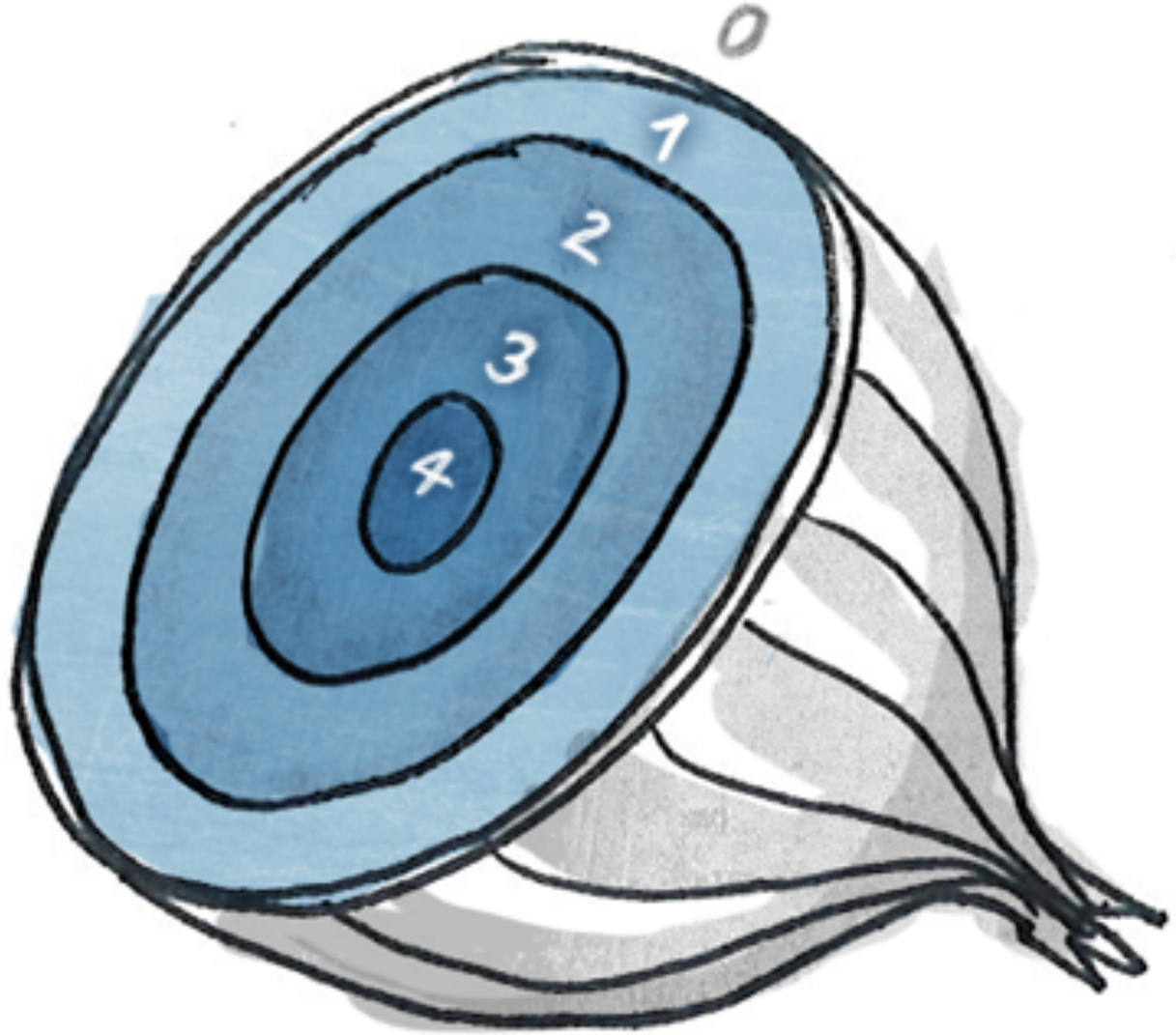
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Application for Broadcast
[**Reliable**, **Uniform**, **Causal**, and **Total-Order**]

Adi Seredinschi
Distributed Programming Laboratory

Question:
What do Distributed Systems have in common with Onions?



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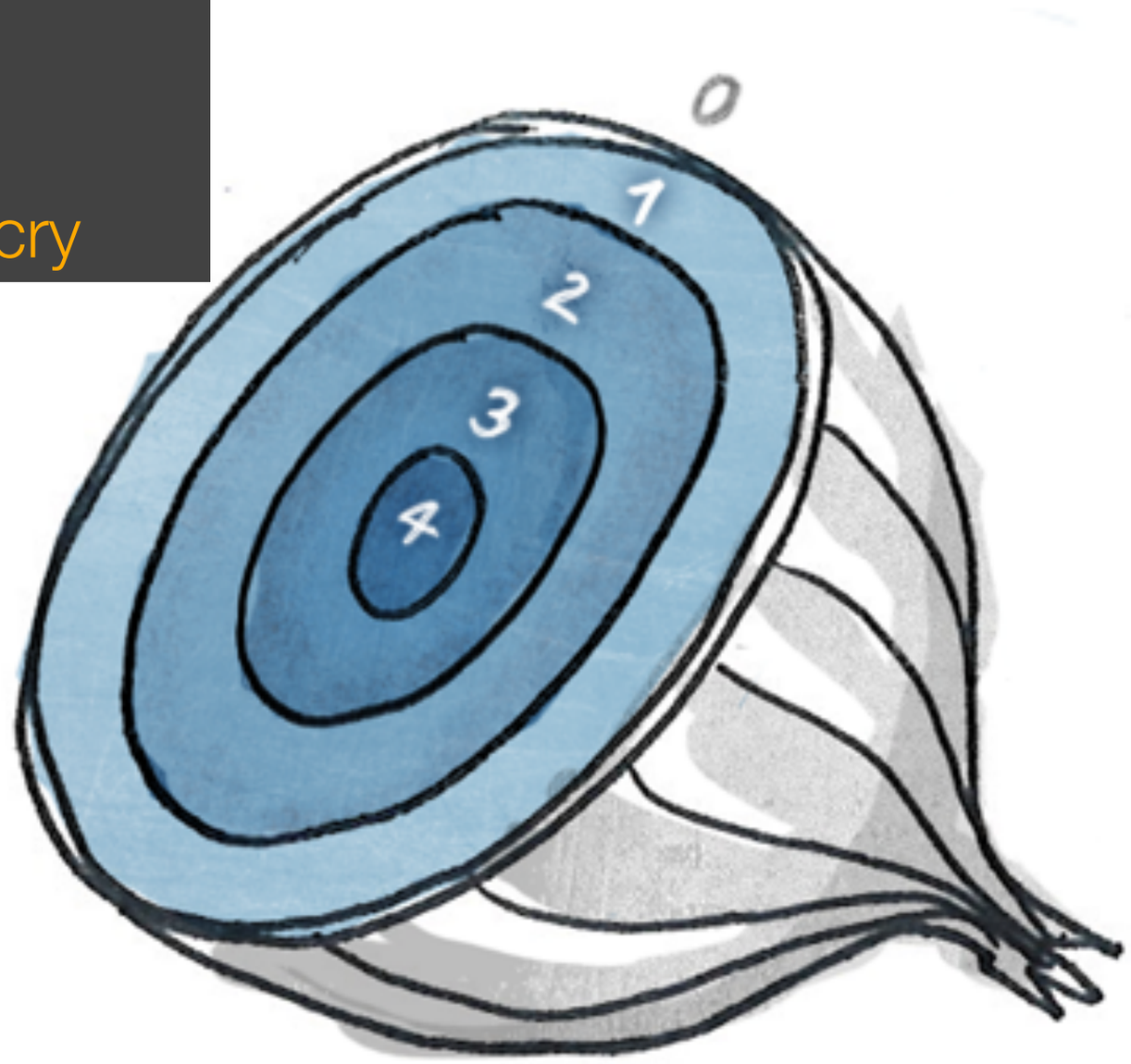
Answer:

