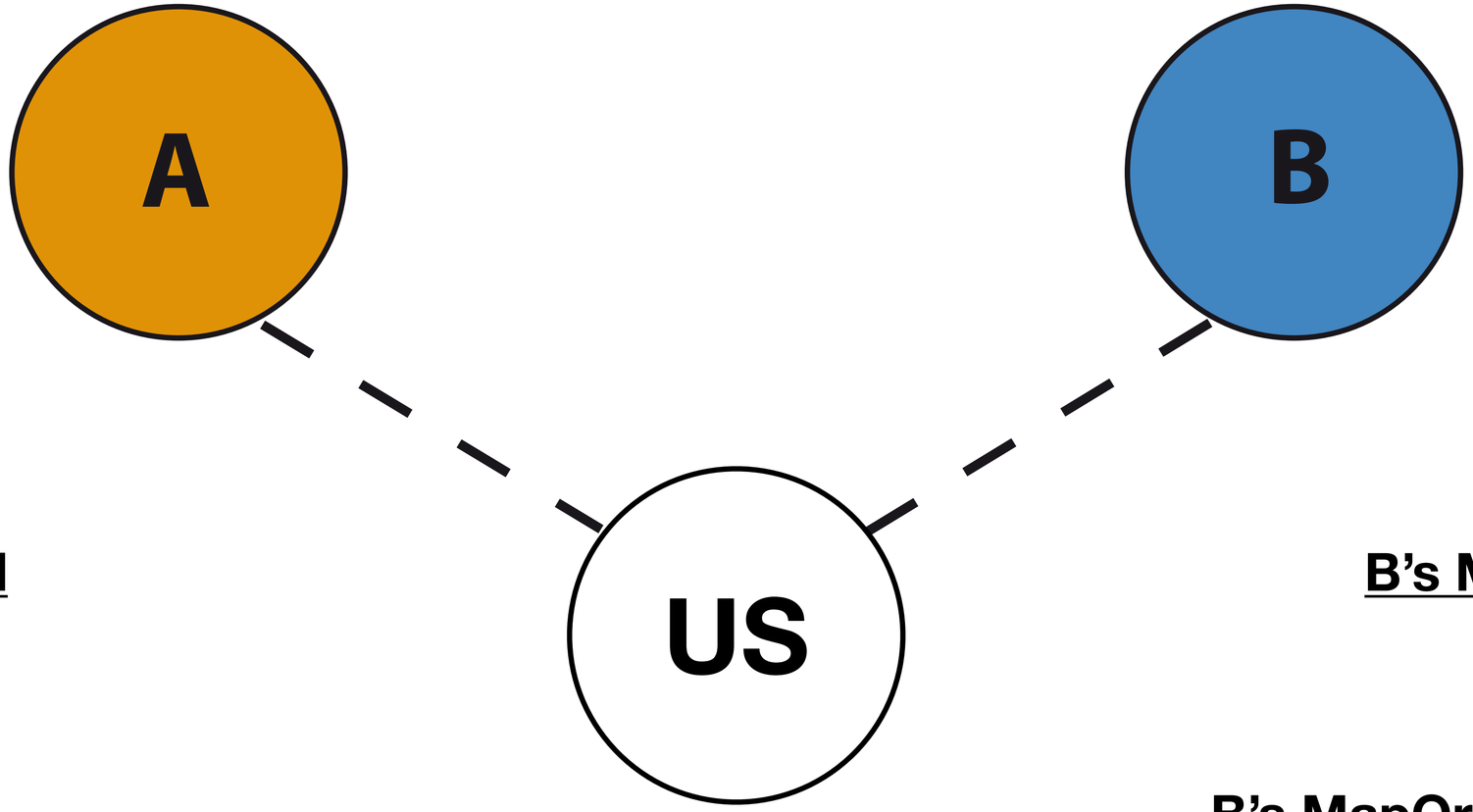

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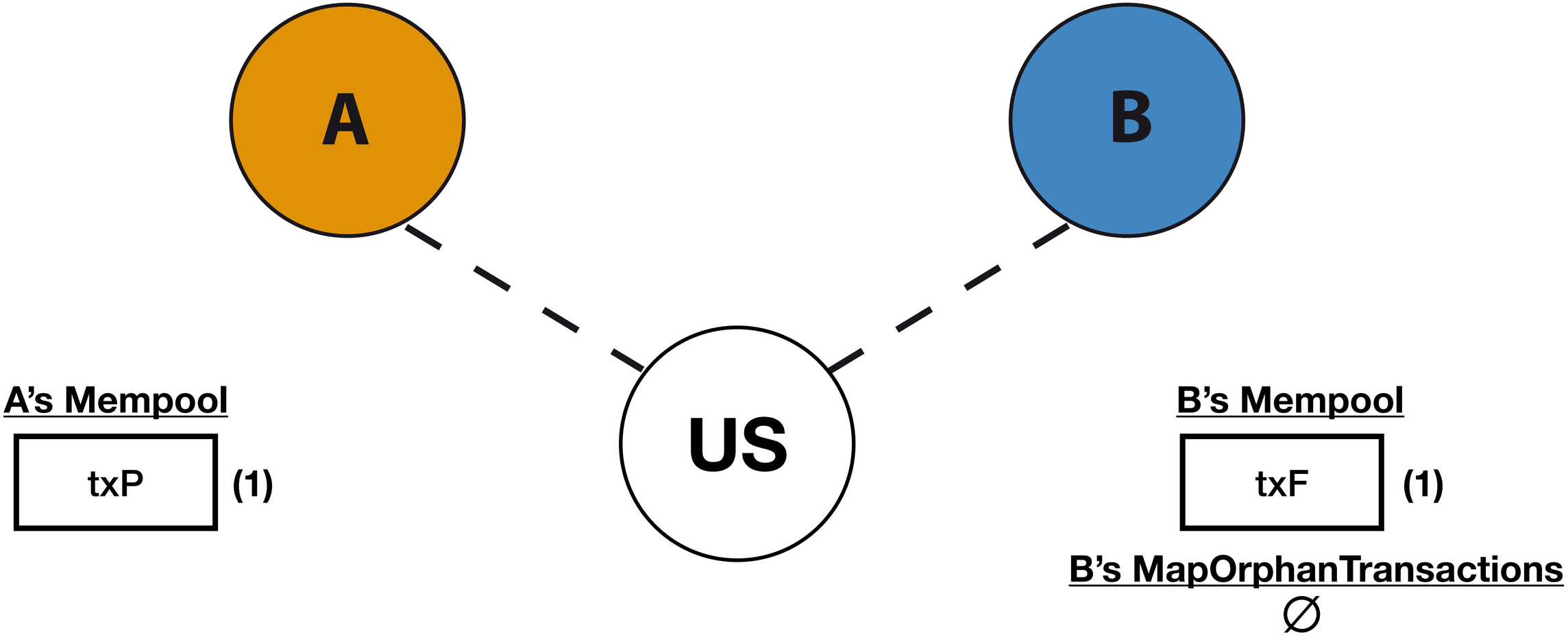

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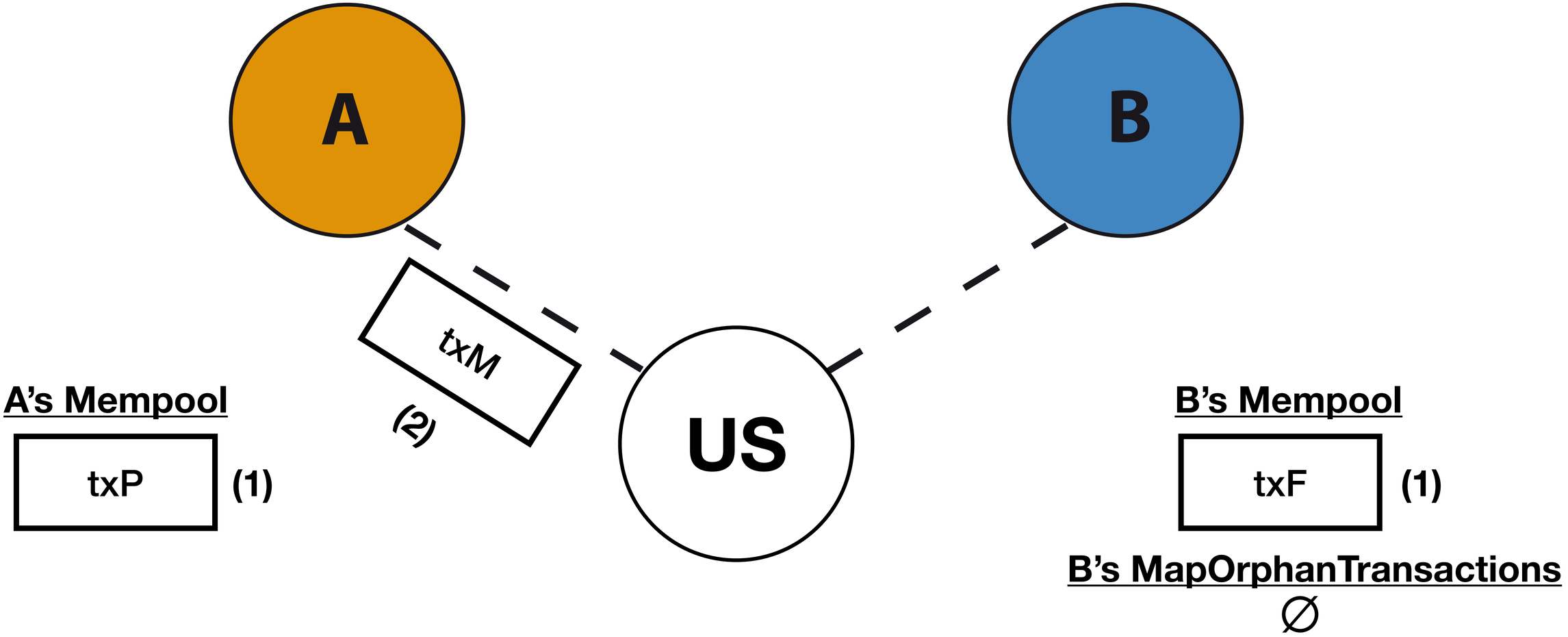

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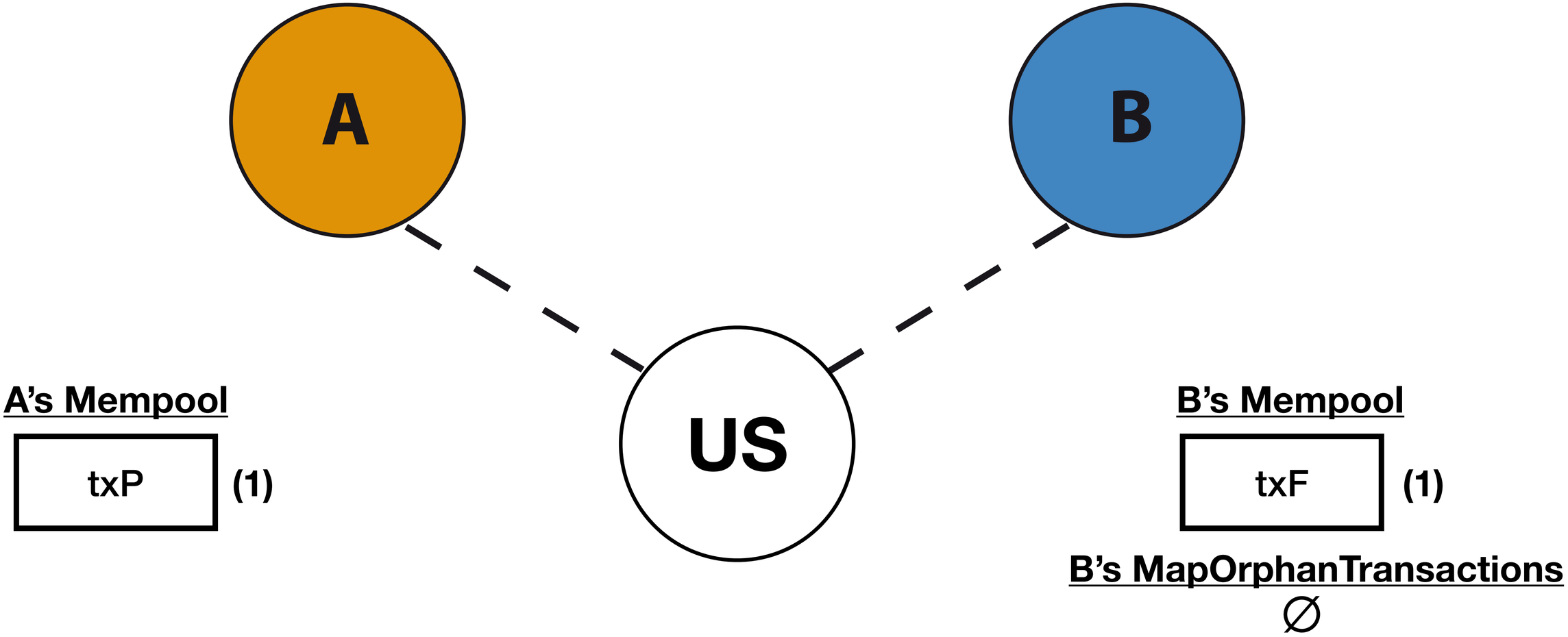

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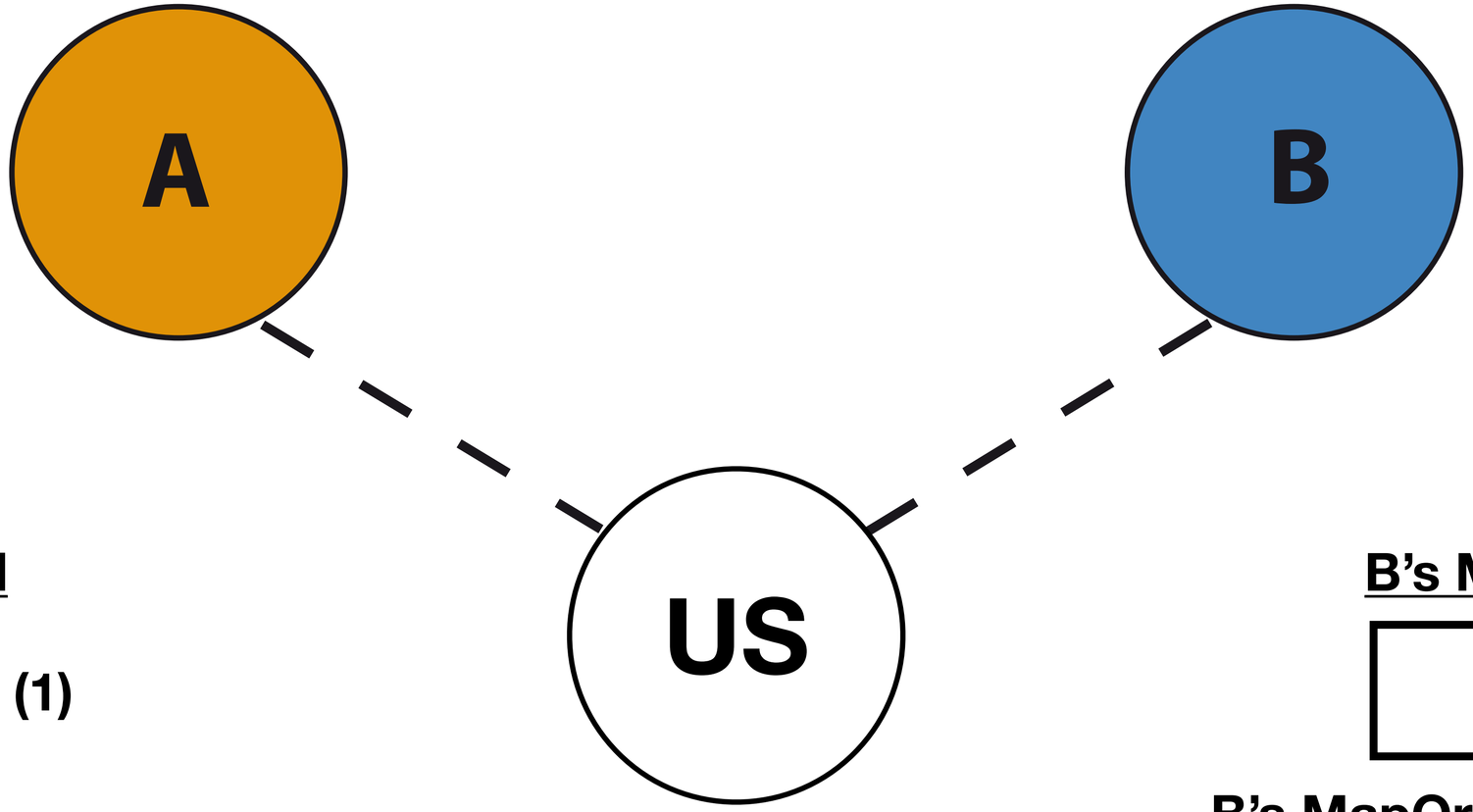