1. Layering
2. Abstraction
3. They make you cry



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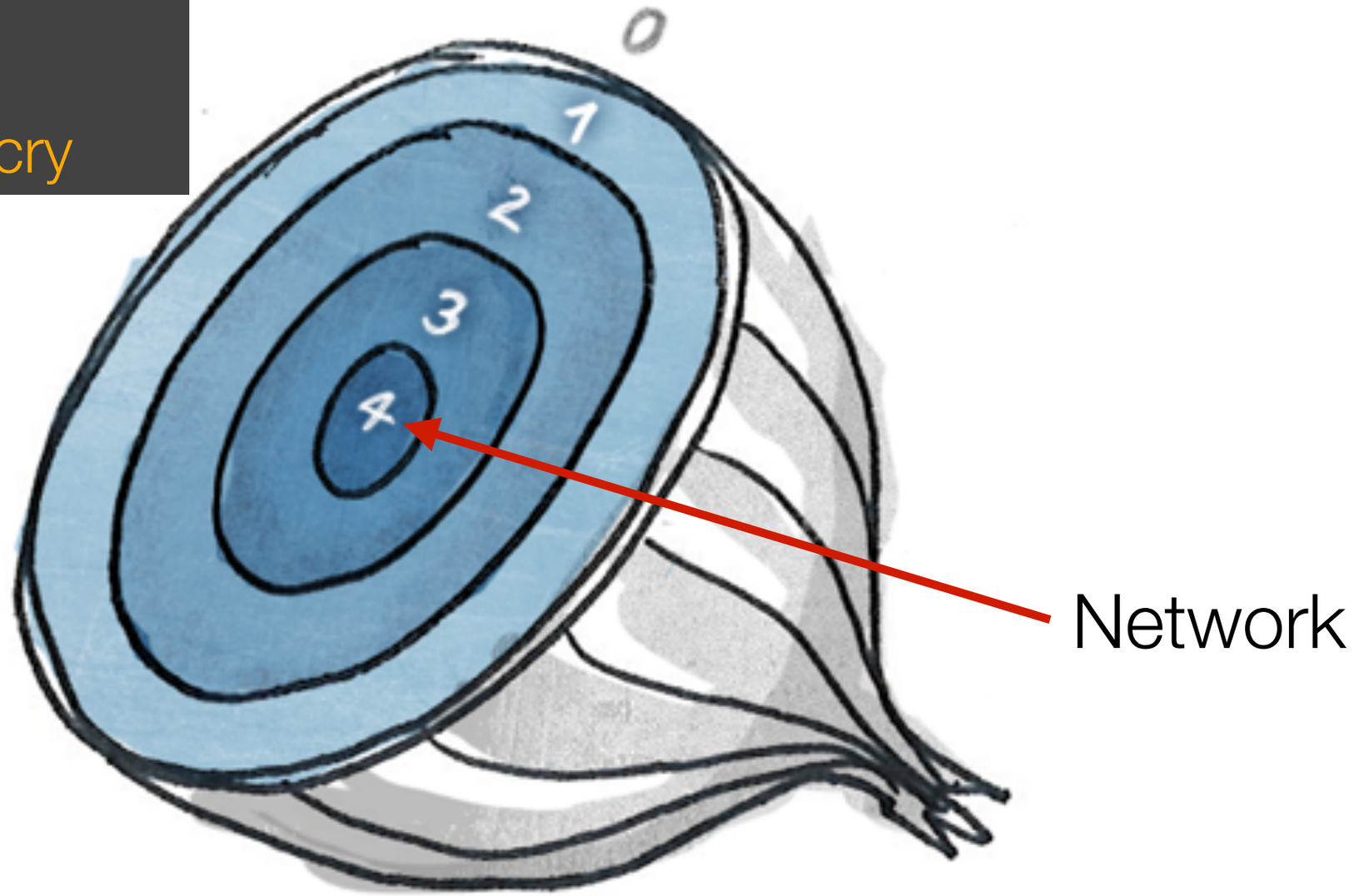

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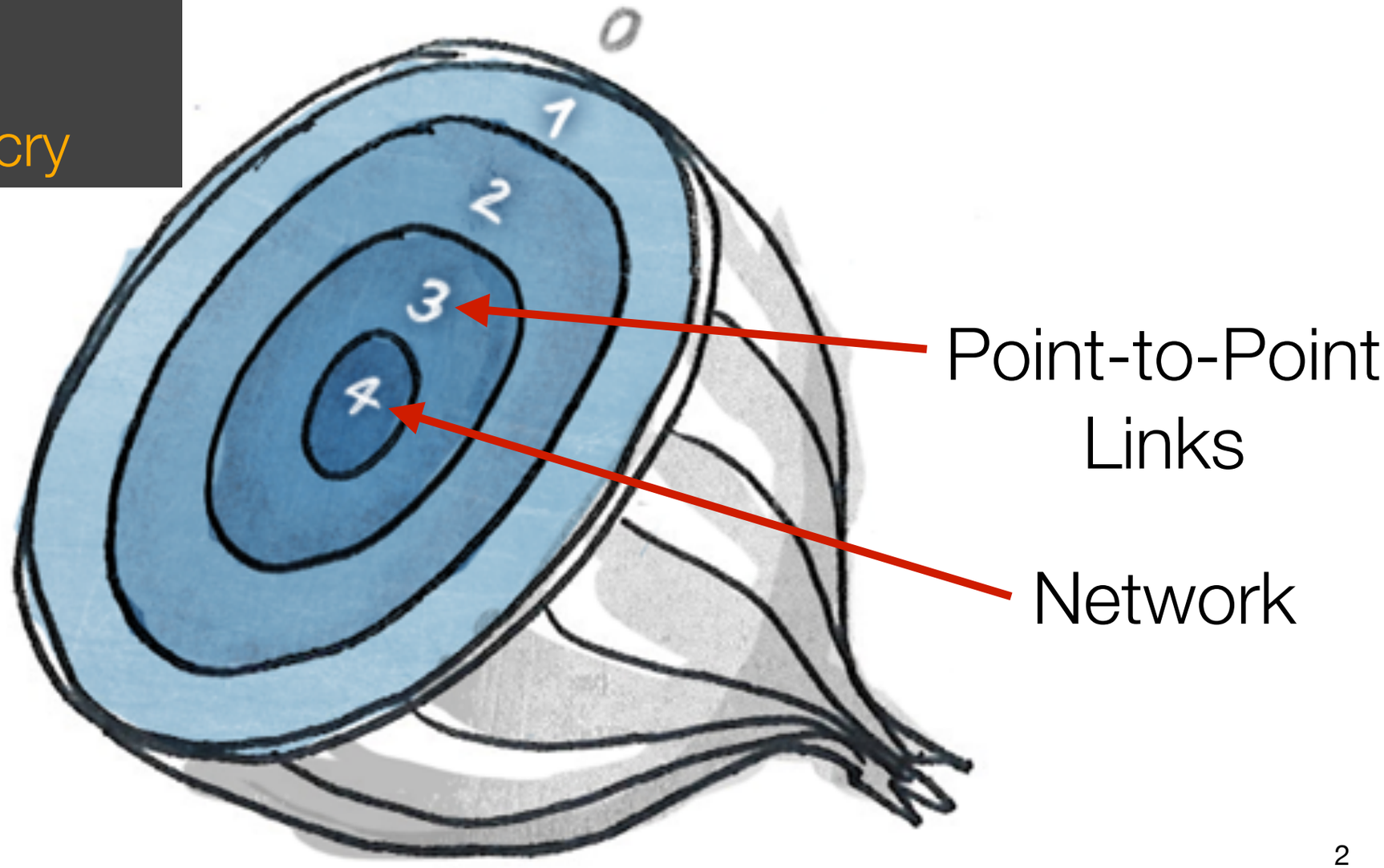

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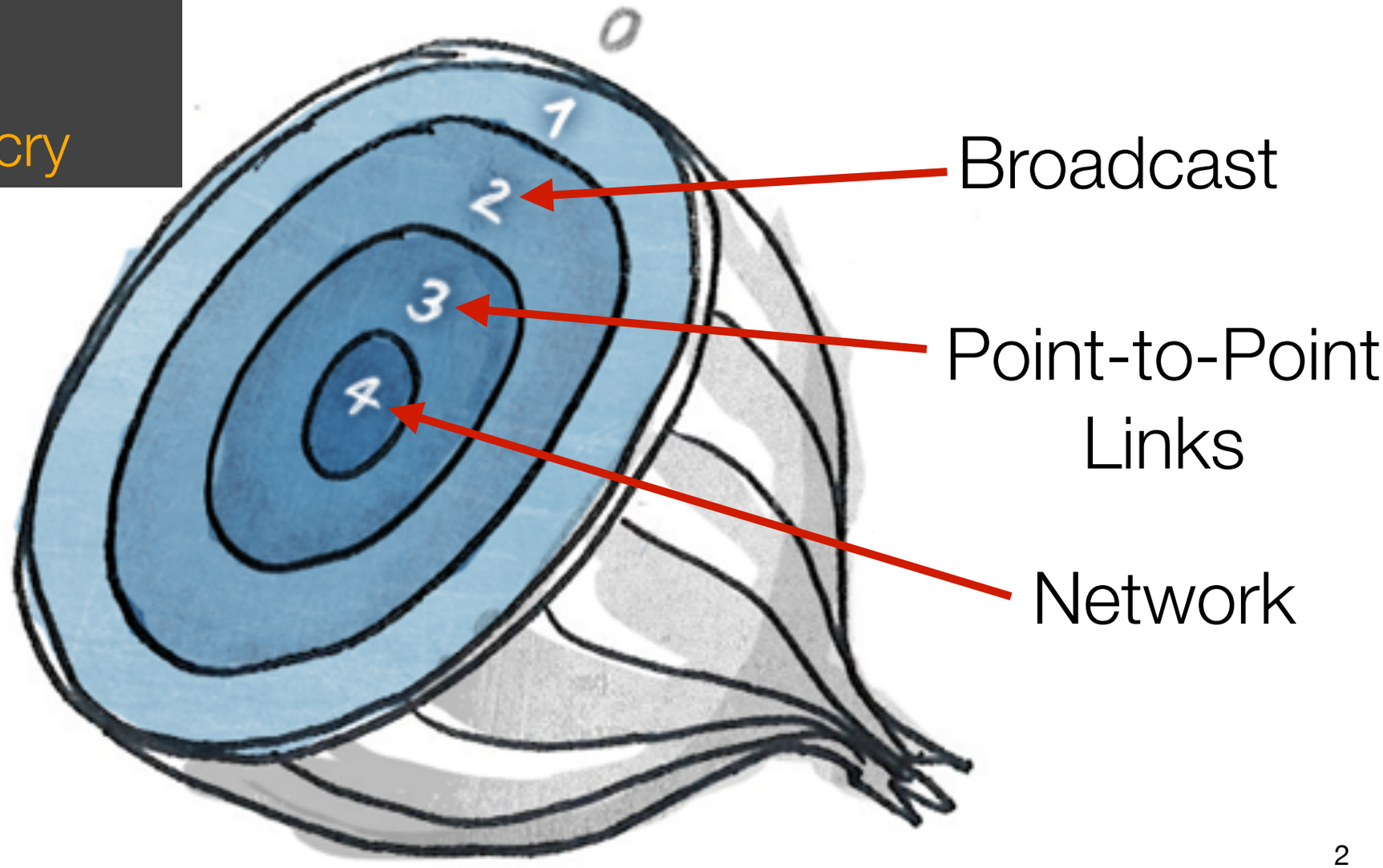

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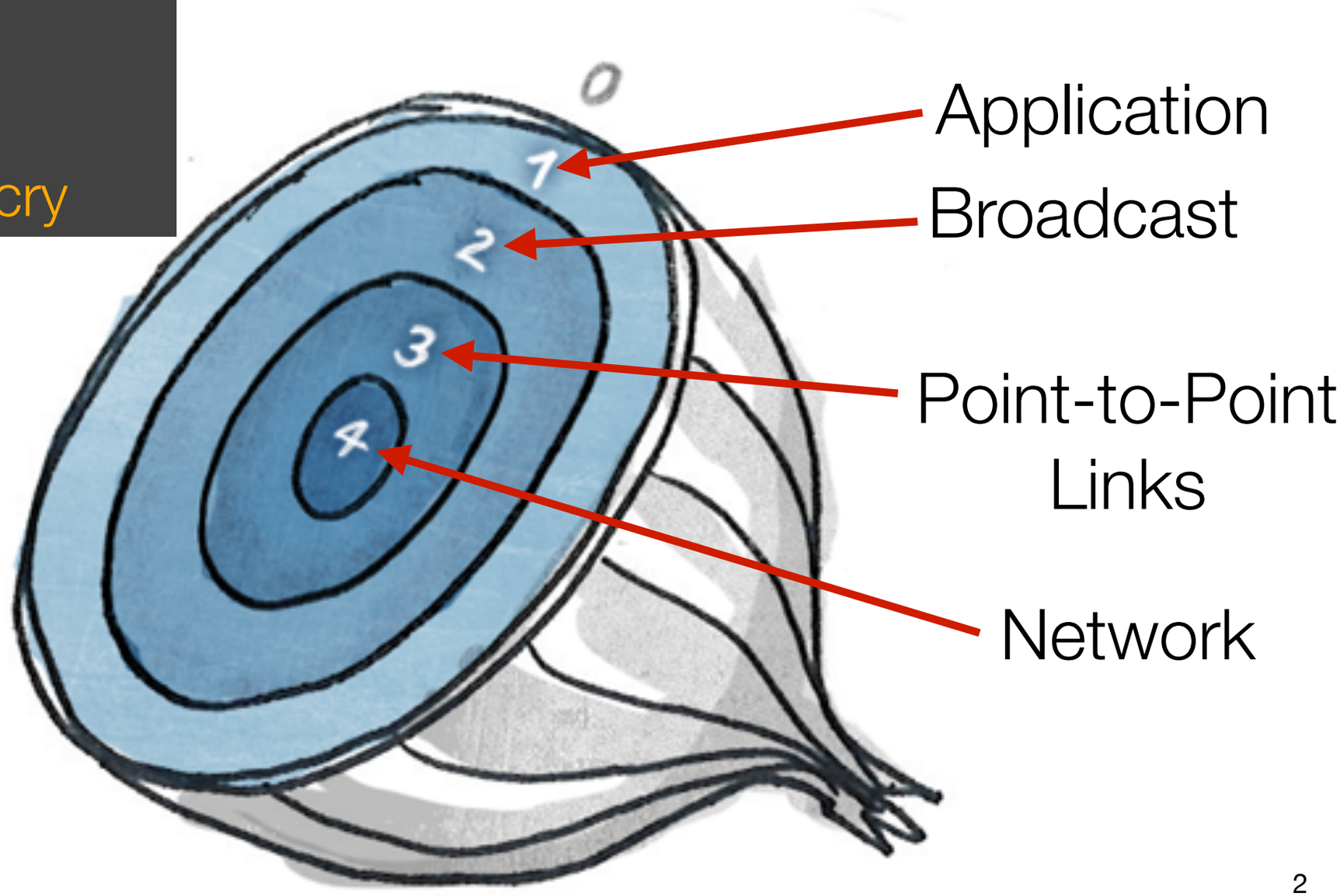

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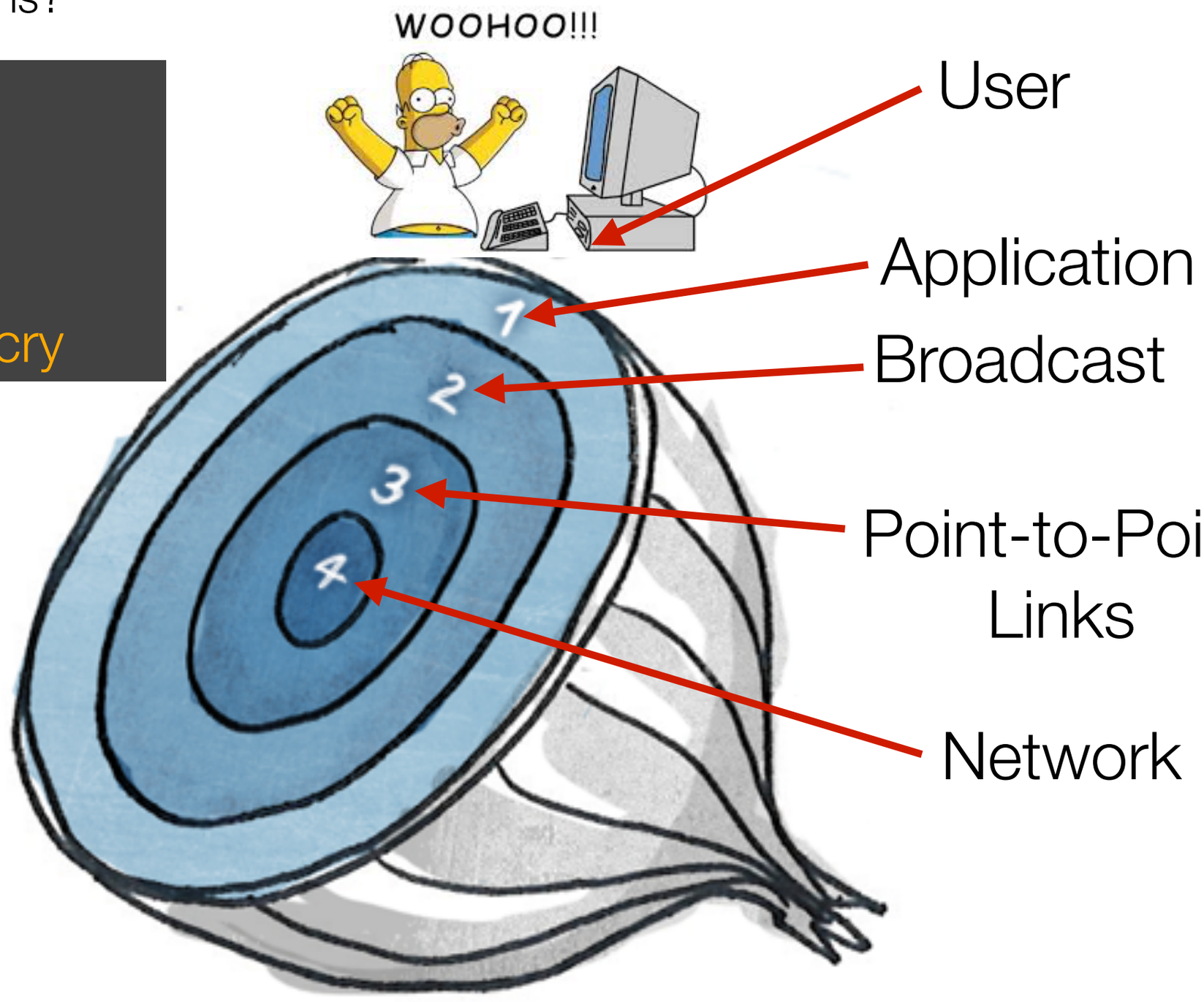