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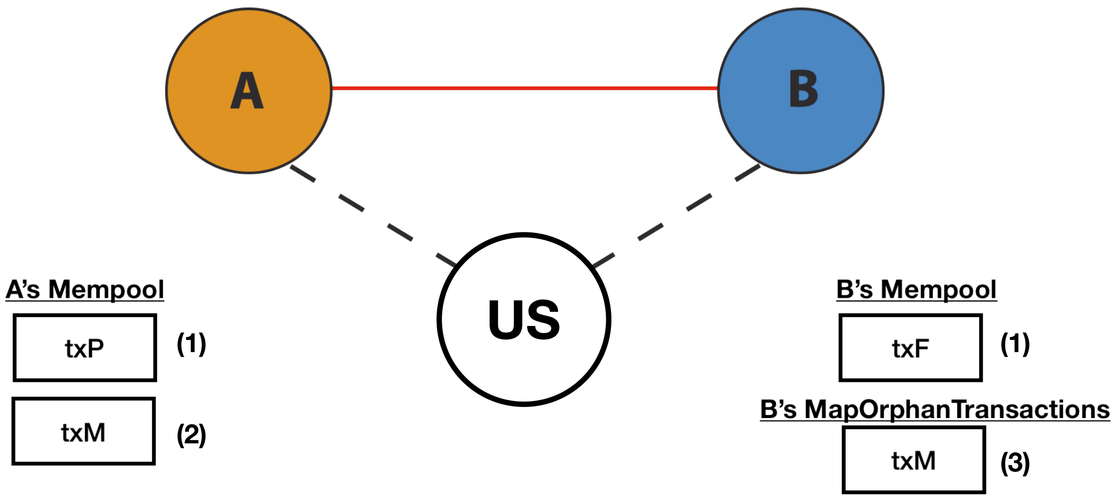
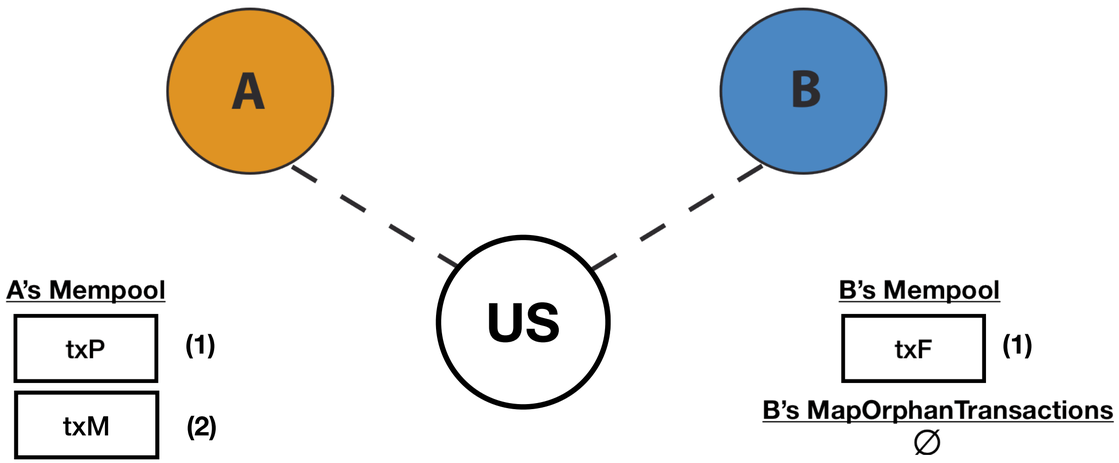
Positive edge inferring



Negative edge inferring



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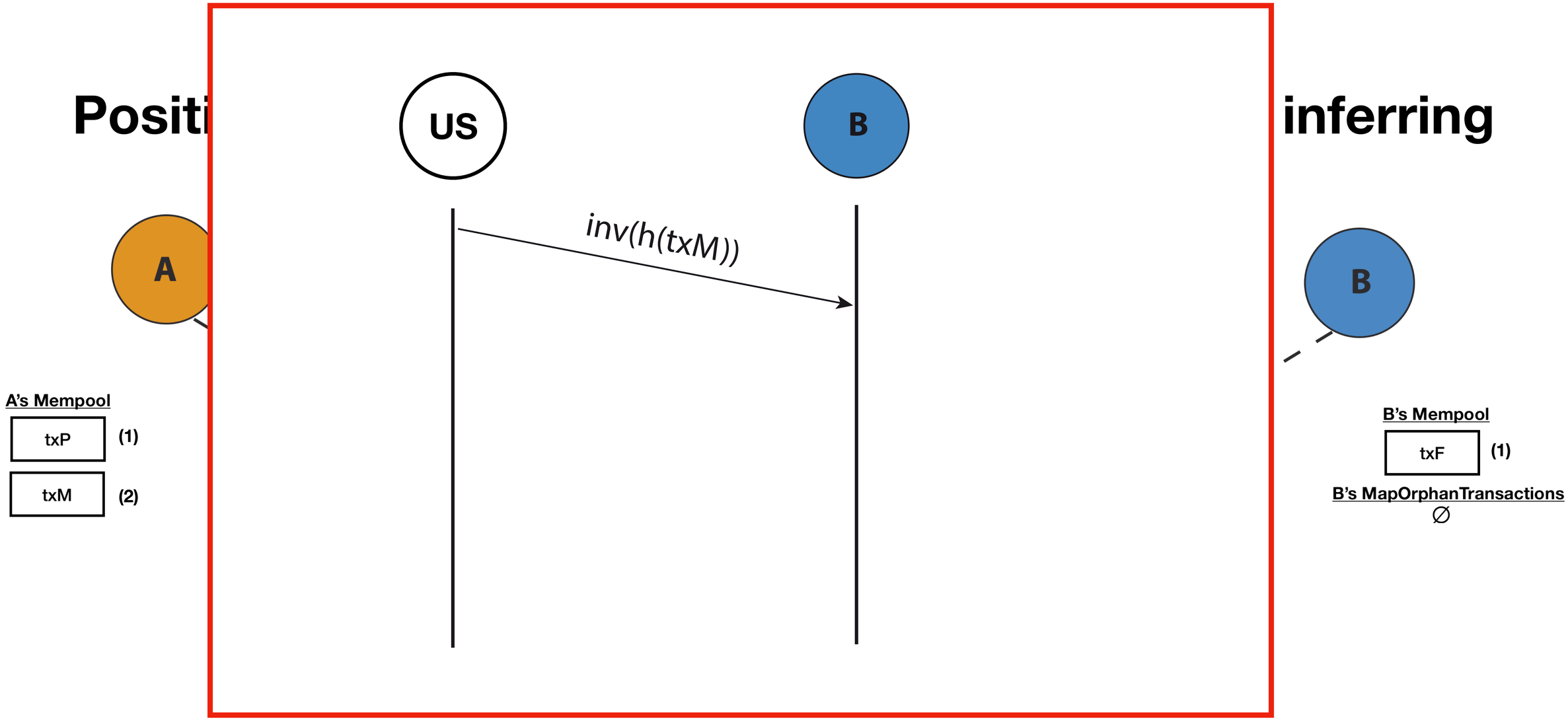

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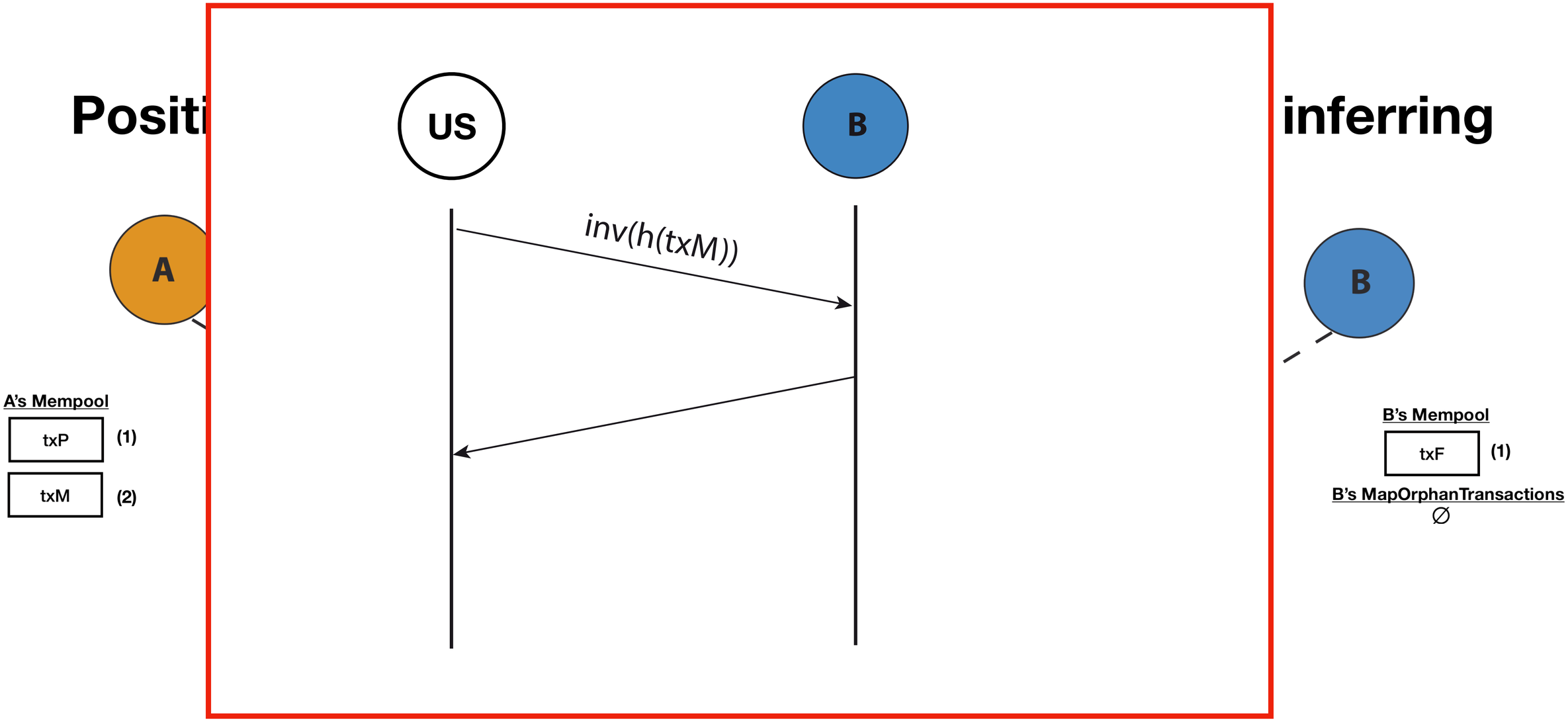

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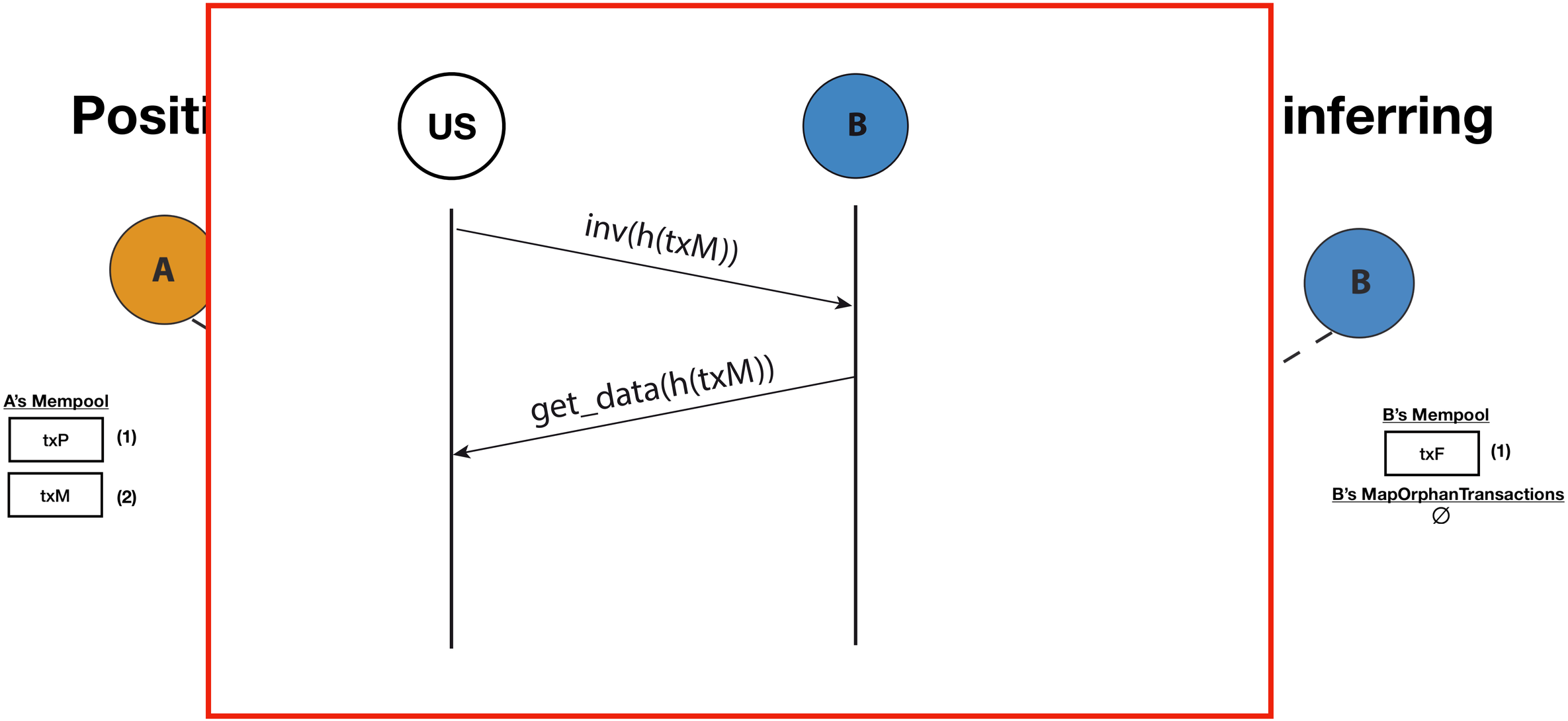

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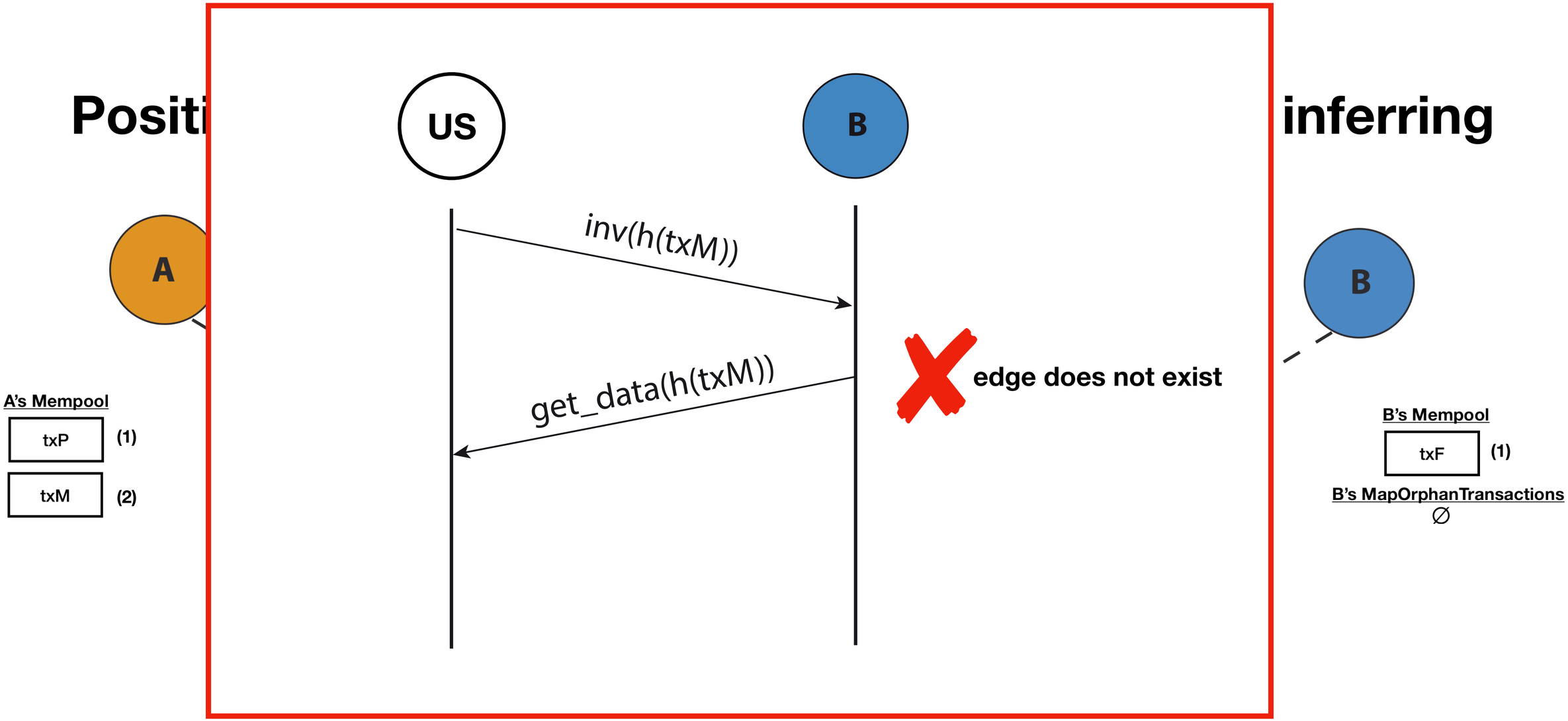
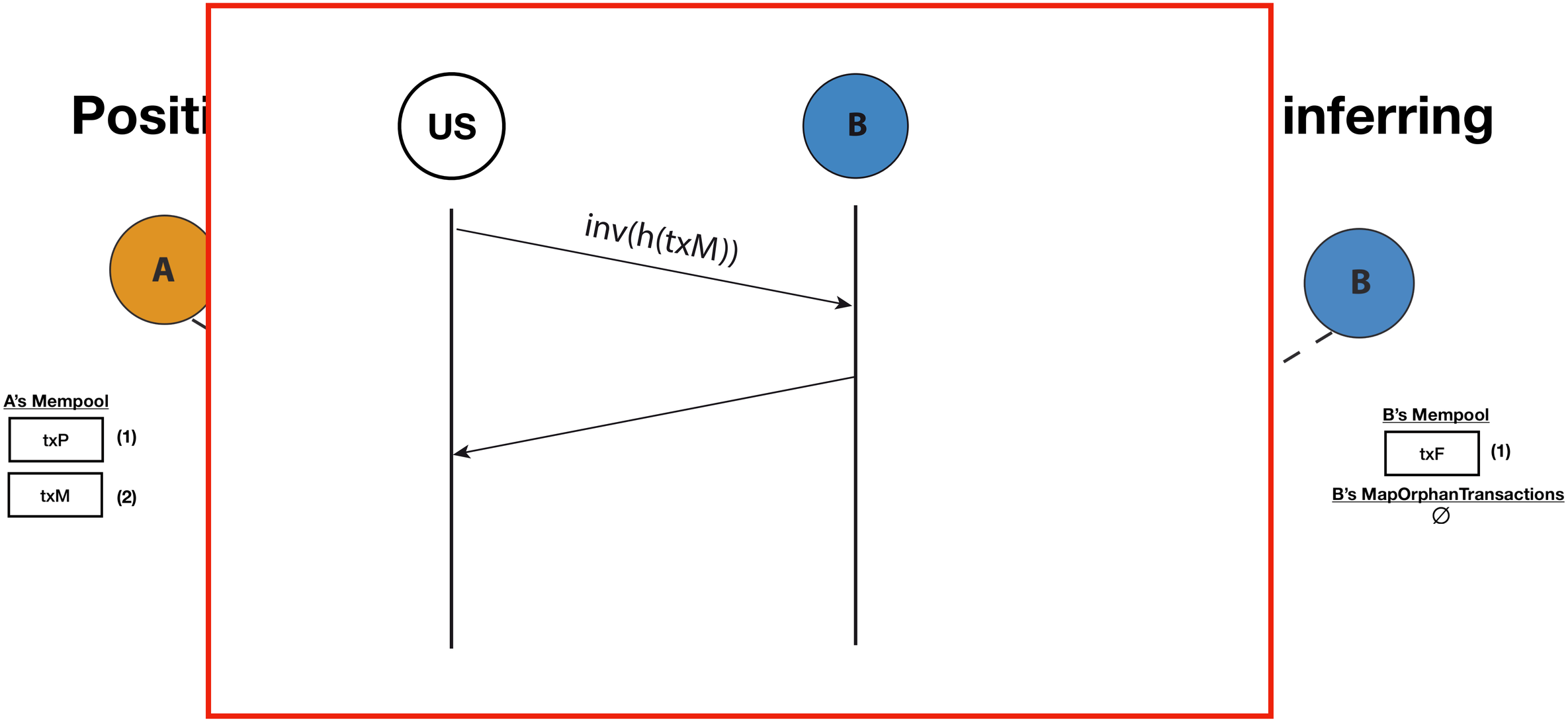
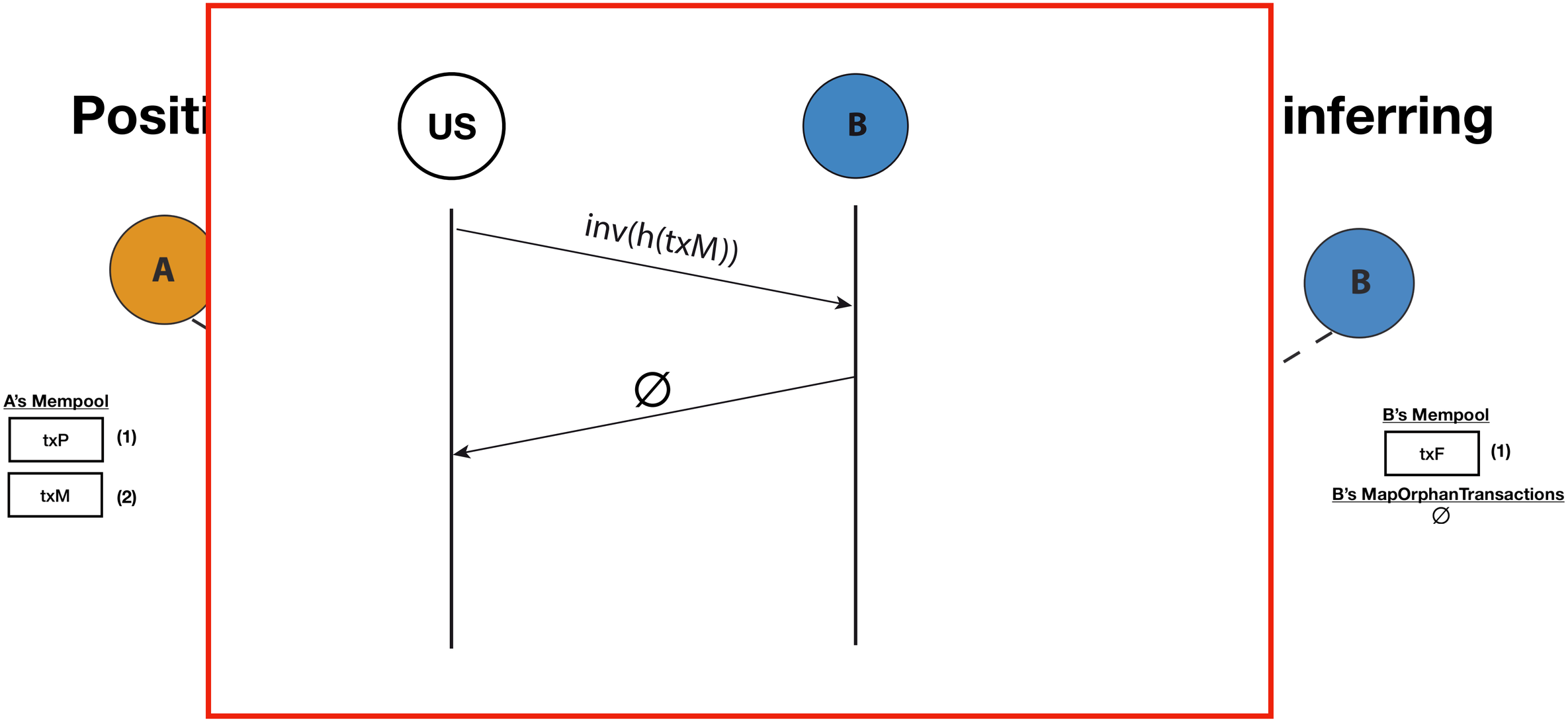