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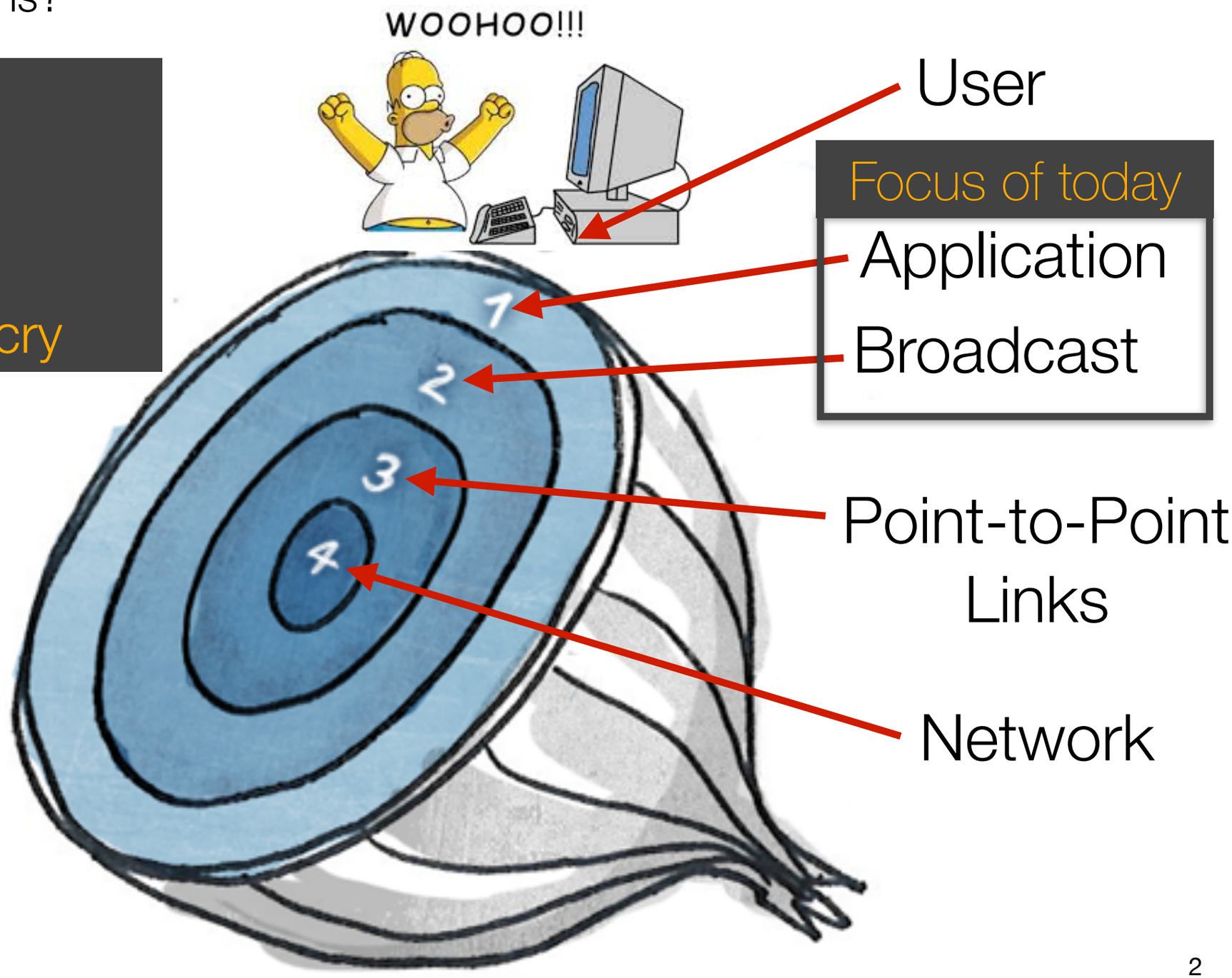

Let’s design a simple application

Broadcast
(we will investigate different properties..)

CAMIPRO-Bitcoin

- The canonical Bitcoin design
  - Uses gossip (best-effort broadcast)
    - Relies heavily on crypto — no time to cover that
- **We will not discuss the canonical design**
  - **Instead, we will design our own version of Bitcoin**
  - **Optimized for CAMIPRO**

CAMIPRO-Bitcoin

Conceptual goals:

1. Replace traditional CAMIPRO
   - Based on CHF
2. Make banks obsolete

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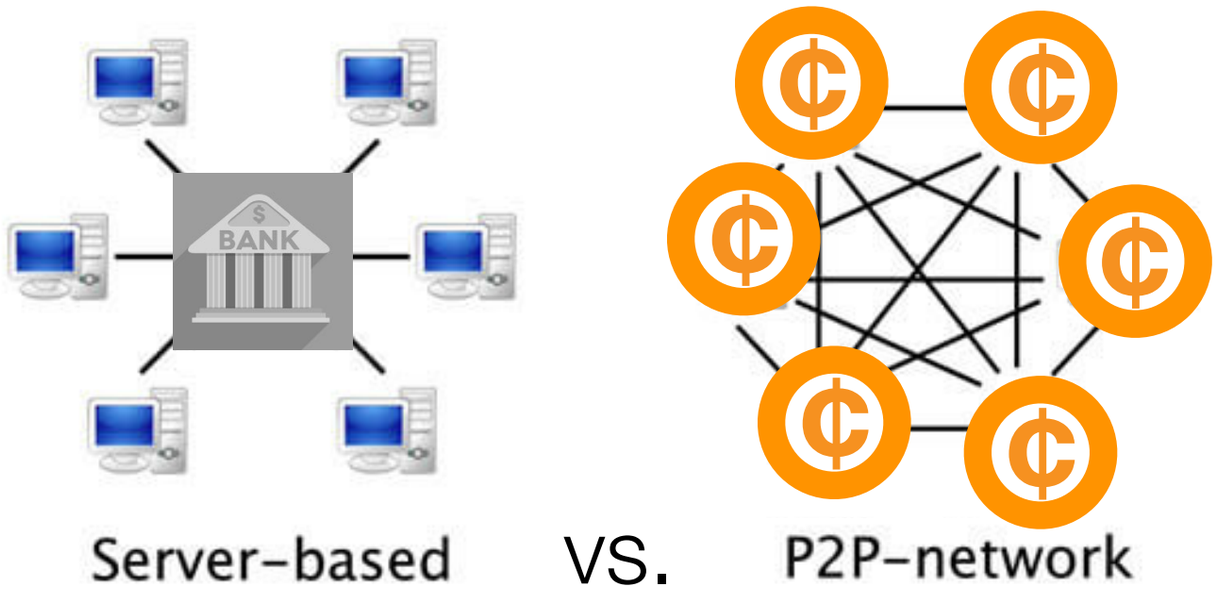
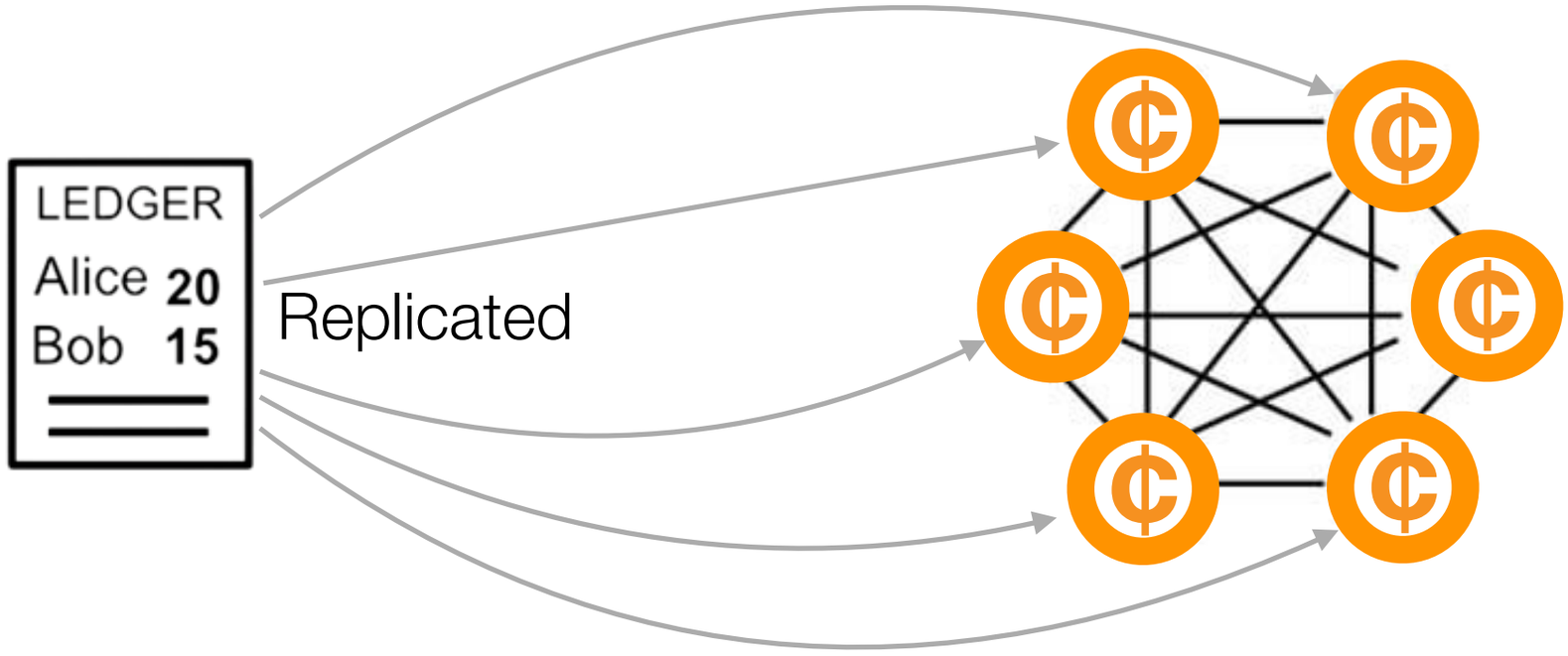
IN PRACTICE