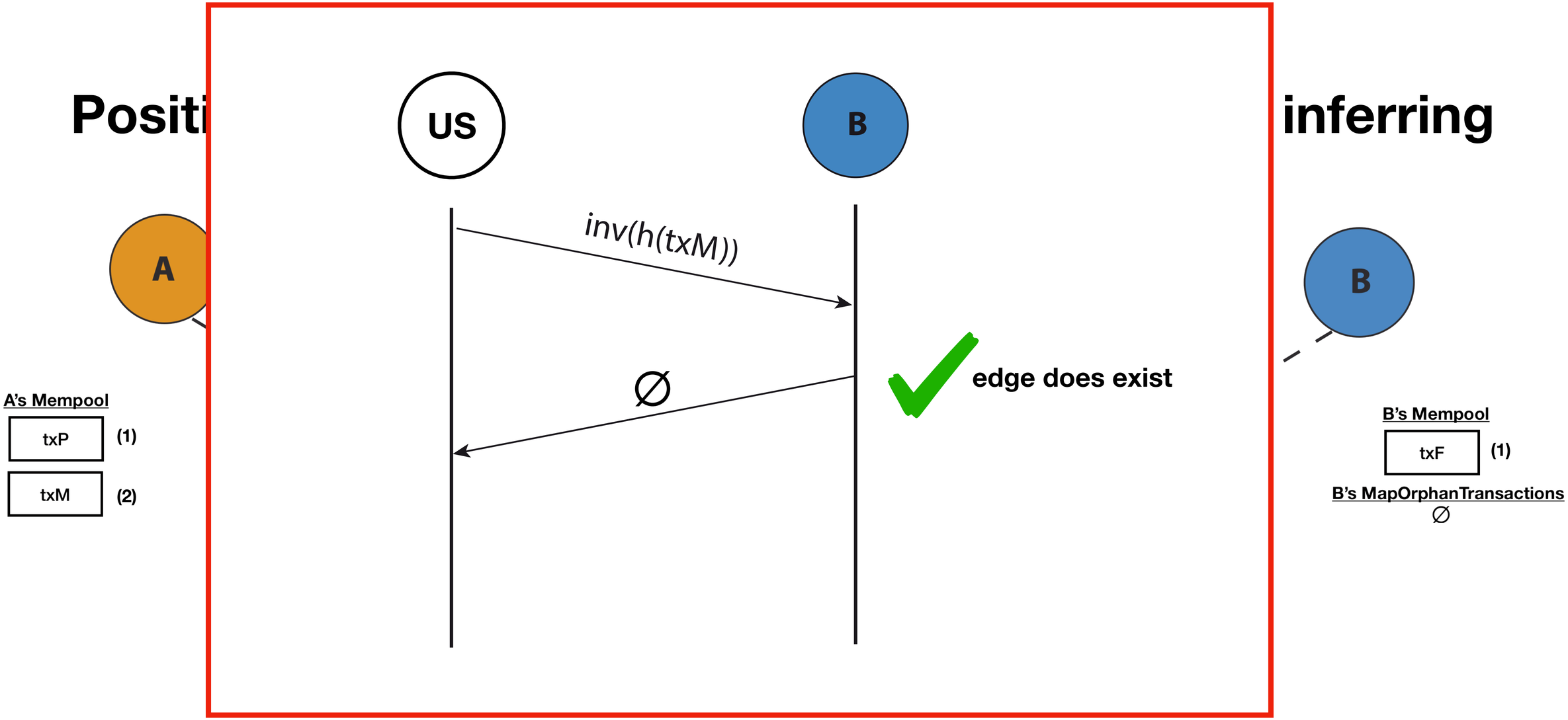
A BASIC TOPOLOGY INFERRING TECHNIQUE



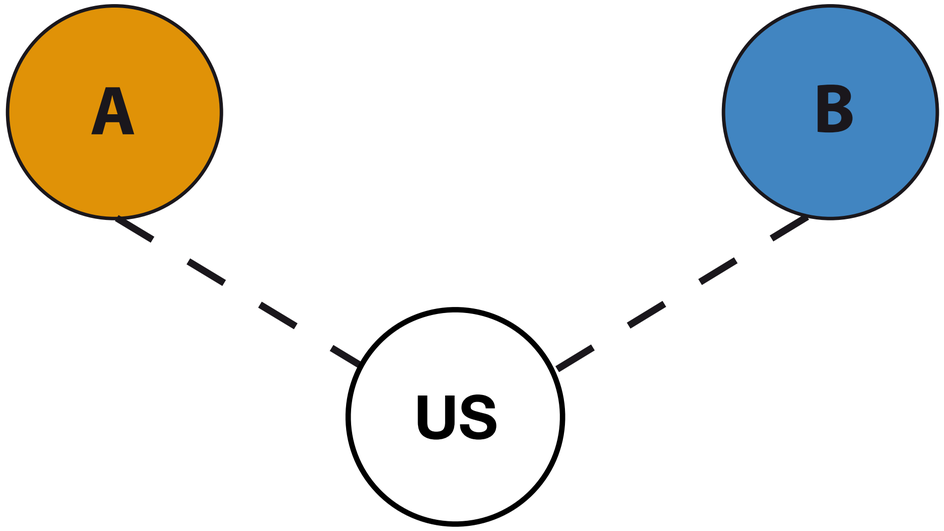
A BASIC TOPOLOGY INFERRING TECHNIQUE



A BASIC TOPOLOGY INFERRING TECHNIQUE

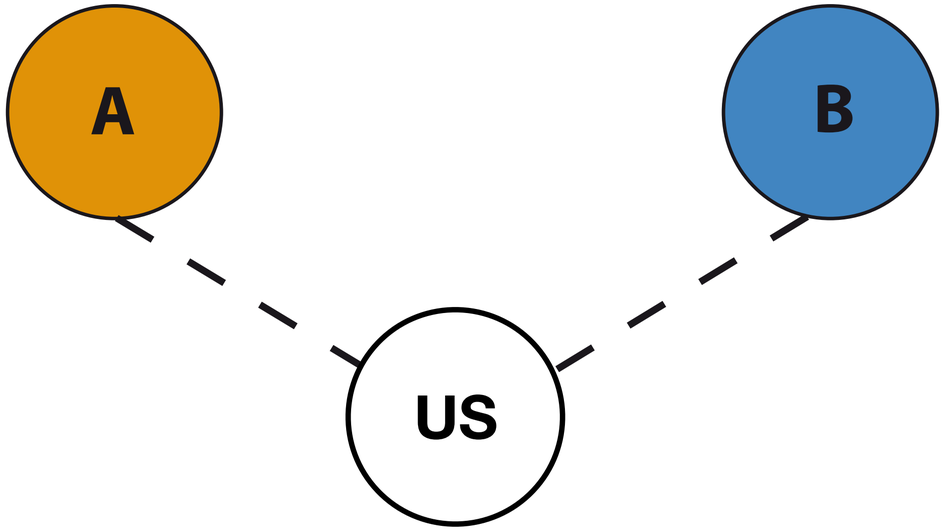


ITS NOT THAT EASY



ITS NOT THAT EASY

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



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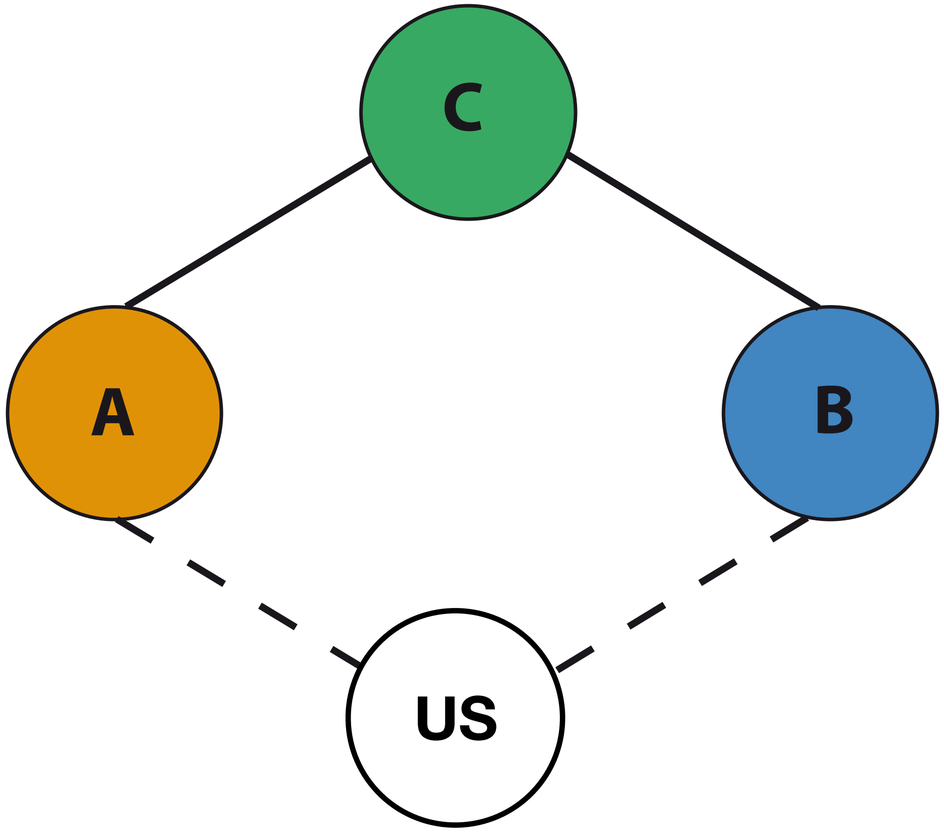

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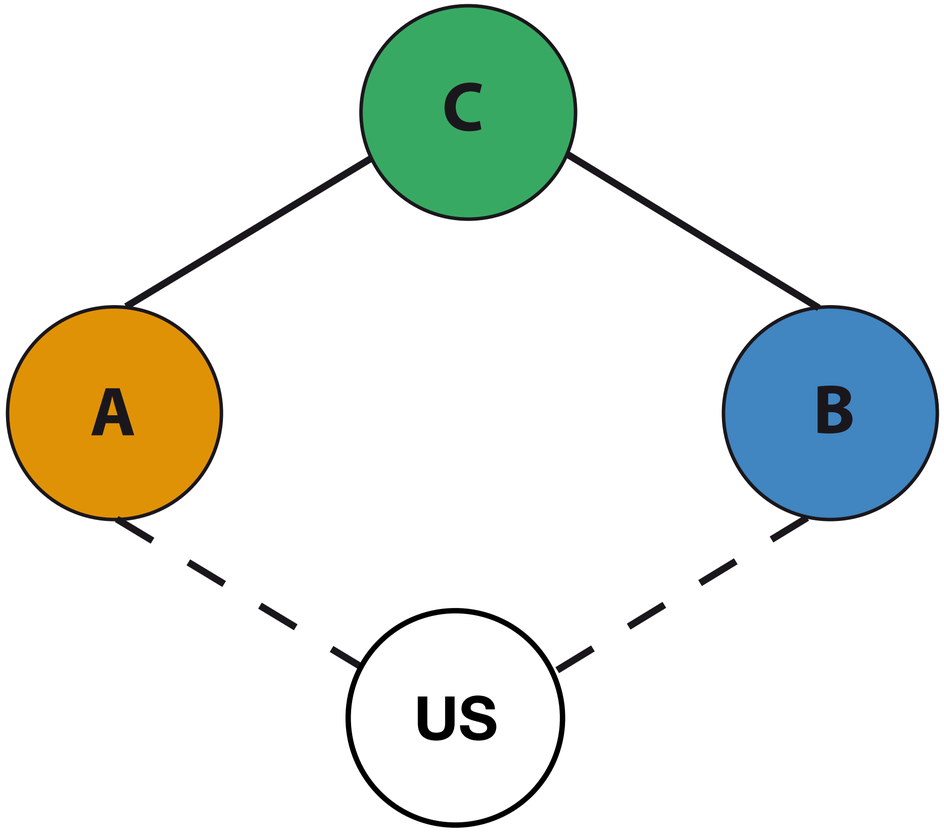

A's Mempool

∅

C's Mempool

∅

B's Mempool

∅

B's MapOrphanTransactions

∅

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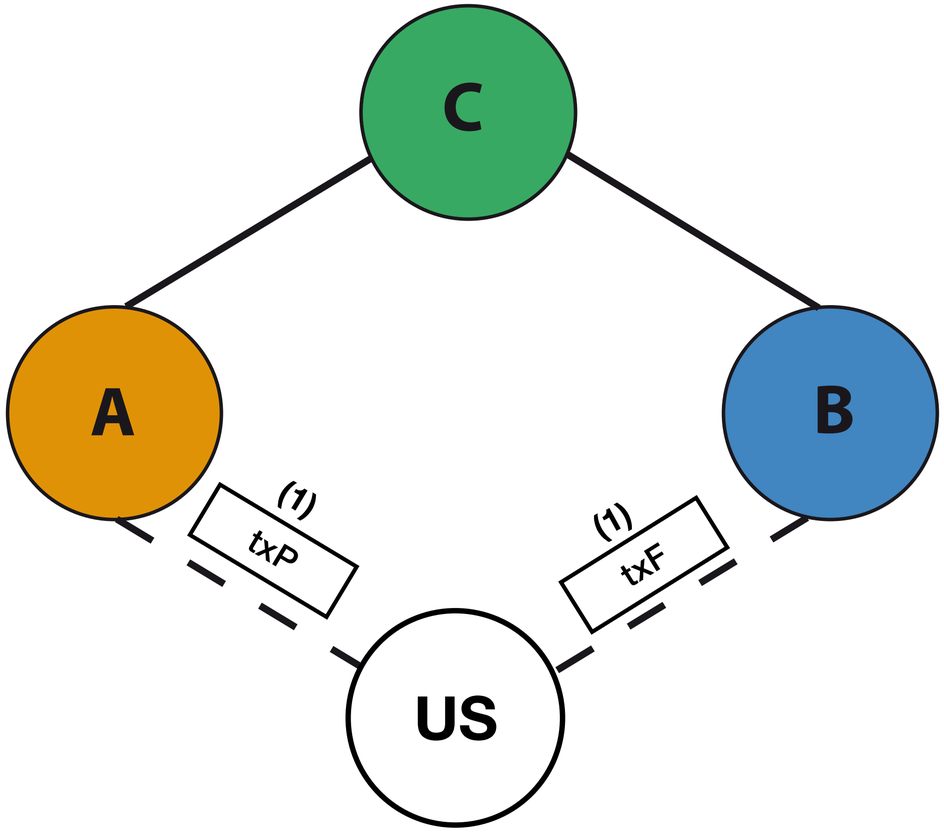

A's Mempool

∅

C's Mempool

∅

B's Mempool

∅

B's MapOrphanTransactions

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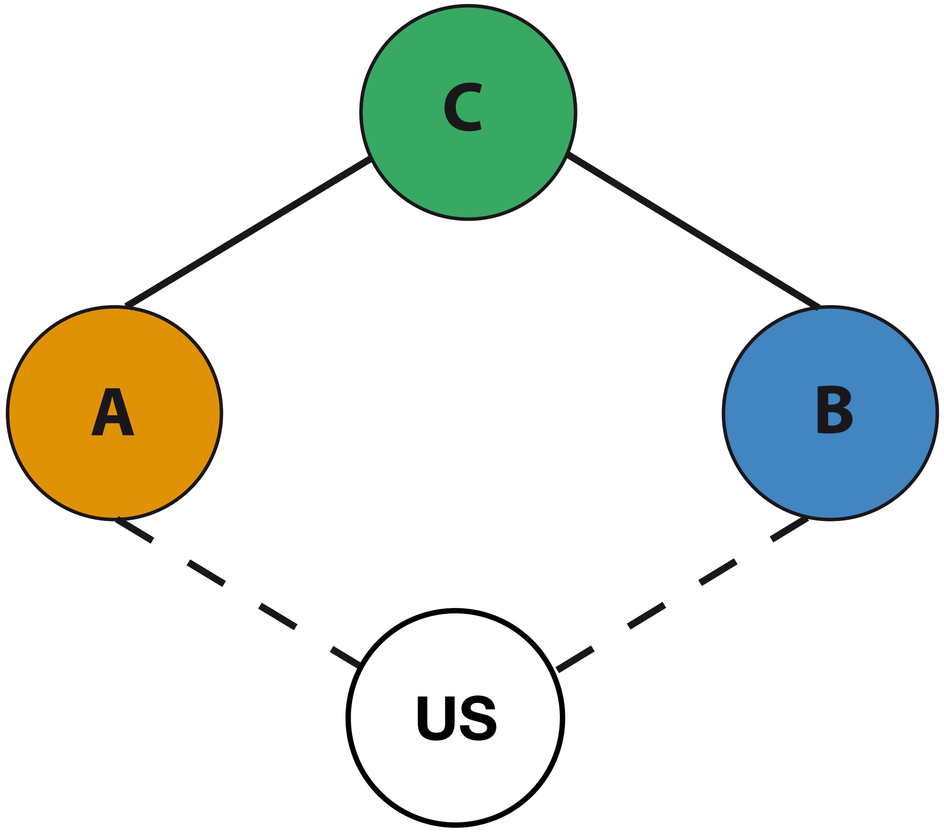

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C's Mempool

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B's Mempool

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B's MapOrphanTransactions

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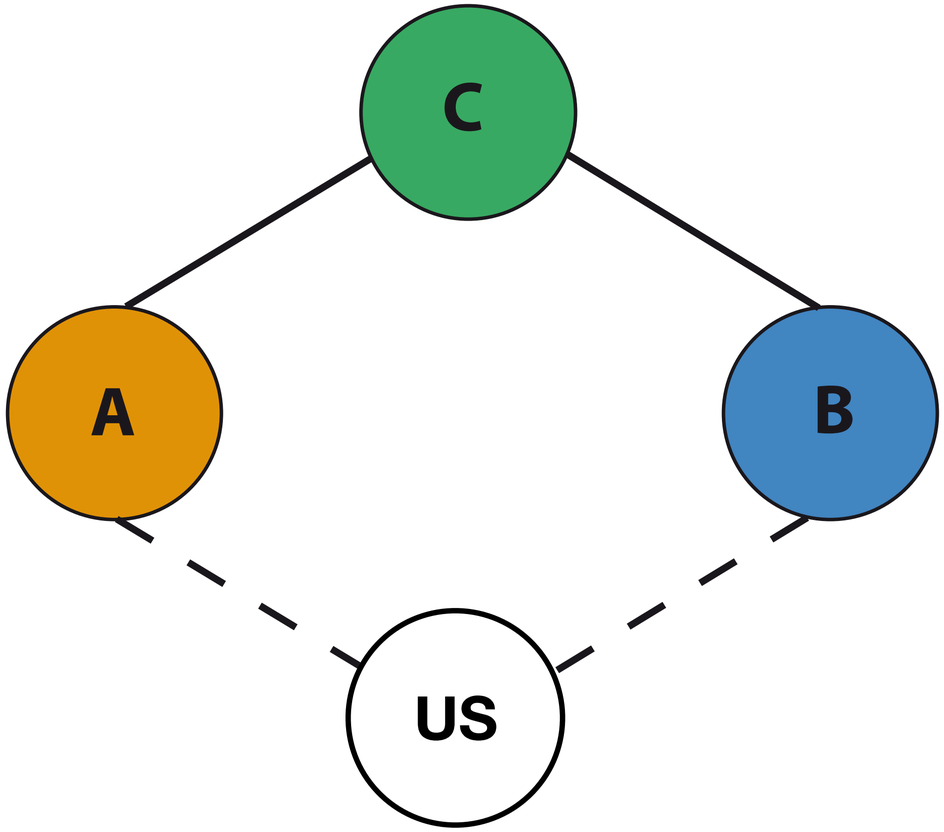


A's Mempool

txP	(1)

C's Mempool

∅

B's Mempool

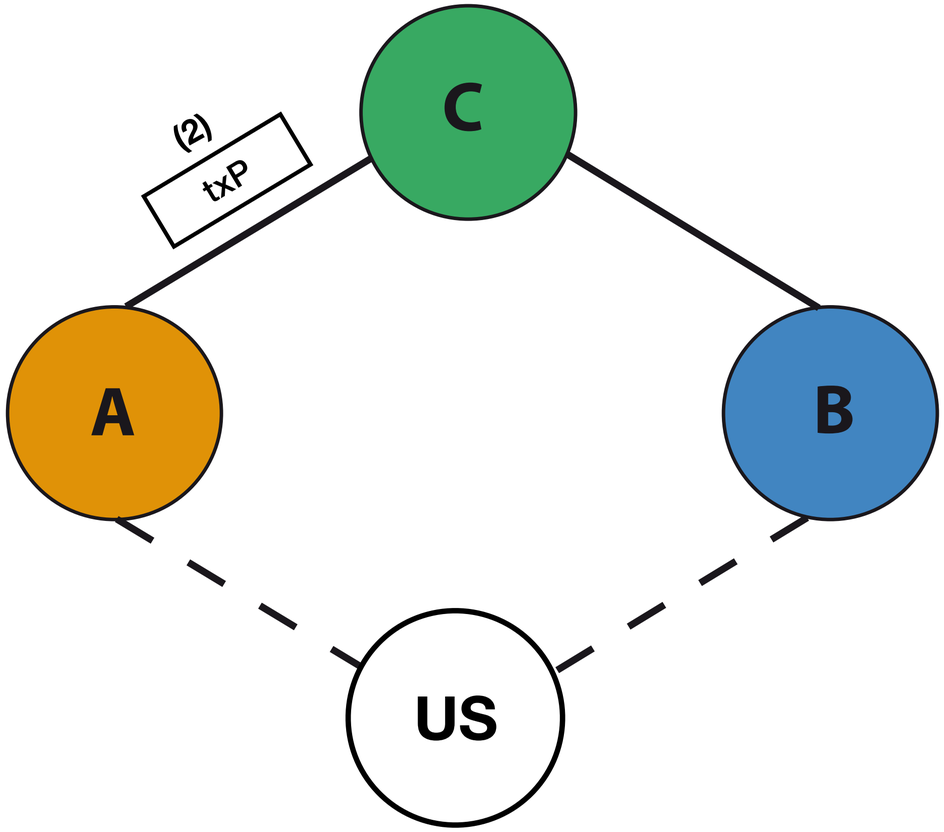
txF	(1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

Long story short, if you add an additional unconnected 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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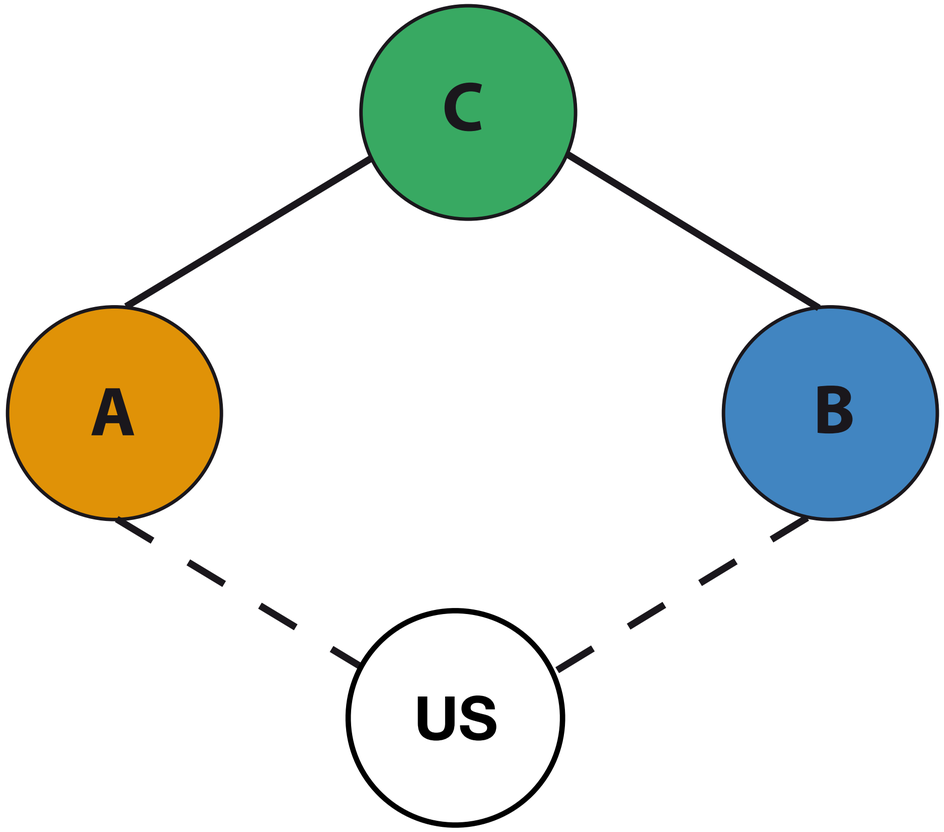

A's Mempool

txP	(1)

C's Mempool

∅

B's Mempool

txF	(1)

B's MapOrphanTransactions

∅

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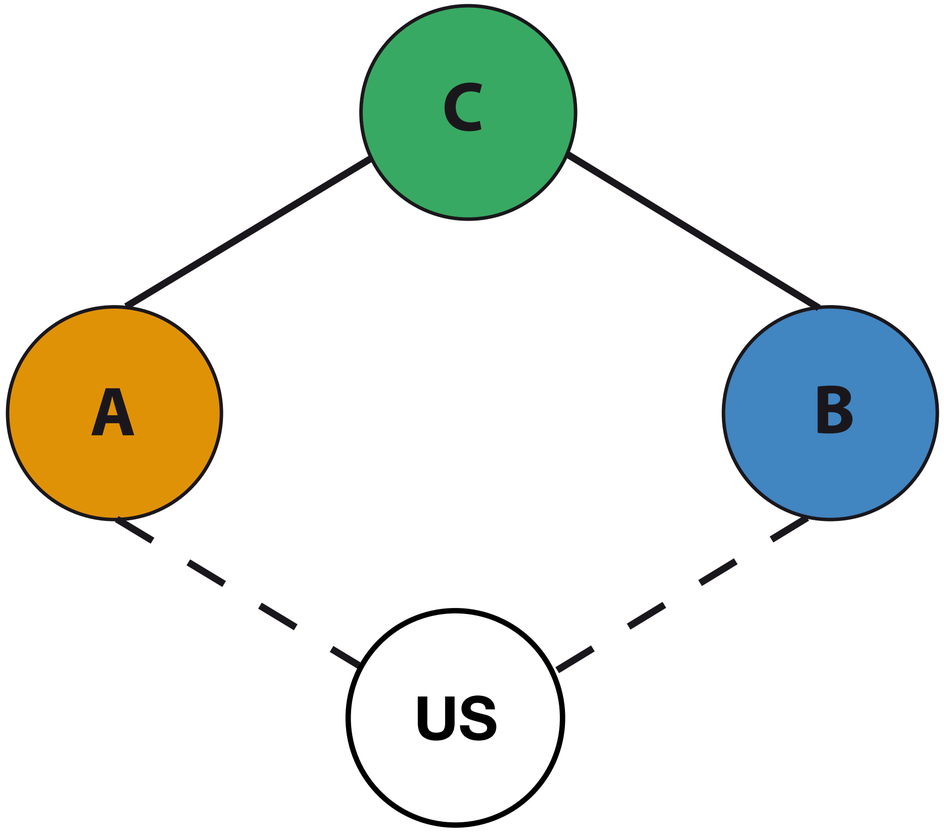

A's Mempool

txP	(1)

C's Mempool

txP	(2)

B's Mempool

txF	(1)

B's MapOrphanTransactions

∅

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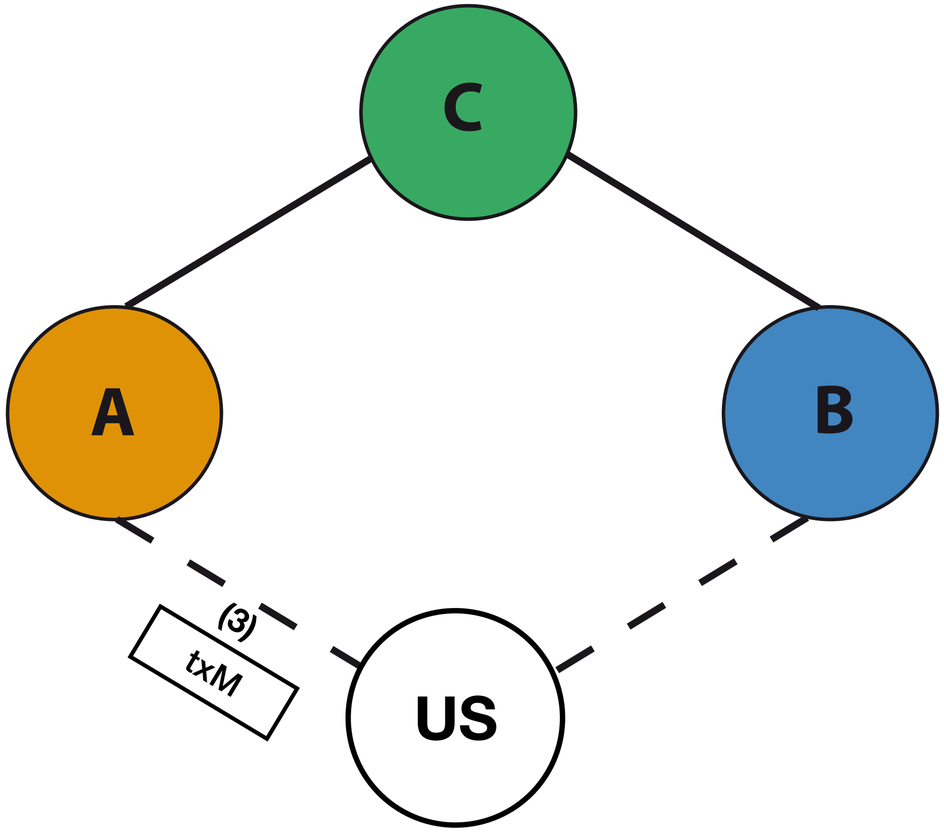

A's Mempool

txP (1)

C's Mempool

txP (2)

B's Mempool

txF (1)

B's MapOrphanTransactions

∅

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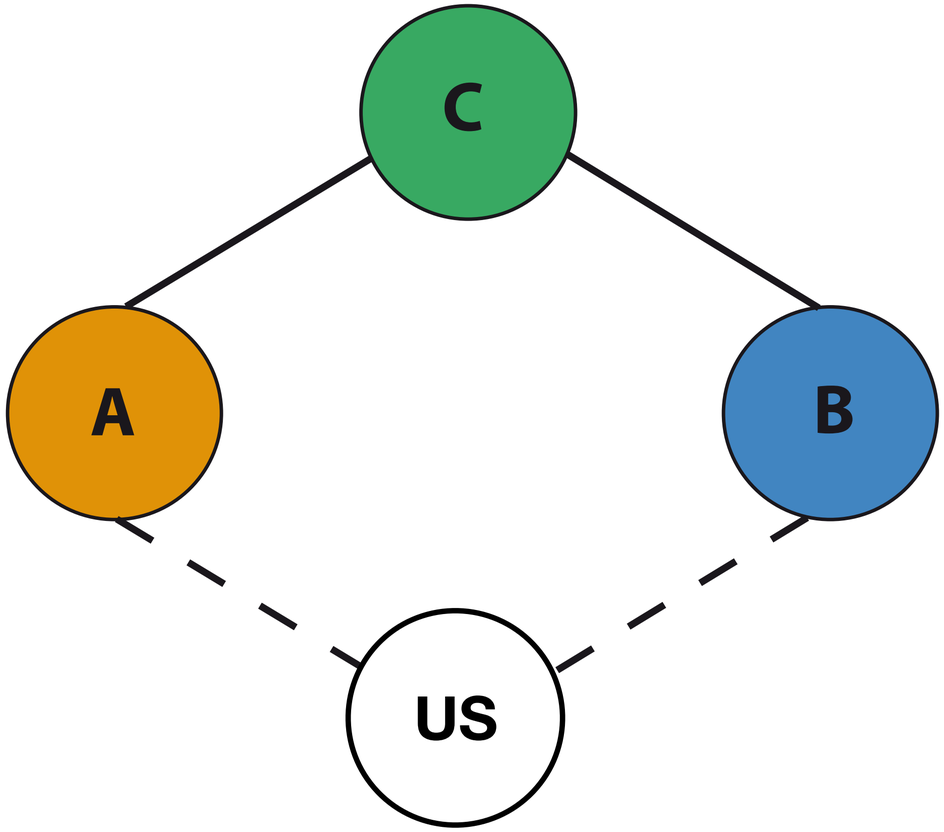
Long story short, if you add an additional unconnected node to the equation it will fail



A's Mempool

txP	(1)

C's Mempool

txP	(2)