Main concepts

- Ledger



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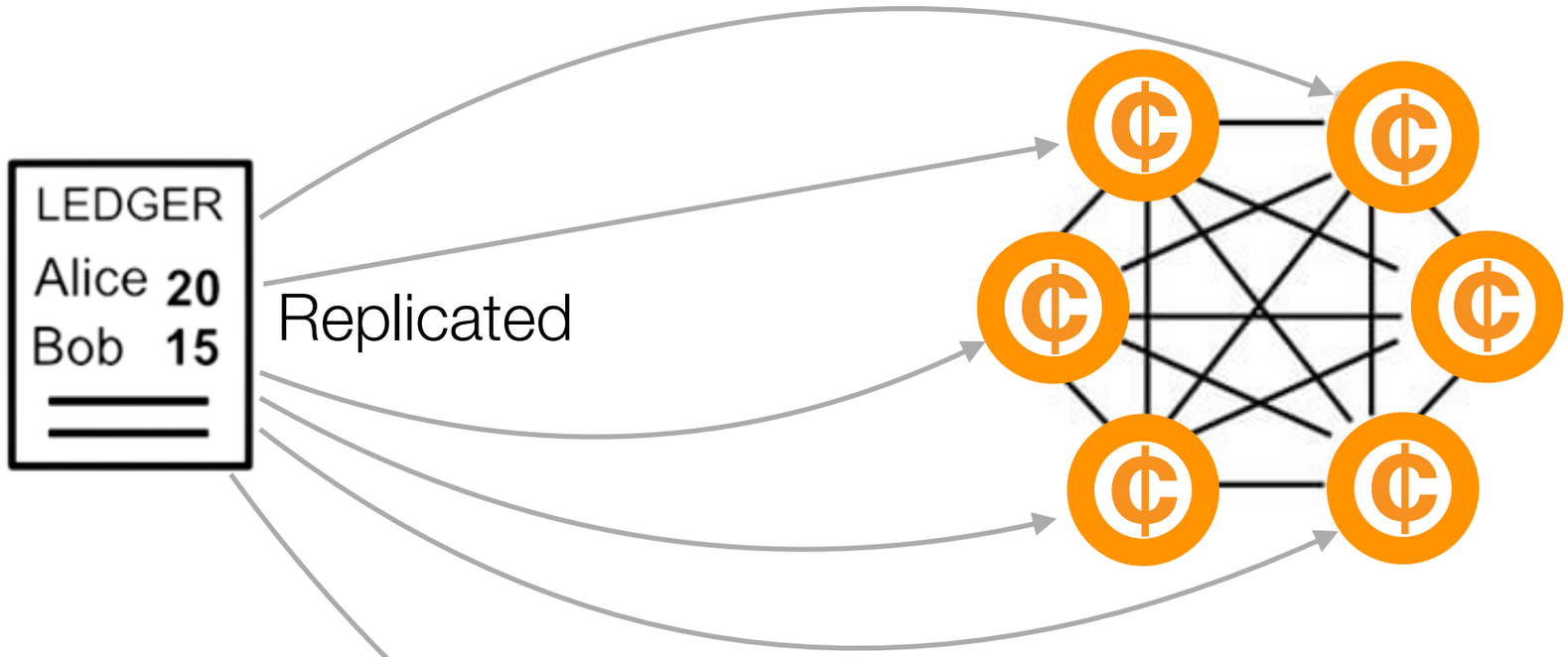
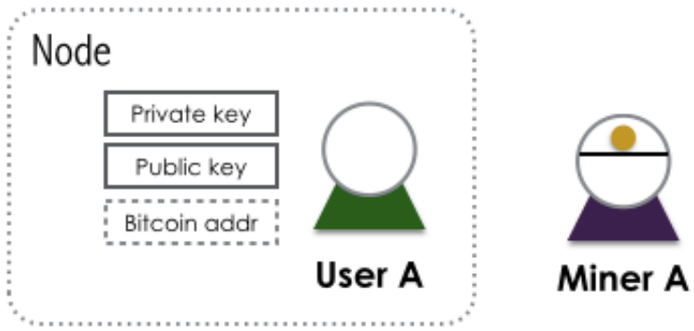
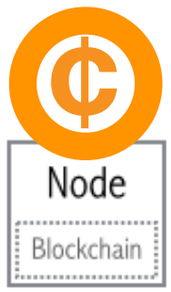


- Node





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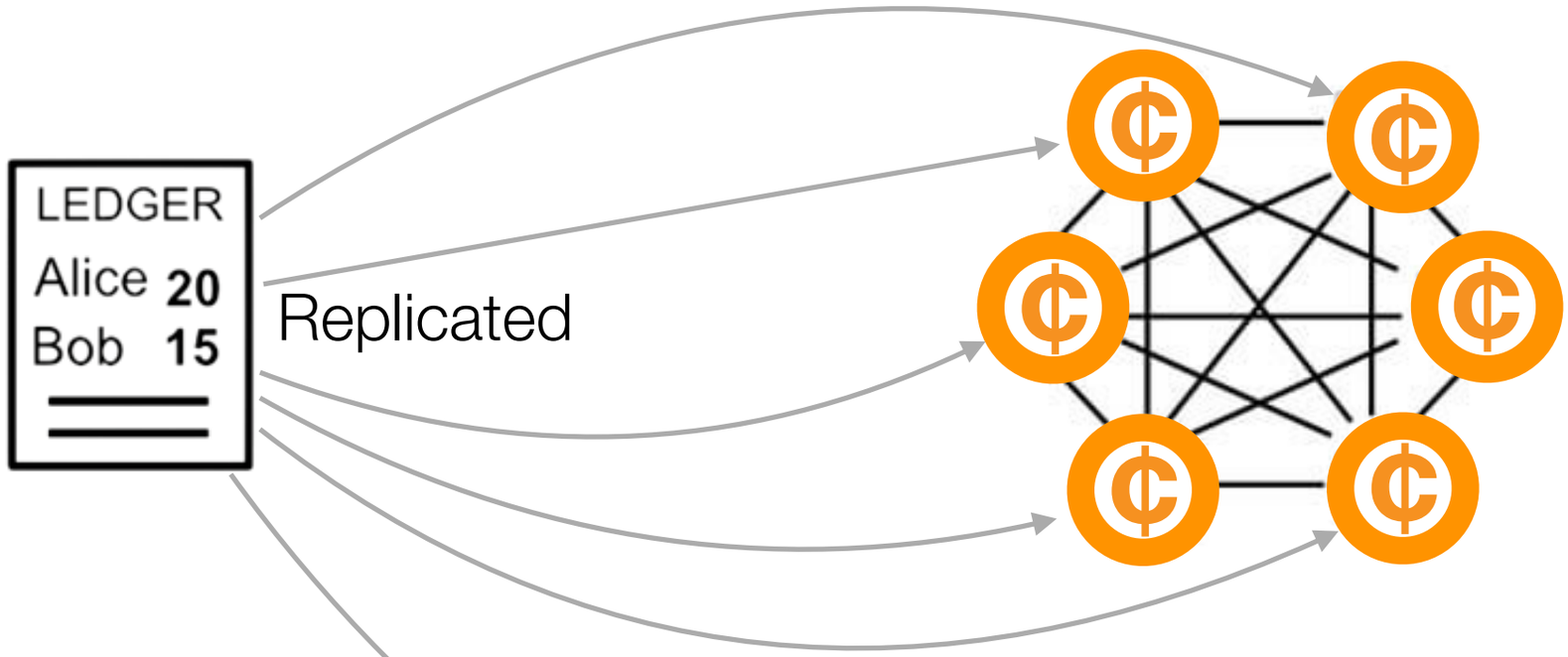

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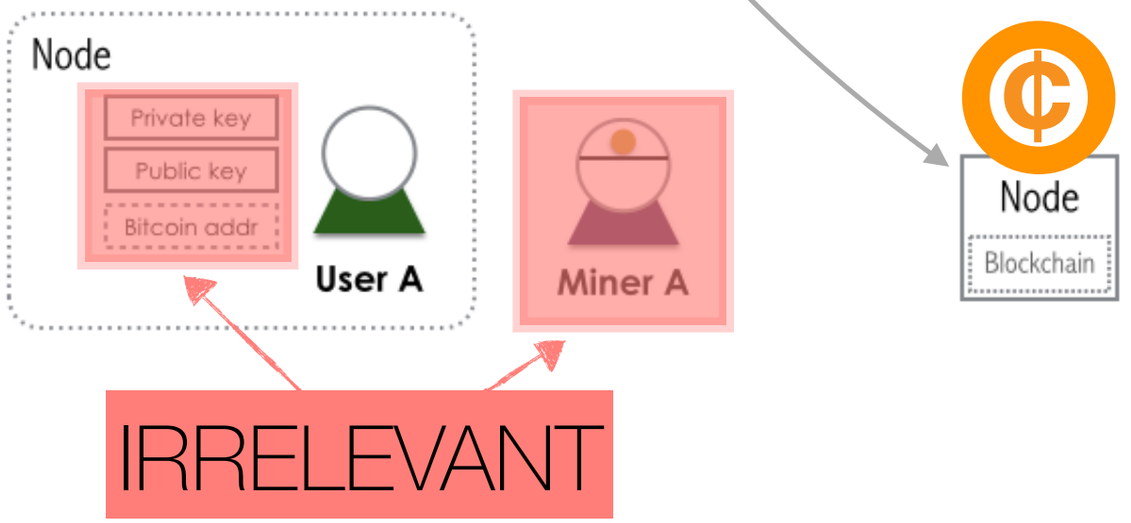