B's Mempool

txF	(1)

B's MapOrphanTransactions

∅

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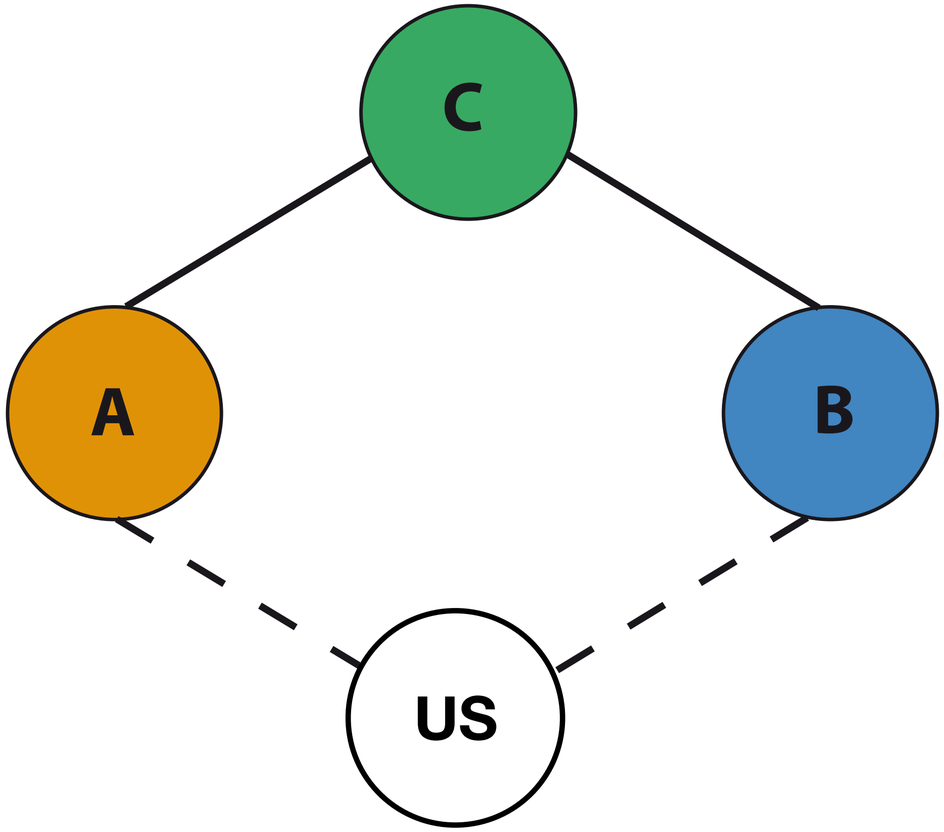
Long story short, if you add an additional unconnected node to the equation it will fail



A's Mempool

txP (1)

txM (3)

C's Mempool

txP (2)

B's Mempool

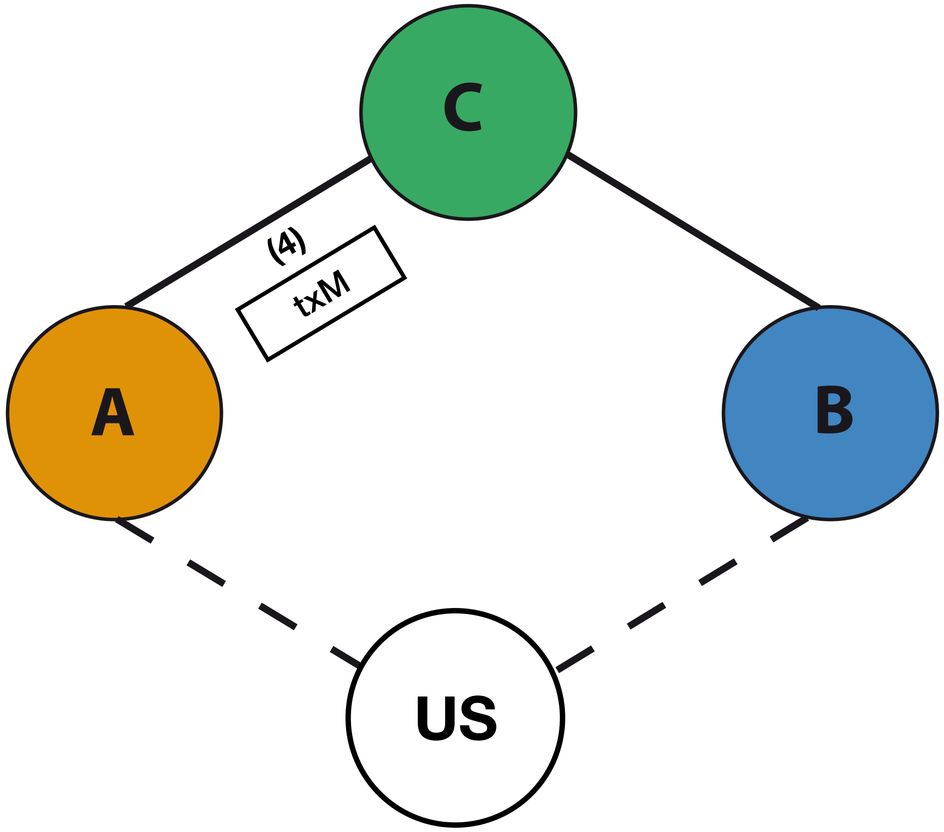
txF (1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

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



A's Mempool

txP	(1)
txM	(3)

C's Mempool

txP	(2)

B's Mempool

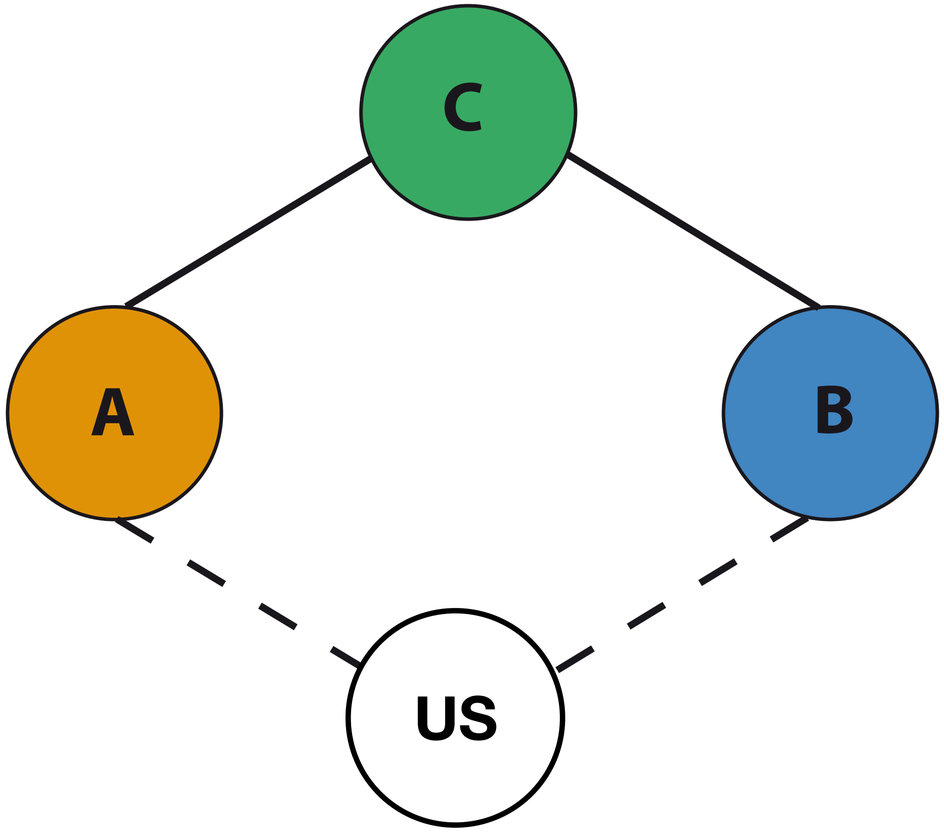
txF	(1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

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



A's Mempool

txP (1)

txM (3)

C's Mempool

txP (2)

B's Mempool

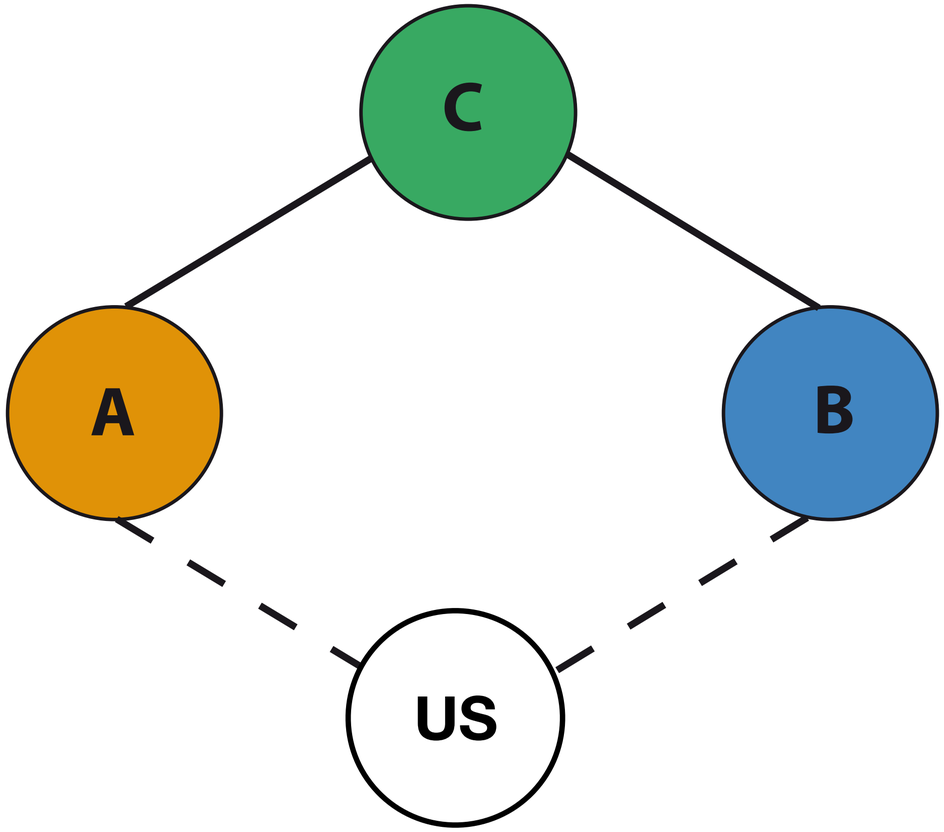
txF (1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

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



A's Mempool

txP (1)

txM (3)

C's Mempool

txP (2)

txM (4)

B's Mempool

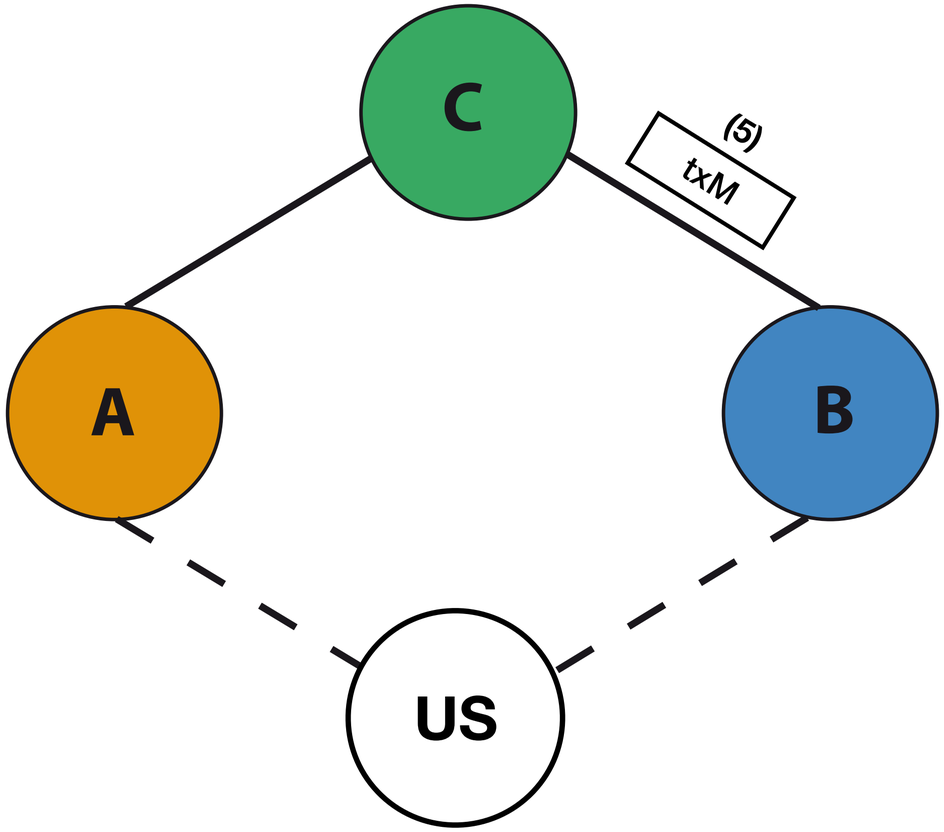
txF (1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

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



A's Mempool

txP (1)

txM (3)

C's Mempool

txP (2)

txM (4)

B's Mempool

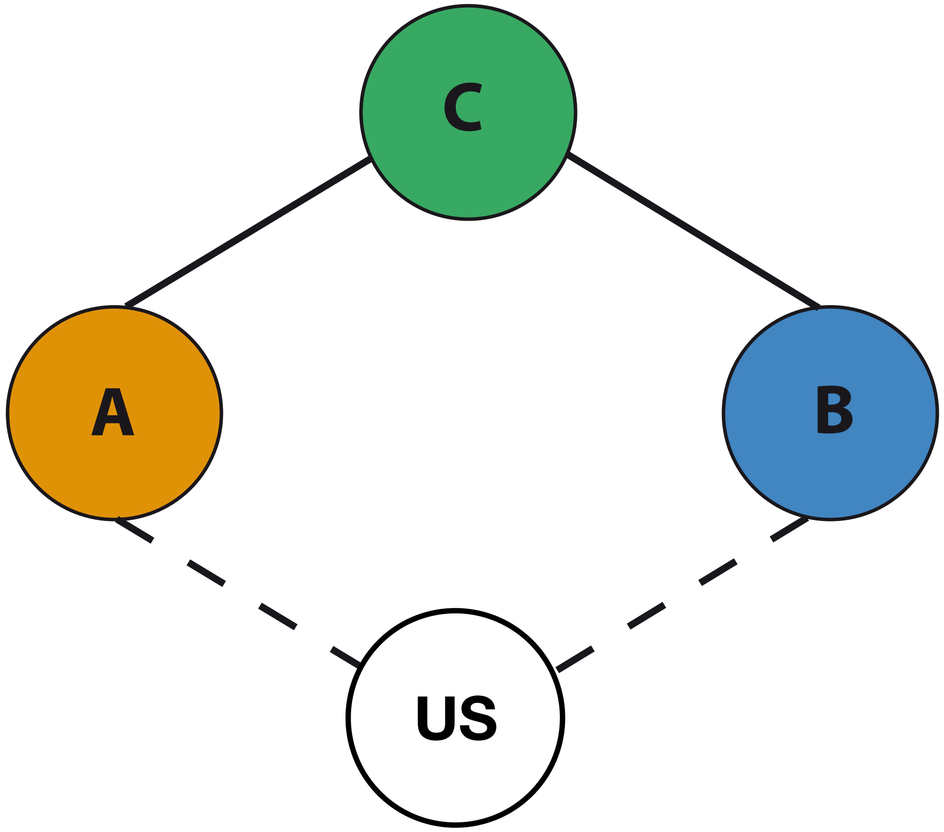
txF (1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

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



A's Mempool

txP (1)

txM (3)

C's Mempool

txP (2)

txM (4)

B's Mempool

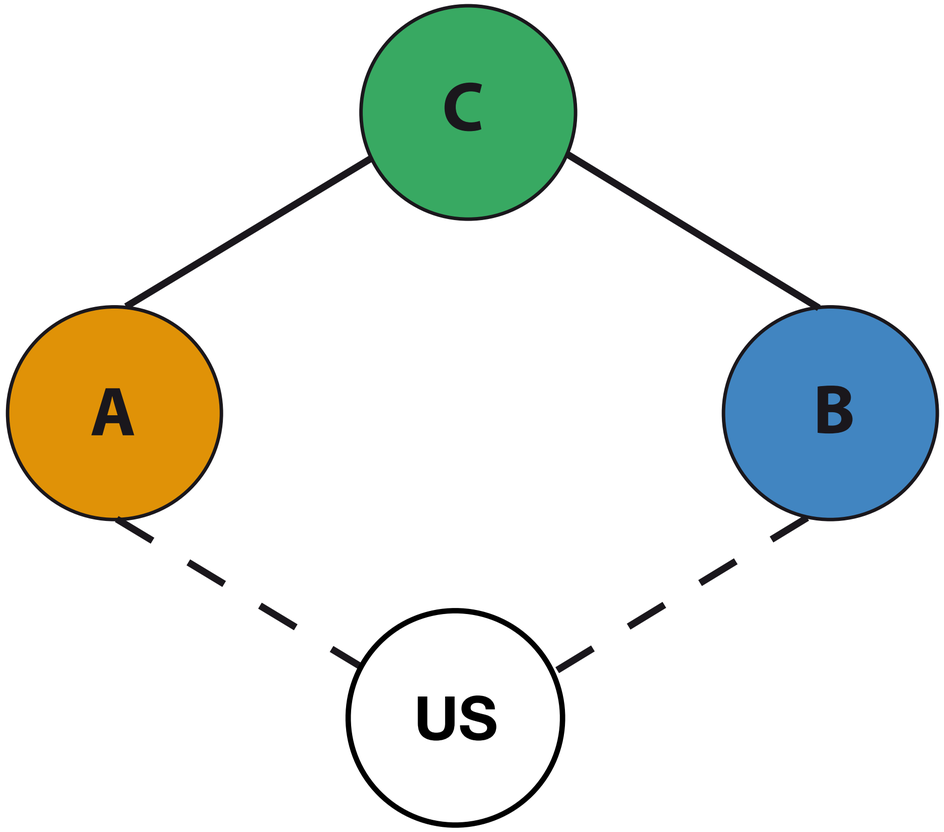
txF (1)

B's MapOrphanTransactions

∅

ITS NOT THAT EASY

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



A's Mempool

txP	(1)
txM	(3)

C's Mempool

txP	(2)
txM	(4)

B's Mempool

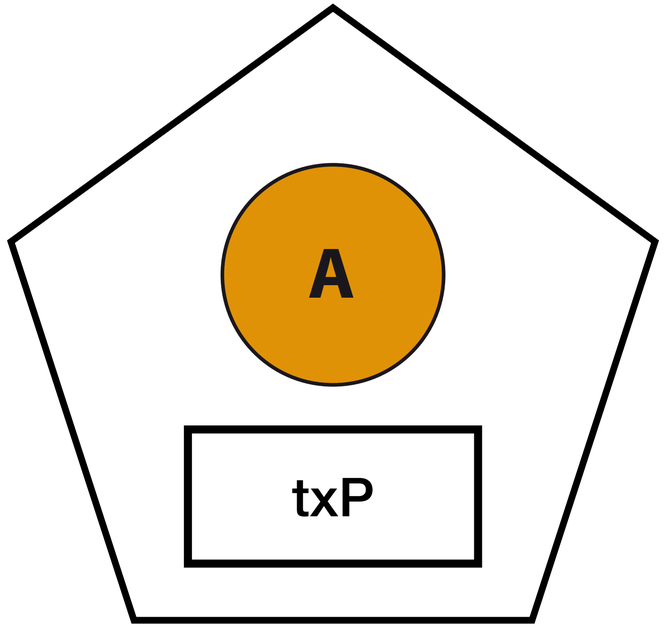
txF	(1)

B's MapOrphanTransactions

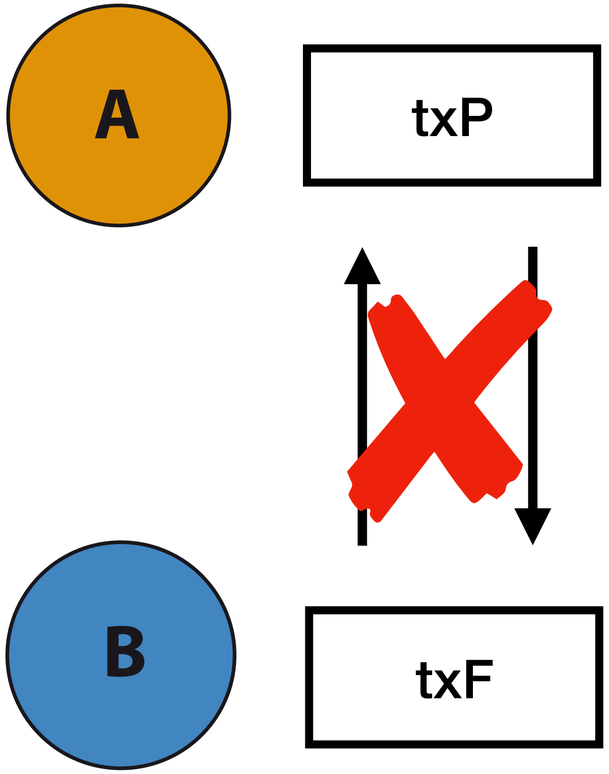
txM	(5)