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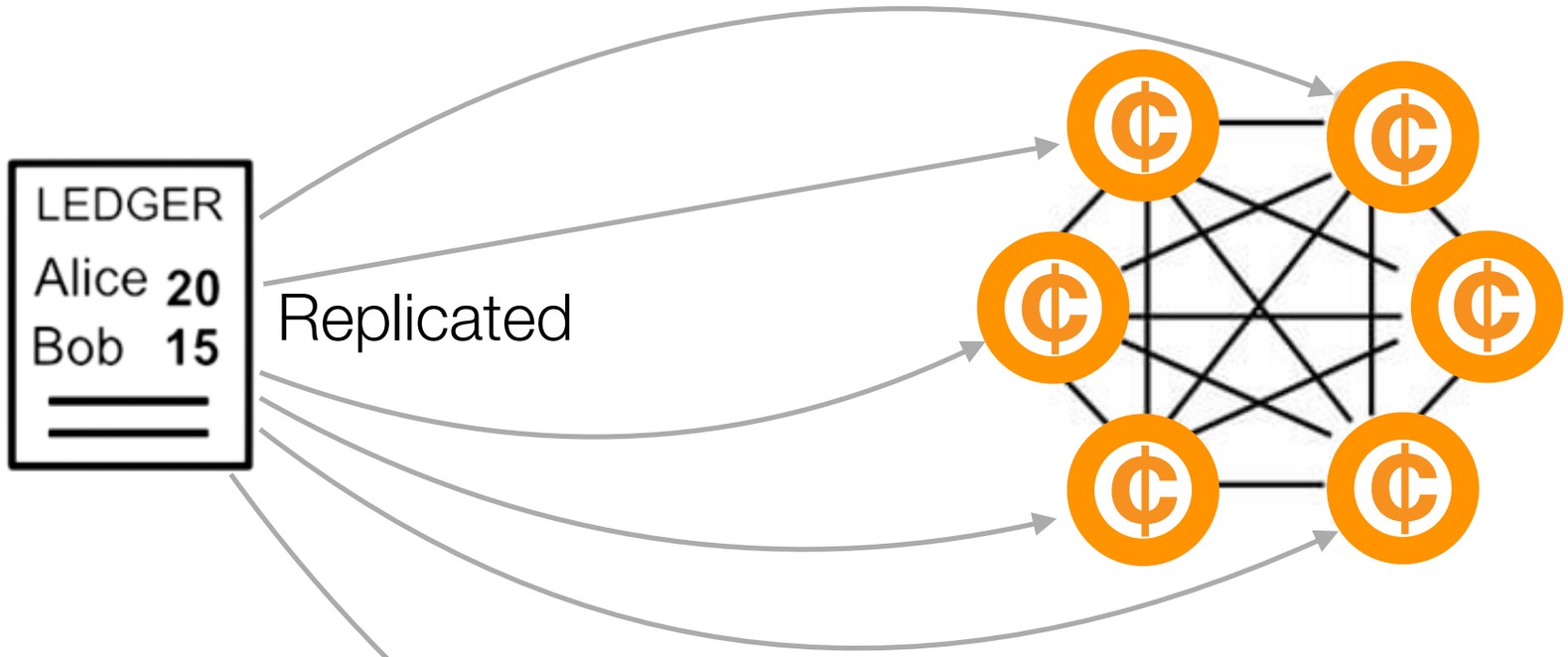

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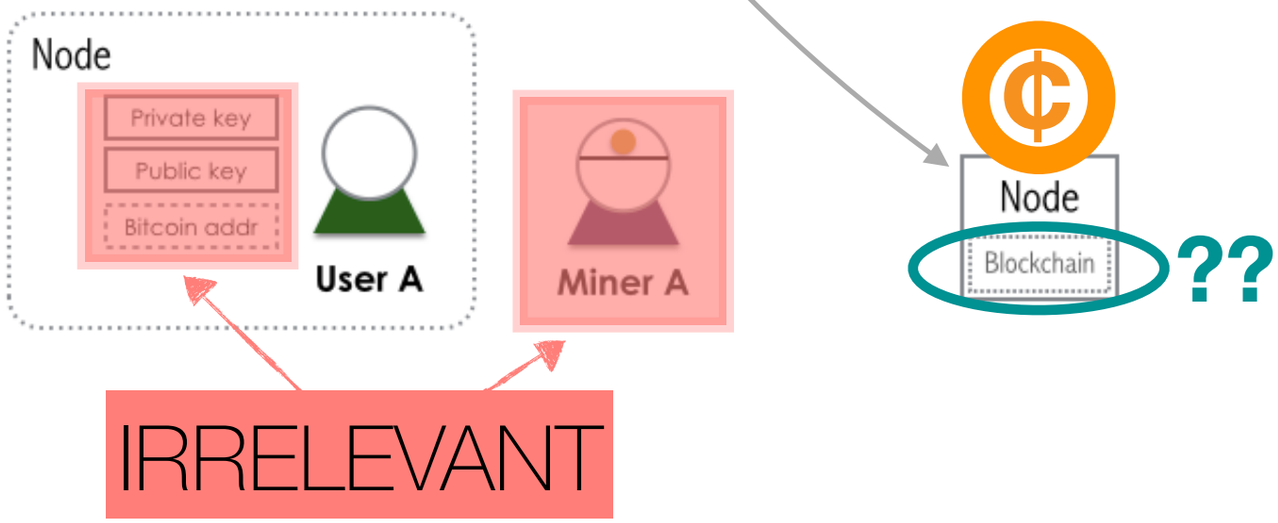

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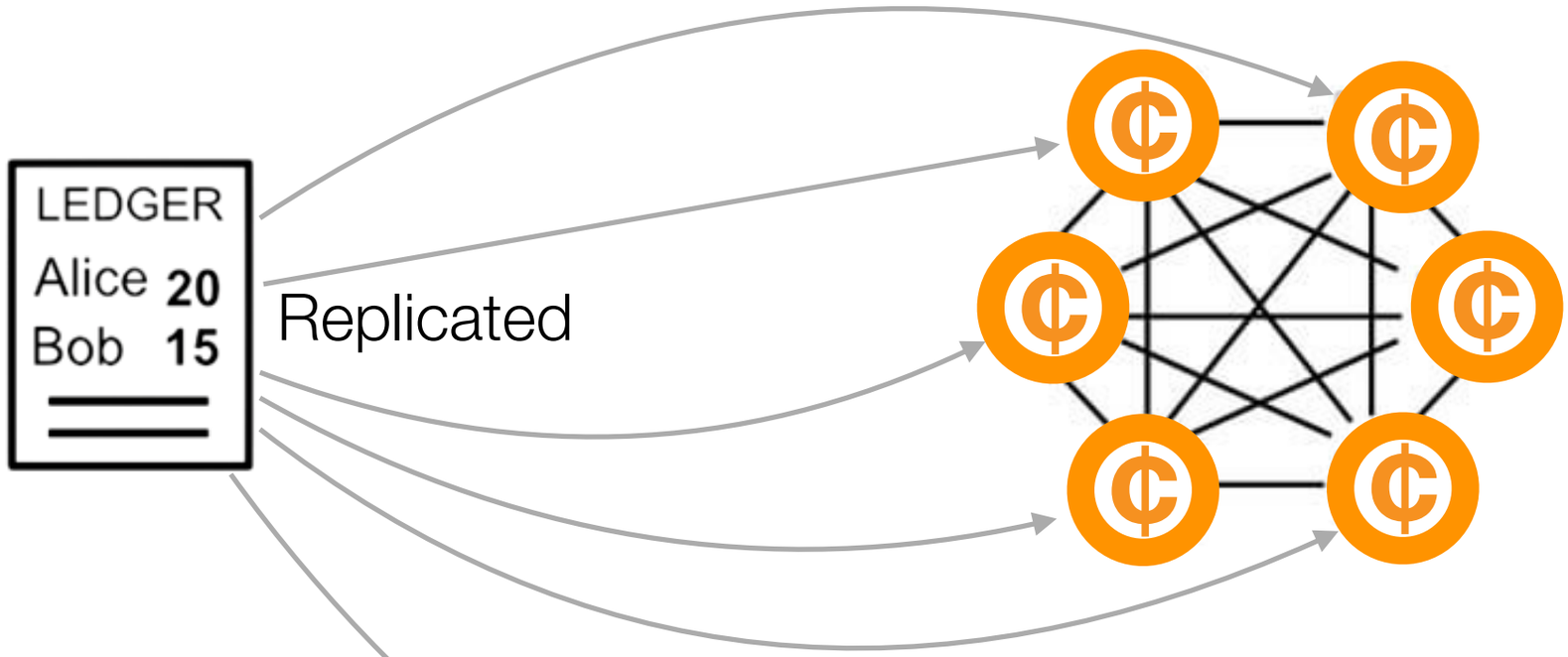