MAKE THIS WORK IN A REAL NETWORK

Isolation



Synchrony



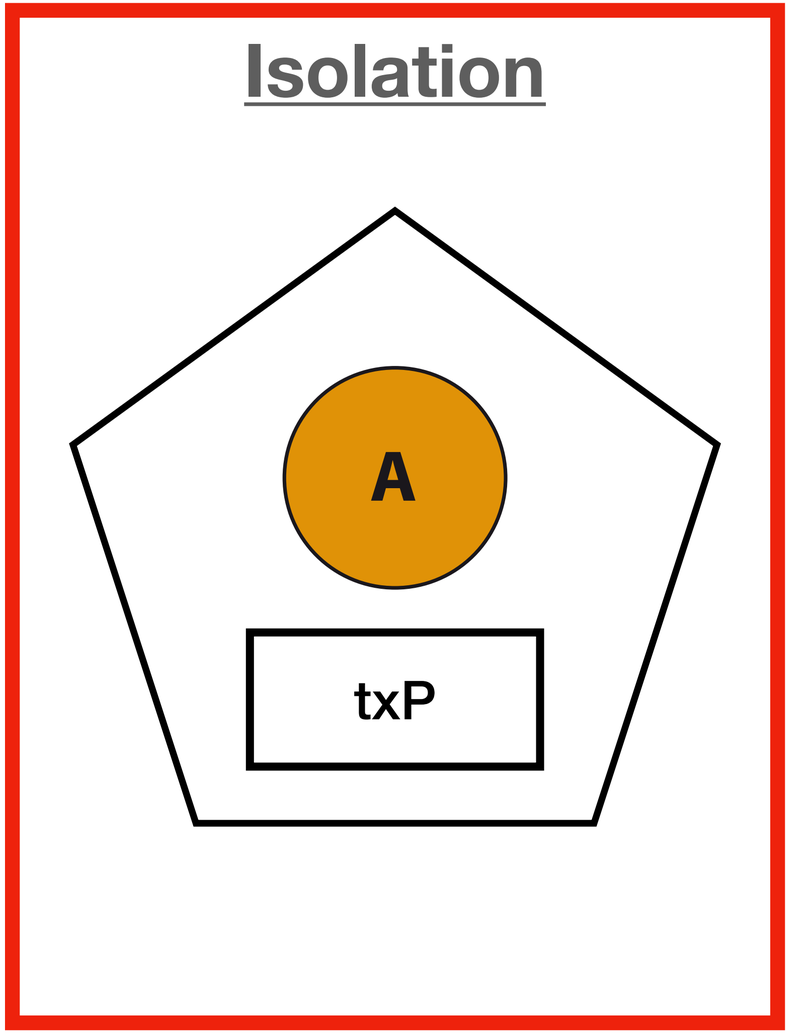
Efficiency

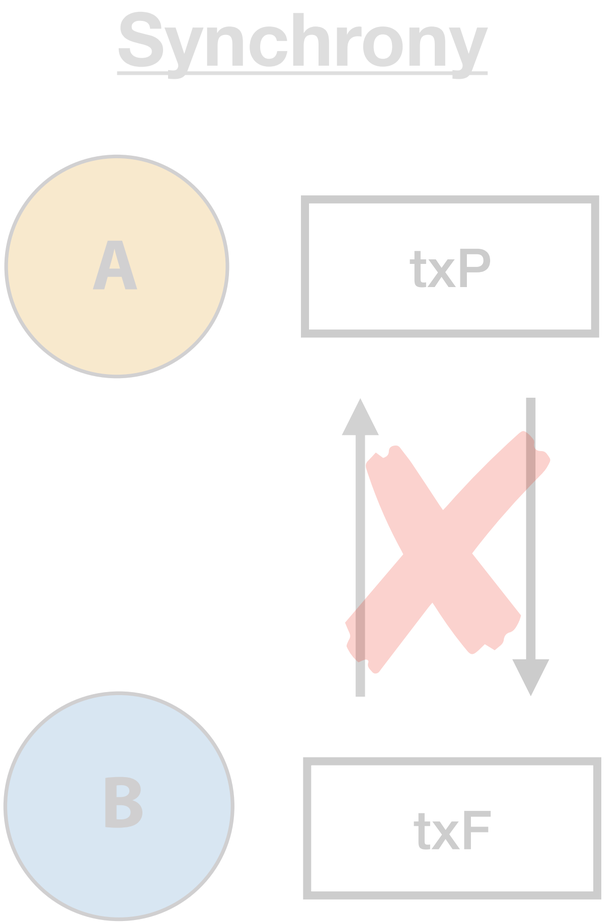
$$\approx O(n)$$

$$\approx O(\sqrt{n})$$

$$n = \#nodes$$

MAKE THIS WORK IN A REAL NETWORK





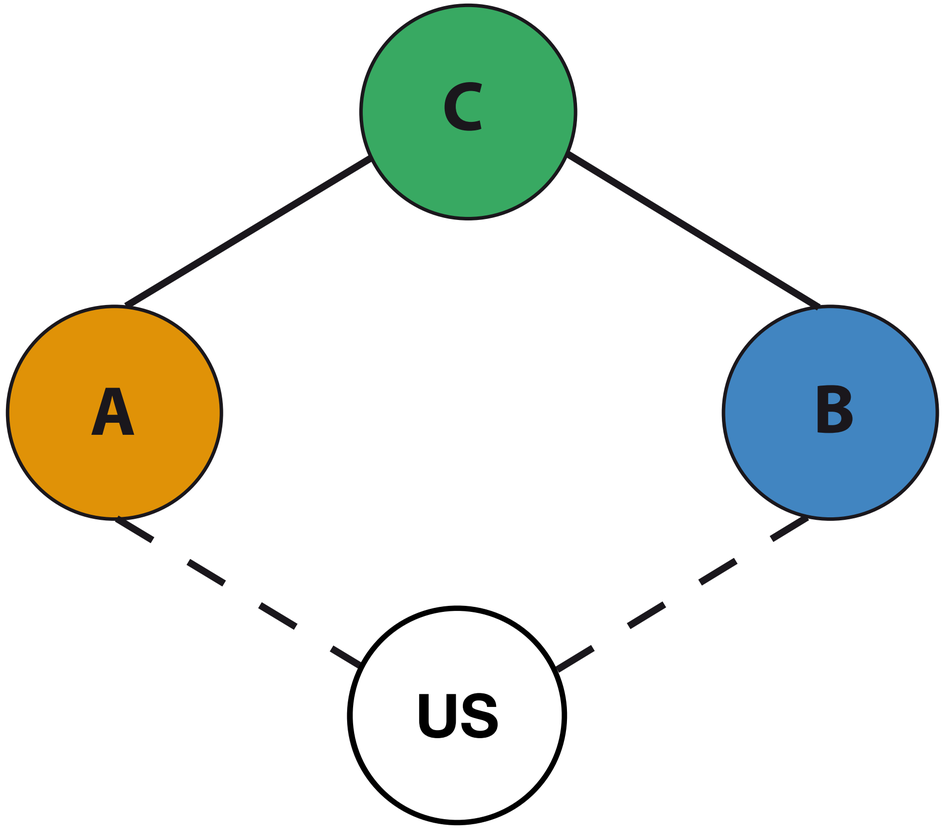
Efficiency

$$\approx O(n)$$

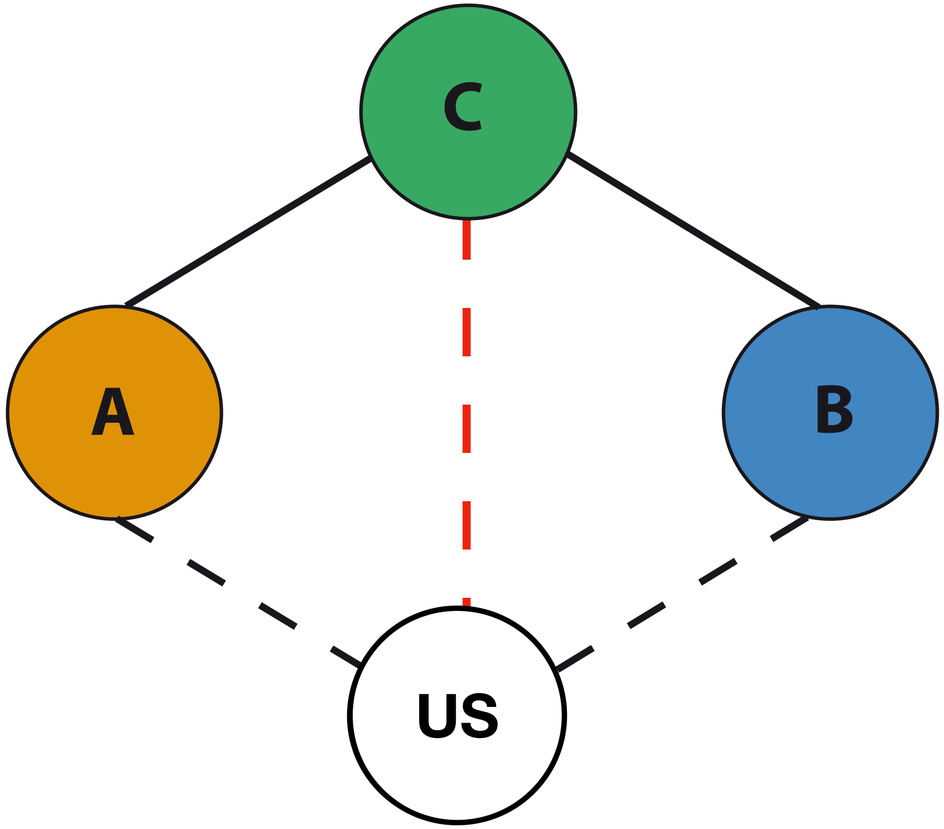
$$\approx O(\sqrt{n})$$

$$n = \#nodes$$

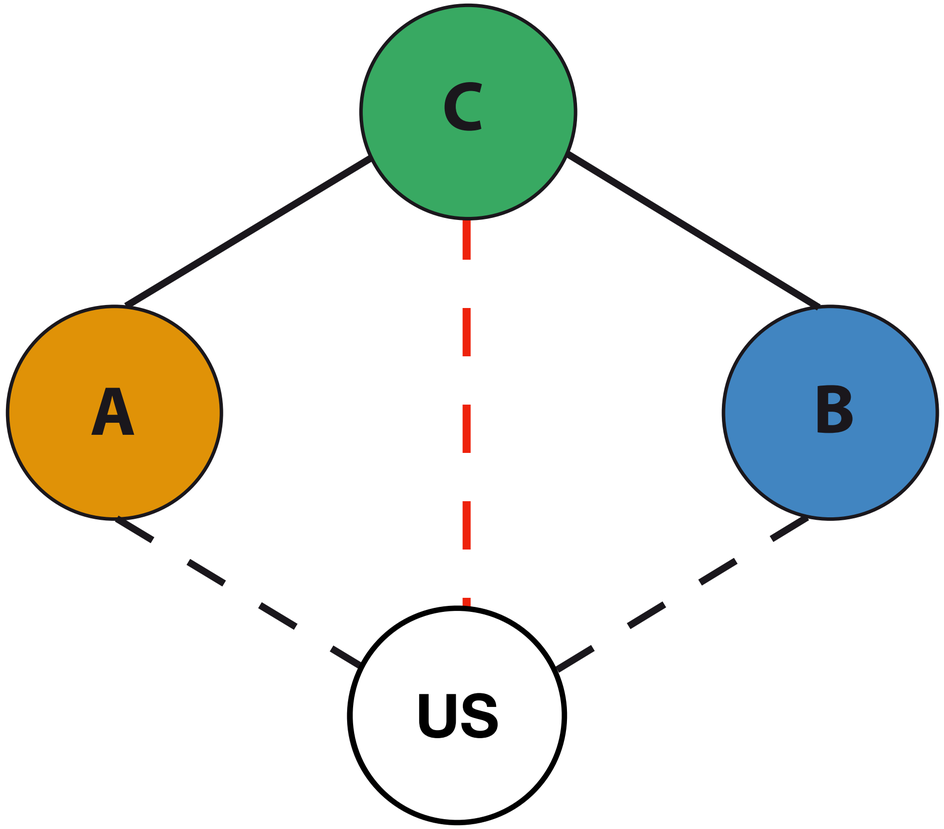
SIMPLIFIED TXPROBE



SIMPLIFIED TXPROBE



SIMPLIFIED TXPROBE



A's Mempool

∅

C's Mempool

∅

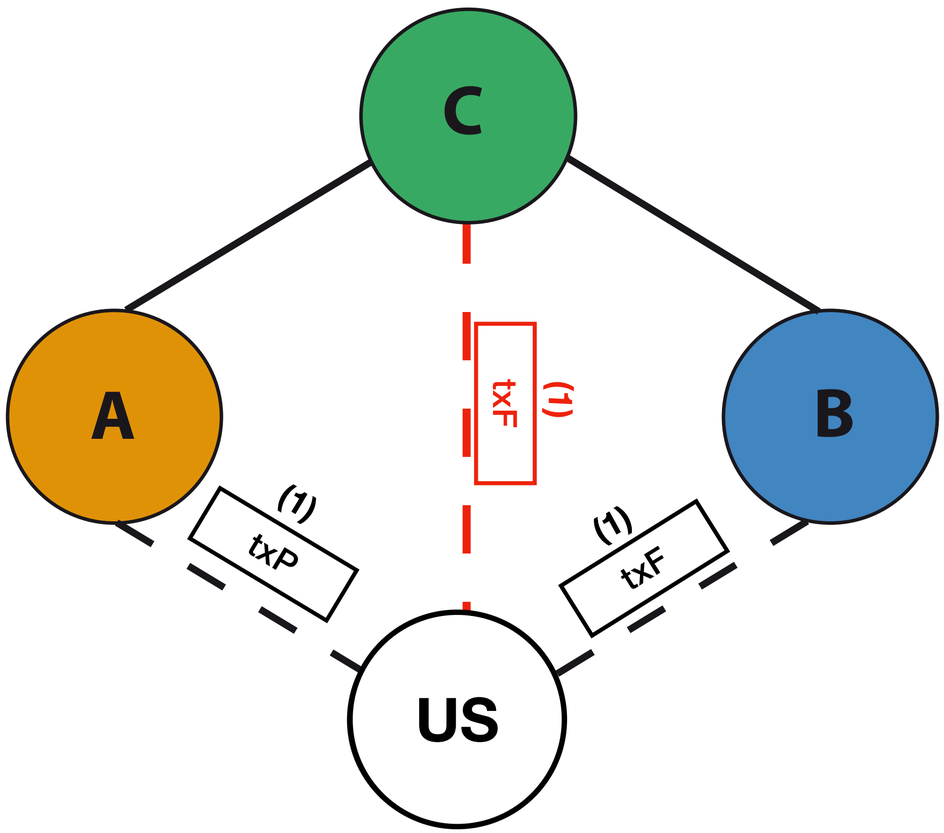
B's Mempool

∅

C's MapOrphanTransactions

∅

SIMPLIFIED TXPROBE



A's Mempool

∅

C's Mempool

∅

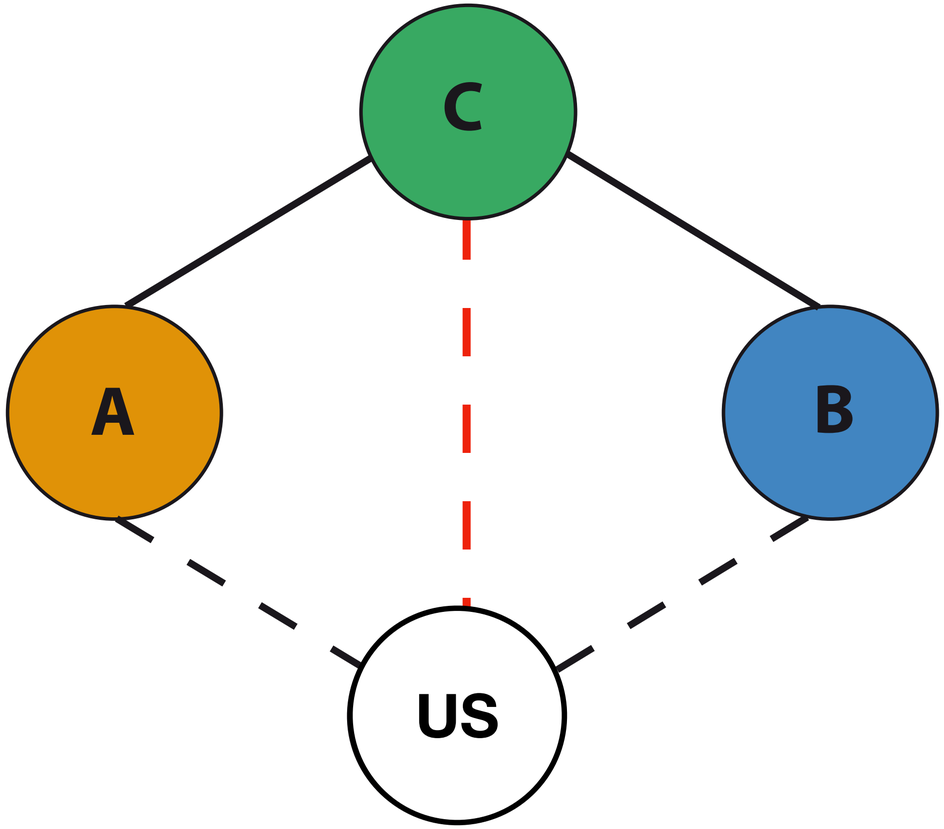
B's Mempool

∅

C's MapOrphanTransactions

∅

SIMPLIFIED TXPROBE



A's Mempool

∅

C's Mempool

∅

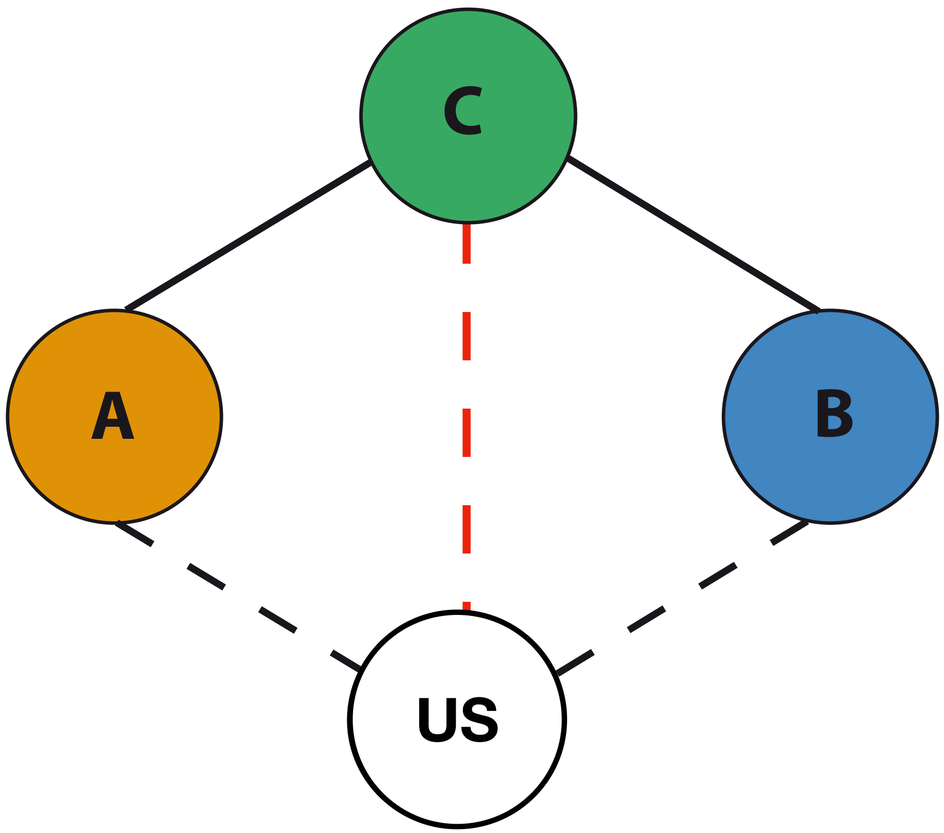
B's Mempool

∅

C's MapOrphanTransactions

∅

SIMPLIFIED TXPROBE



A's Mempool

txP	(1)

C's Mempool

txF	(1)

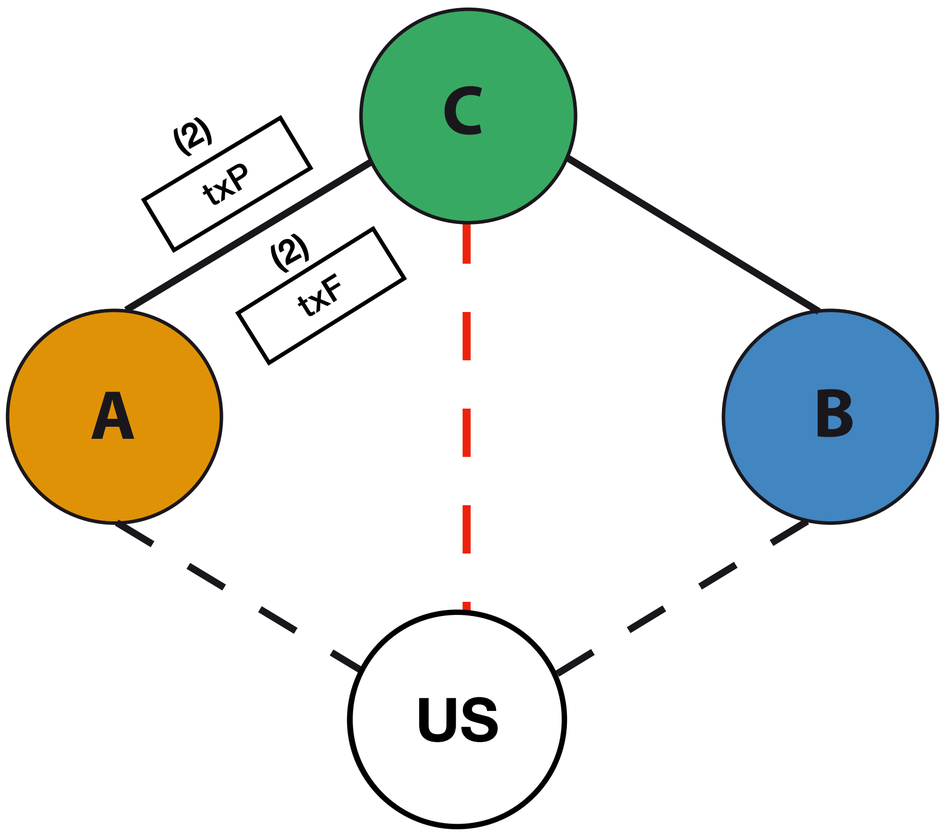
B's Mempool

txF	(1)

C's MapOrphanTransactions

∅

SIMPLIFIED TXPROBE



A's Mempool

txP (1)

C's Mempool

txF (1)

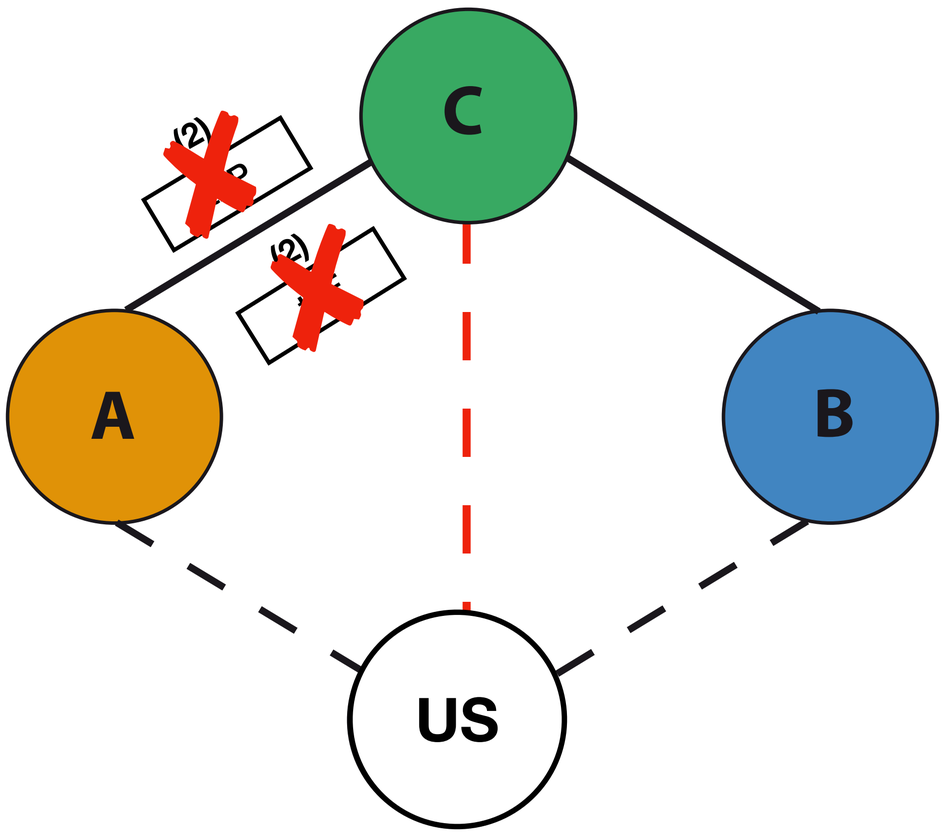
B's Mempool

txF (1)

C's MapOrphanTransactions

∅

SIMPLIFIED TXPROBE



A's Mempool

txP (1)

C's Mempool

txF (1)

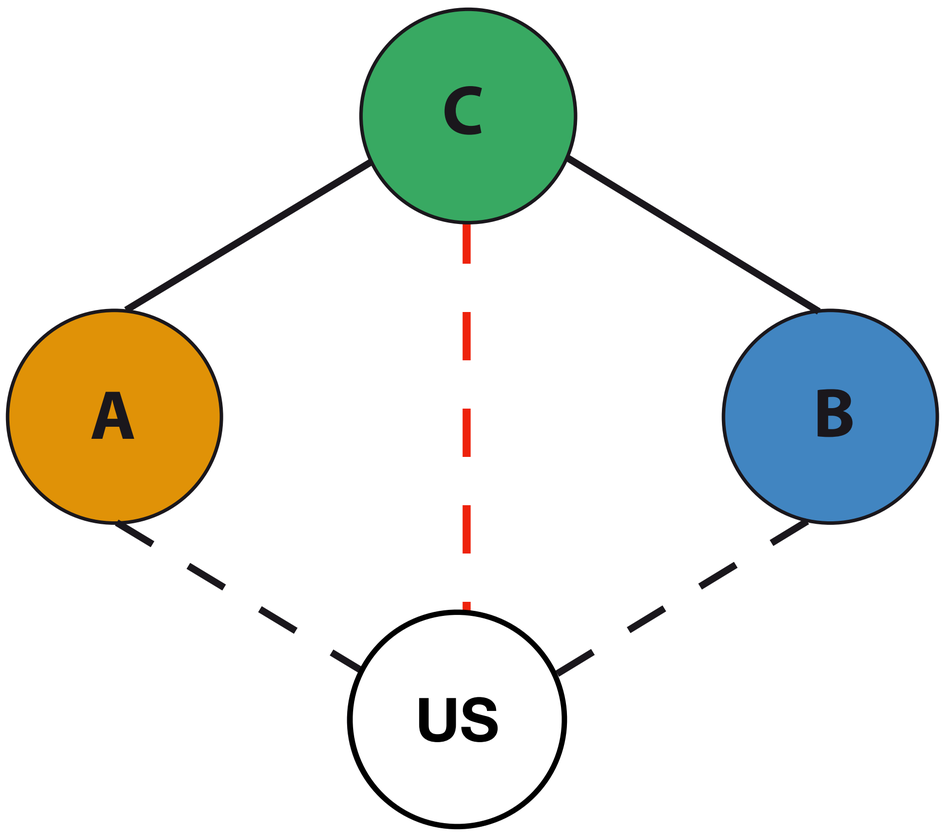
B's Mempool

txF (1)

C's MapOrphanTransactions

∅

SIMPLIFIED TXPROBE



A's Mempool

txP	(1)

C's Mempool

txF	(1)

B's Mempool

txF	(1)

C's MapOrphanTransactions

∅

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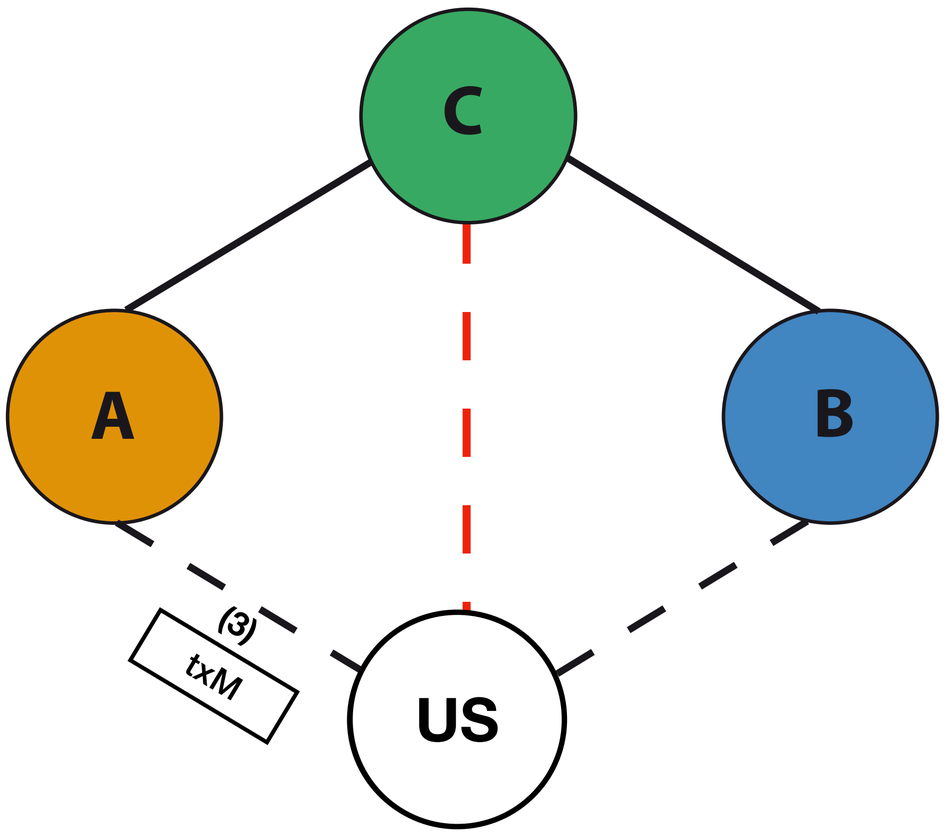


A's Mempool

txP (1)

C's Mempool

txF (1)

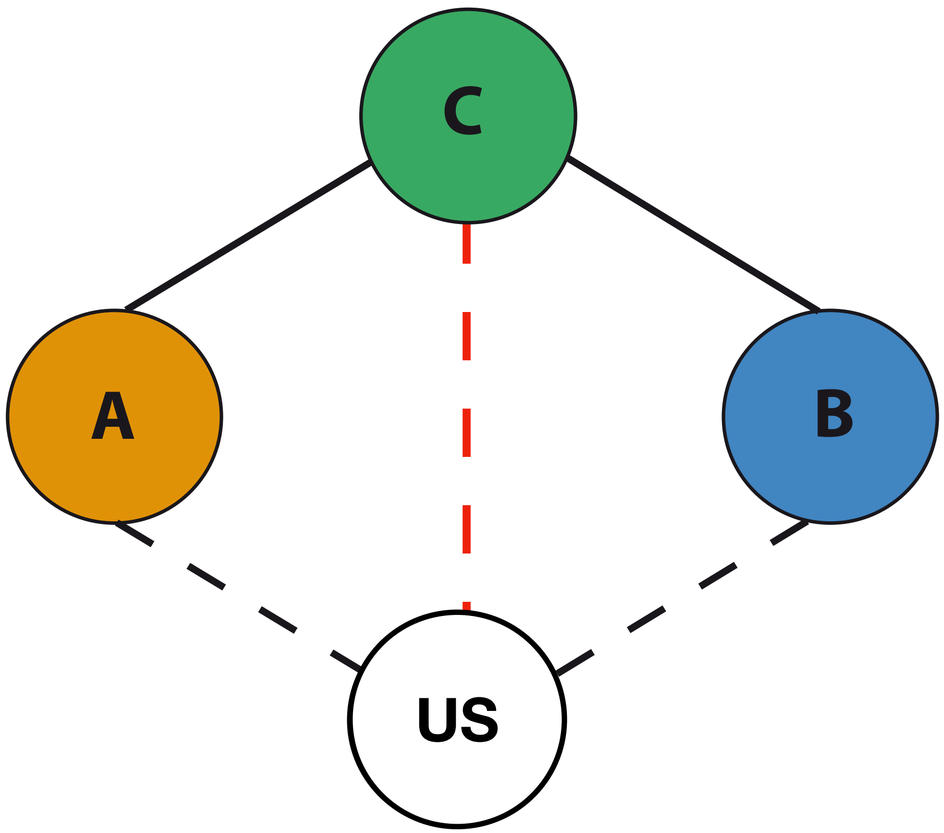
B's Mempool

txF (1)

C's MapOrphanTransactions

∅

SIMPLIFIED TXPROBE



A's Mempool

txP	(1)

C's Mempool

txF	(1)

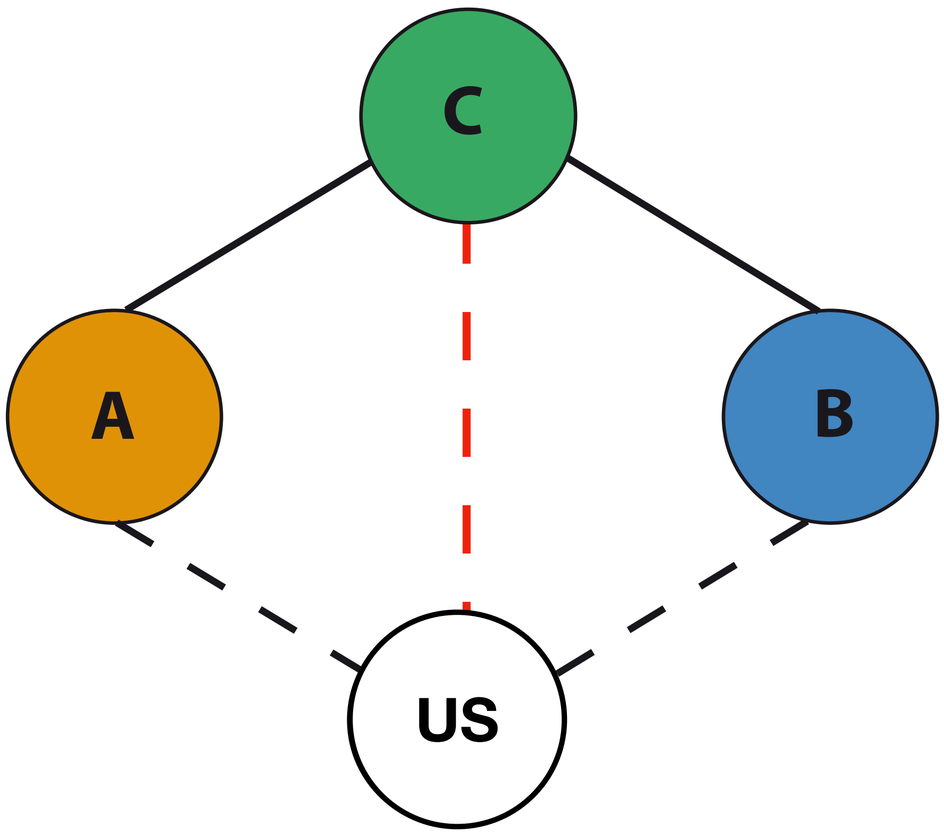
B's Mempool

txF	(1)

C's MapOrphanTransactions

∅

SIMPLIFIED TXPROBE



A's Mempool

txP (1)

txM (3)

C's Mempool

txF (1)

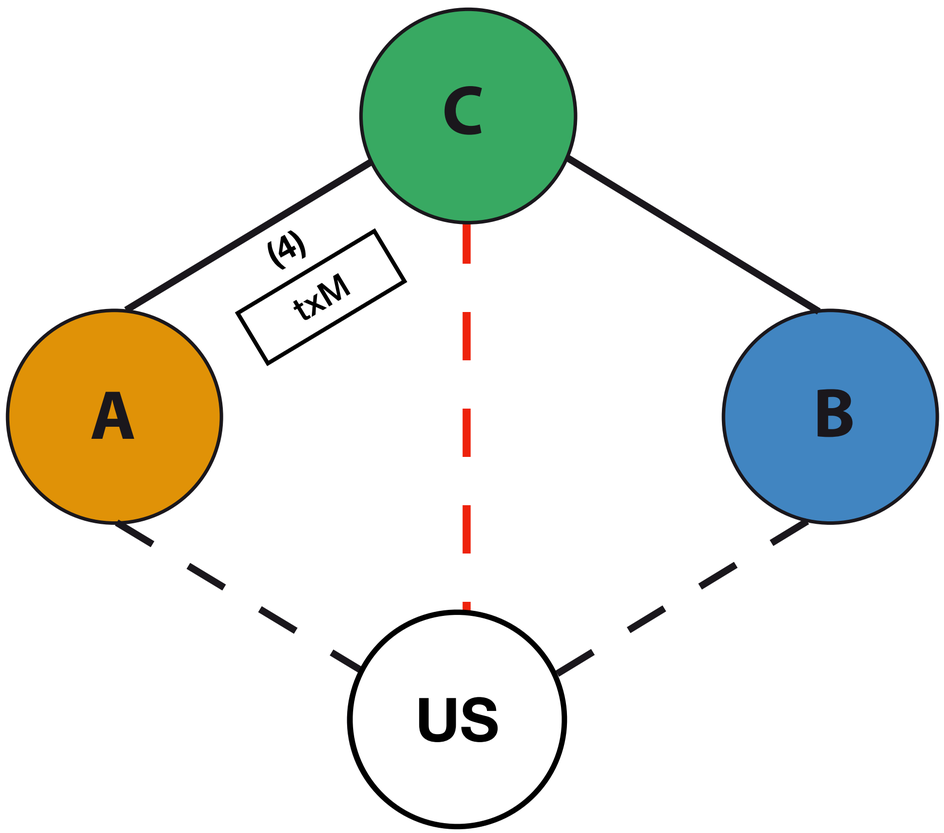
B's Mempool

txF (1)

C's MapOrphanTransactions

∅

SIMPLIFIED TXPROBE



A's Mempool

txP (1)

txM (3)

C's Mempool

txF (1)

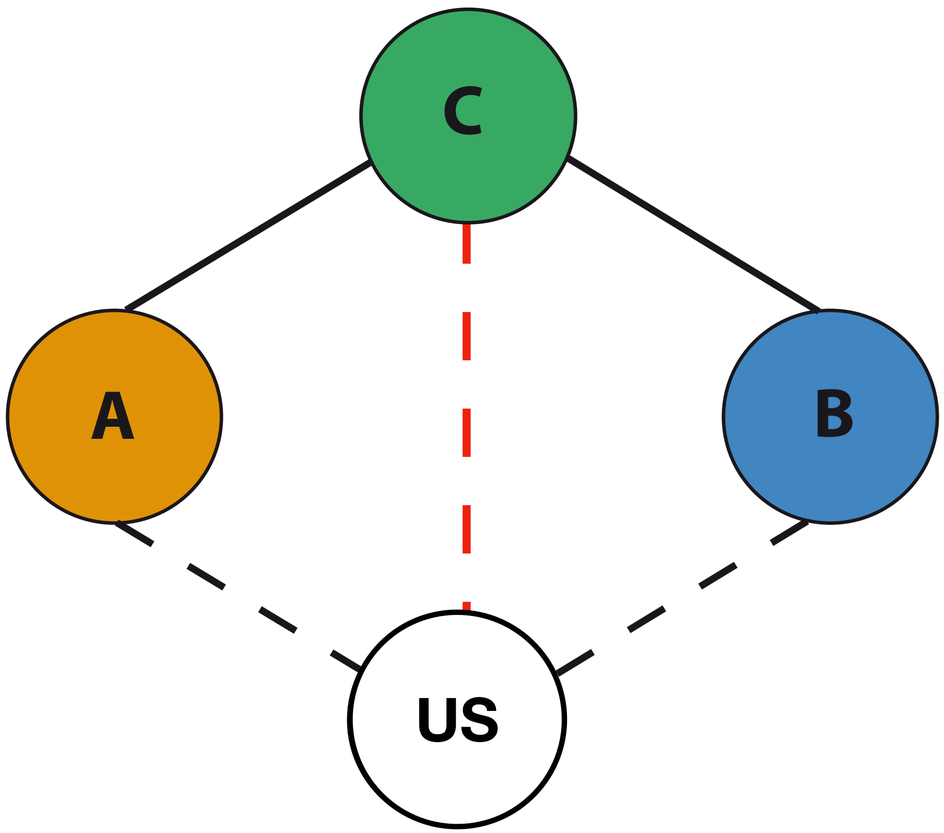
B's Mempool

txF (1)

C's MapOrphanTransactions

∅

SIMPLIFIED TXPROBE



A's Mempool

txP (1)

txM (3)

C's Mempool

txF (1)

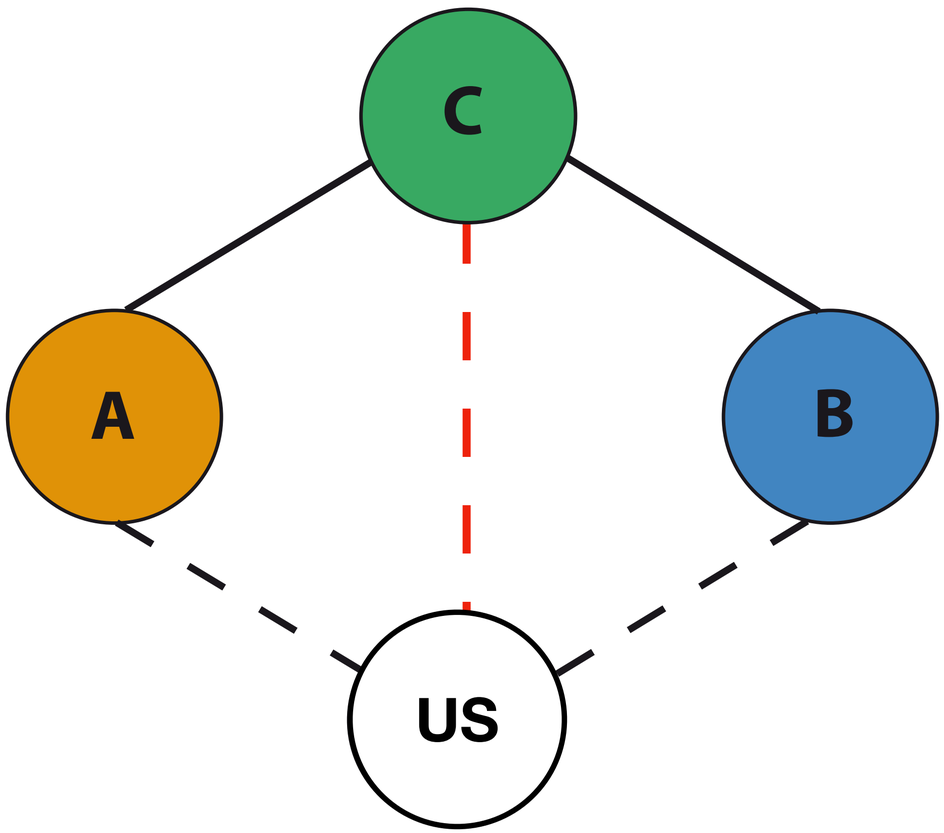
B's Mempool

txF (1)

C's MapOrphanTransactions

∅

SIMPLIFIED TXPROBE



A's Mempool

txP (1)

txM (3)

C's Mempool

txF (1)

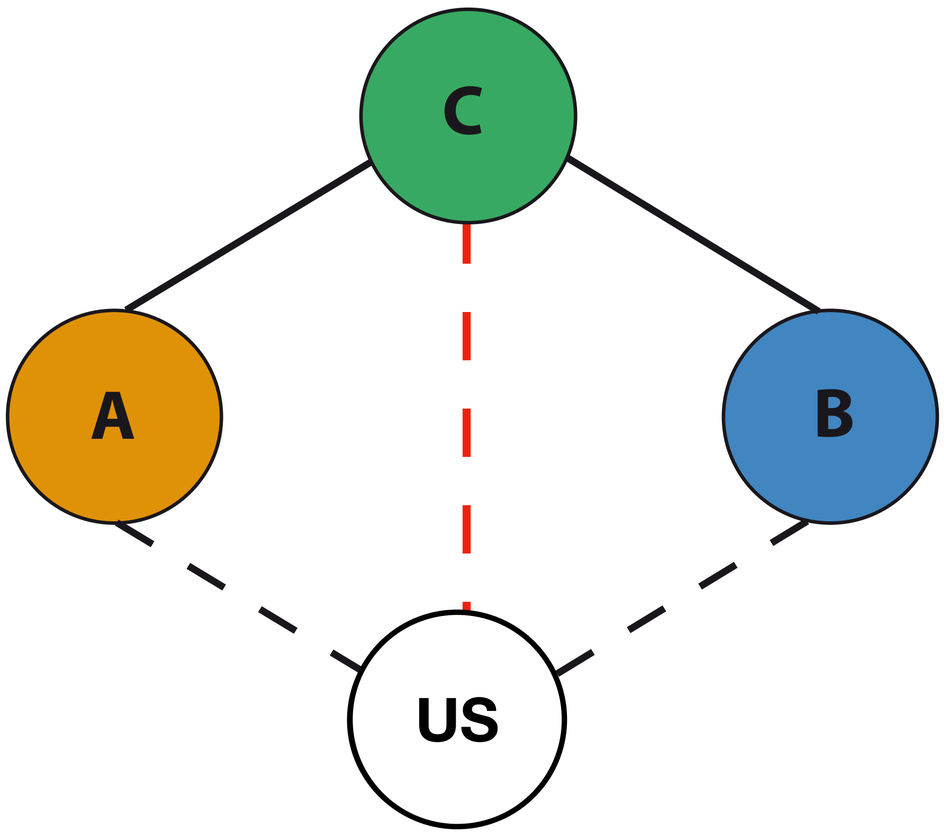
B's Mempool

txF (1)

C's MapOrphanTransactions

txM (4)

SIMPLIFIED TXPROBE



A's Mempool

txP	(1)
txM	(3)

C's Mempool

txF	(1)

B's Mempool

txF	(1)

C's MapOrphanTransactions

txM	(4)

TXPROBE - PROTOCOL RECAP

- **Choose** a target node
- **Create** Parent, Marker and Flood transactions
- **Send** Parent to target and flood to the rest
- **Send** Marker to target
- **Let** Marker propagate
- **Request** marker back

TXPROBE - PROTOCOL RECAP

- **Choose** a target node
- **Create** Parent, Marker and Flood transactions
- **Send** Parent to target and flood to the rest
- **Send** Marker to target
- **Let** Marker propagate
- **Request** marker back

For every node in the network

TXPROBE - COSTS ESTIMATION

For a network like **Bitcoin mainnet:**

nodes ≈ 10000

time ≈ 8.25 hours

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

TXPROBE - DATA VALIDATION (TESTNET)

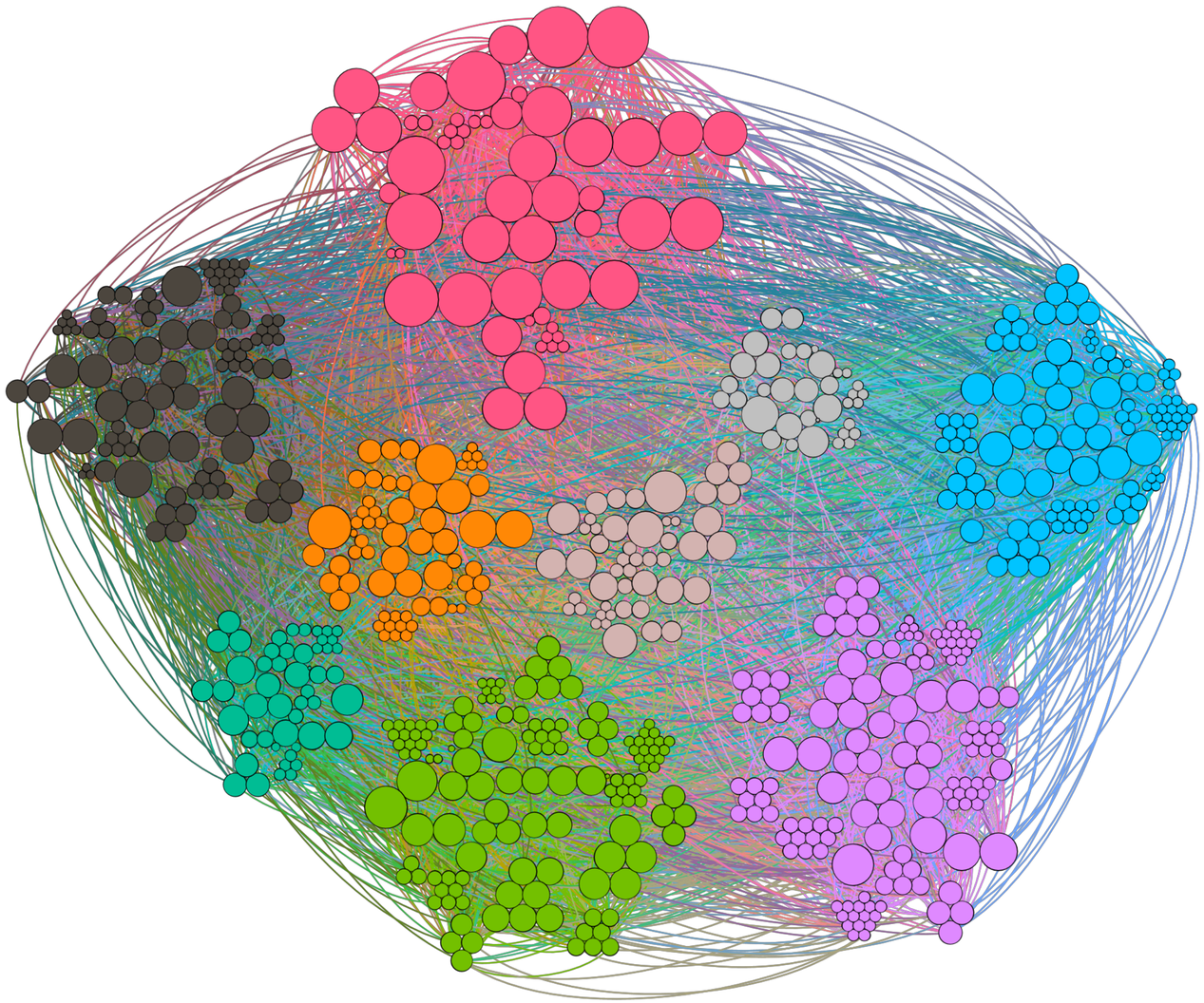
We run 5 Bitcoin Core nodes as **ground truth**

We define our **precision / recall** by checking how well can we infer the ground truth nodes connections

Over 40 trials and with 95% confidence:

- **Precision** = 100%
- **Recall** = 93.86% - 95.45%

TXPROBE - TESTNET TOPOLOGY



precision = 100%

recall = 97.40%

size ⟶ degree

color ⟶ Louvain community unfolding

Higher **community structure** and **modularity** than random graph

CONCLUSIONS

CONCLUSIONS

Select orphan transaction uniformly for eviction #14626

Merged **MarcoFalke** merged 1 commit into `bitcoin:master` from `sipa:201810_uniform_orphan_eviction` 3 days ago

Conversation 20 | Commits 1 | Checks 0 | Files changed 1

sipa commented on 31 Oct 2018 — Member

The previous code was biased towards evicting transactions whose txid has a larger gap (lexicographically) with the previous txid in the orphan pool.

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The previous code was biased towards evicting transactions whose txid has a larger gap (lexicographically) with the previous txid in the orphan pool.

randomize GETDATA(tx) request order and introduce bias toward outbound #14897

Merged sipa merged 1 commit into `bitcoin:master` from `naumenkogs:master` 10 days ago

Conversation 115 | Commits 1 | Checks 0 | Files changed 6

naumenkogs commented on 8 Dec 2018 • edited by MarcoFalke — Contributor

This code makes executing two particular (and potentially other) attacks harder.

InvBlock

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Is topology hiding a design goal, or is it a **mean to achieve other goals (e.g: Transaction privacy)?**

QUESTIONS

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**