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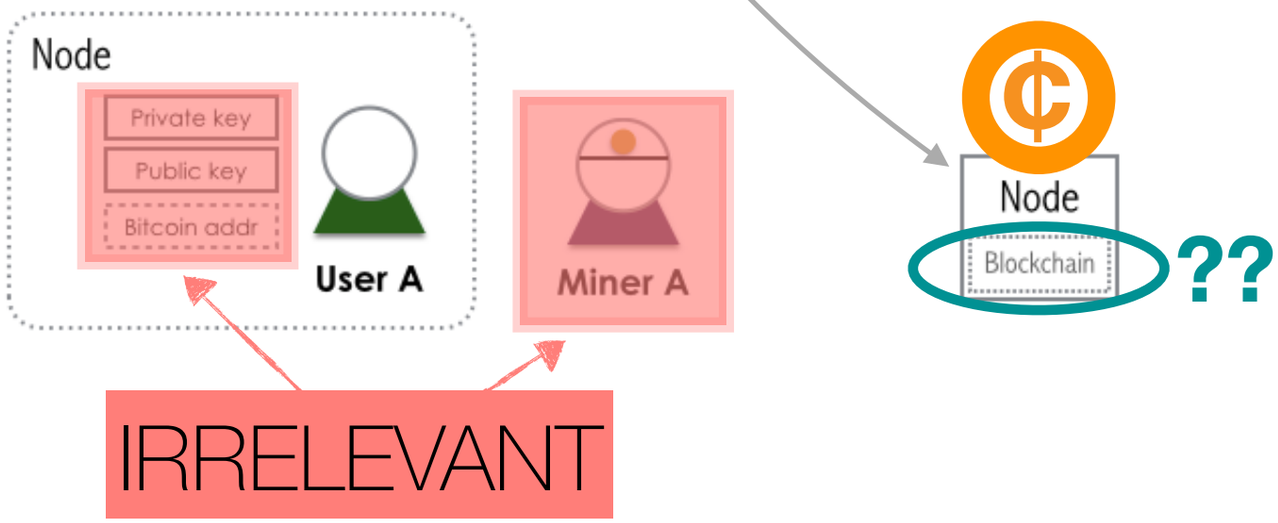
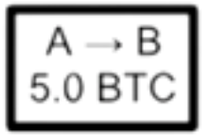


- Transaction  “Alice gives some money to Bob”

Main concepts

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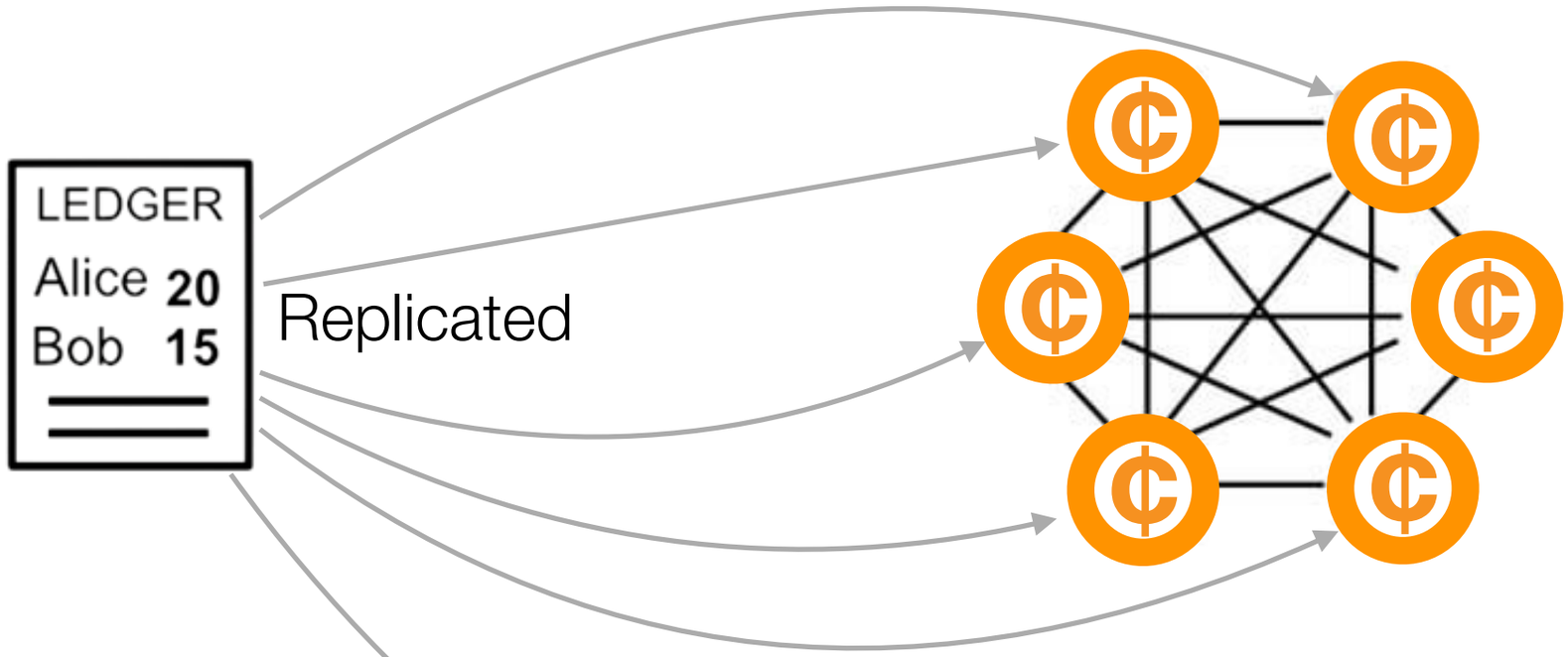

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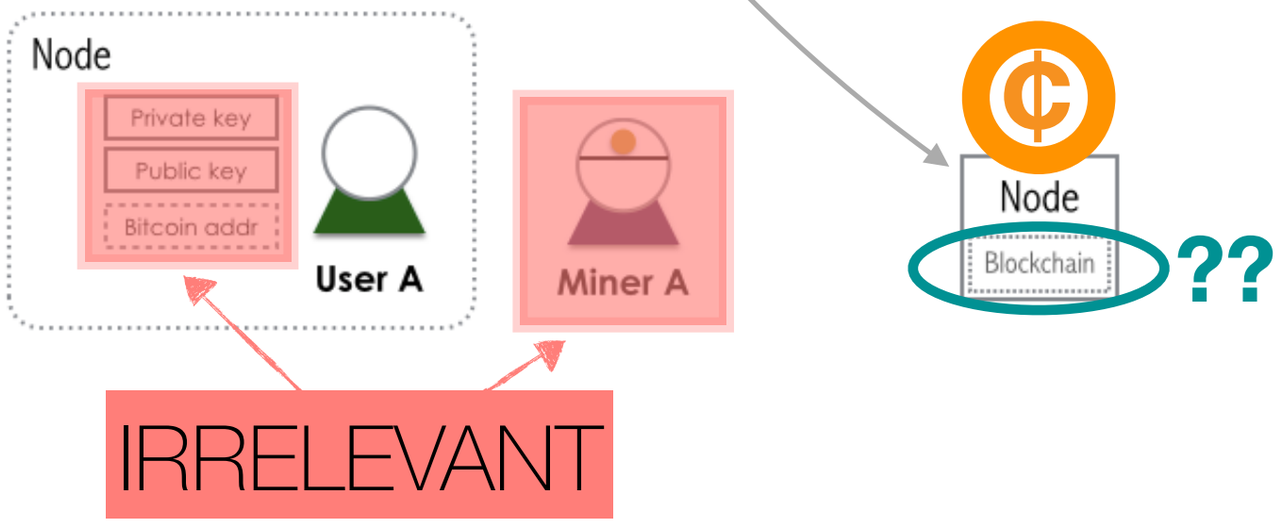
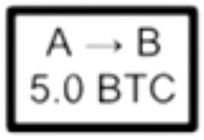
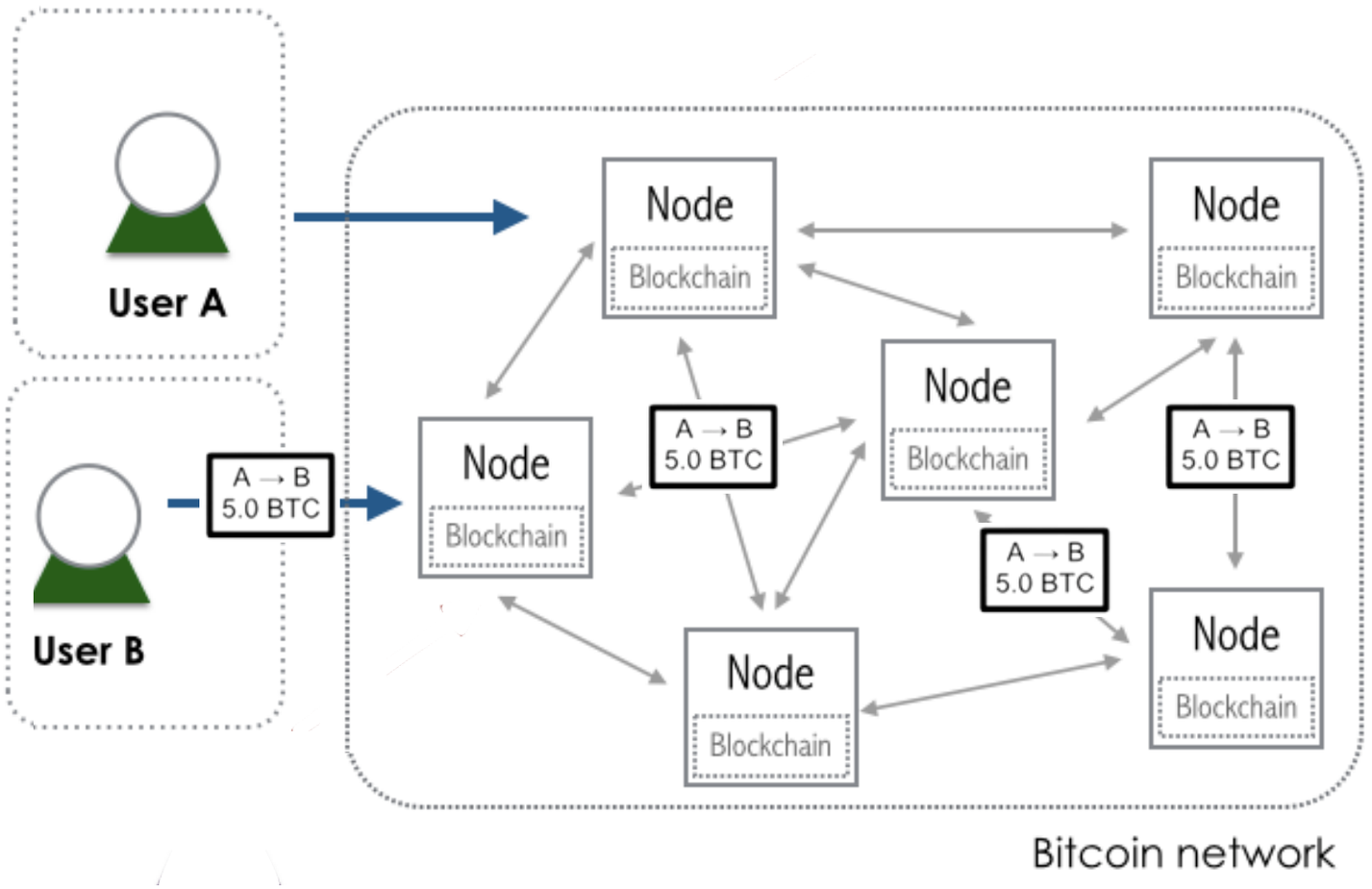


- Transaction 

"Alice gives some money to Bob"

Let's see how they all fit together..

High-level interactions



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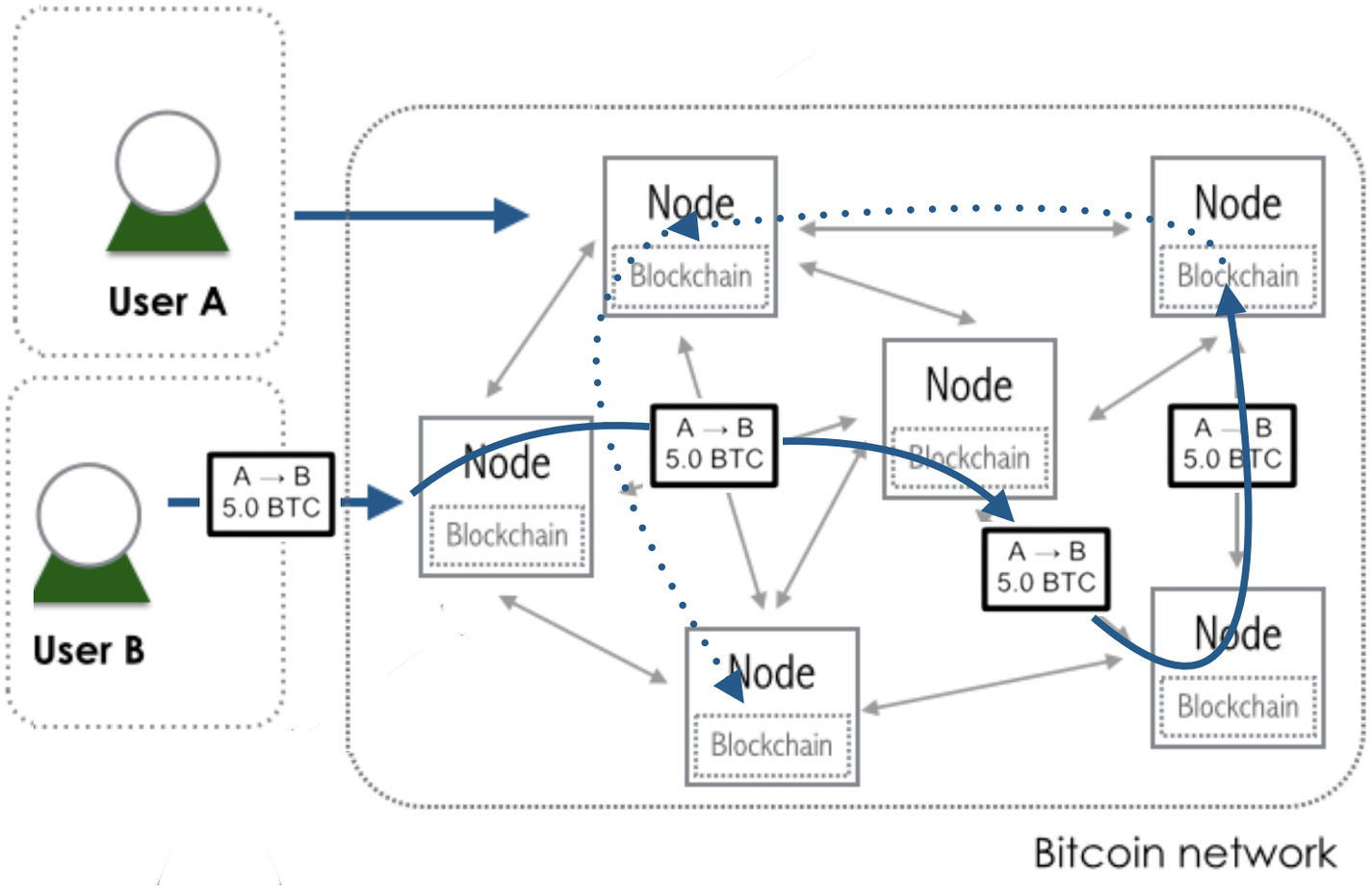

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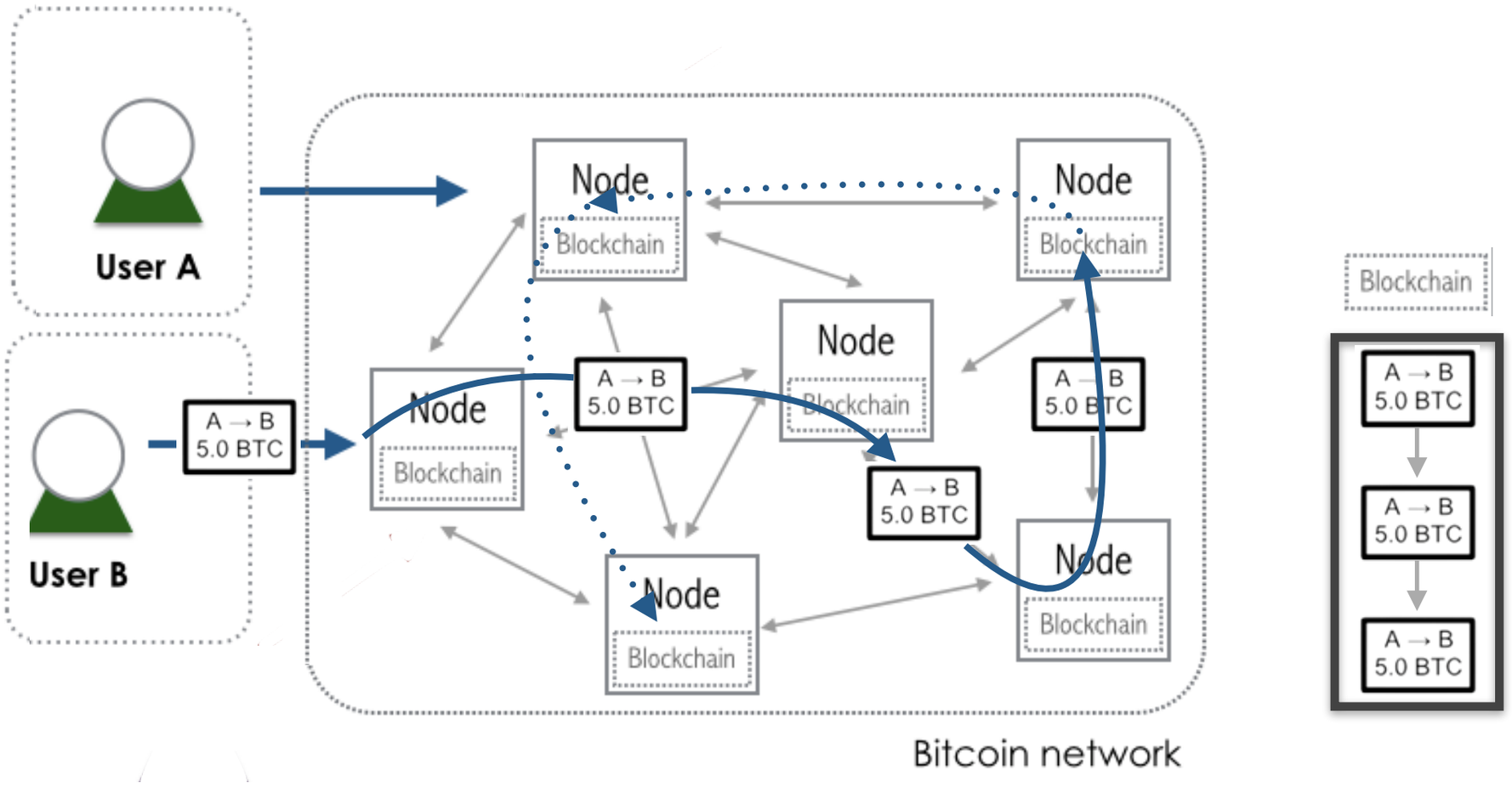

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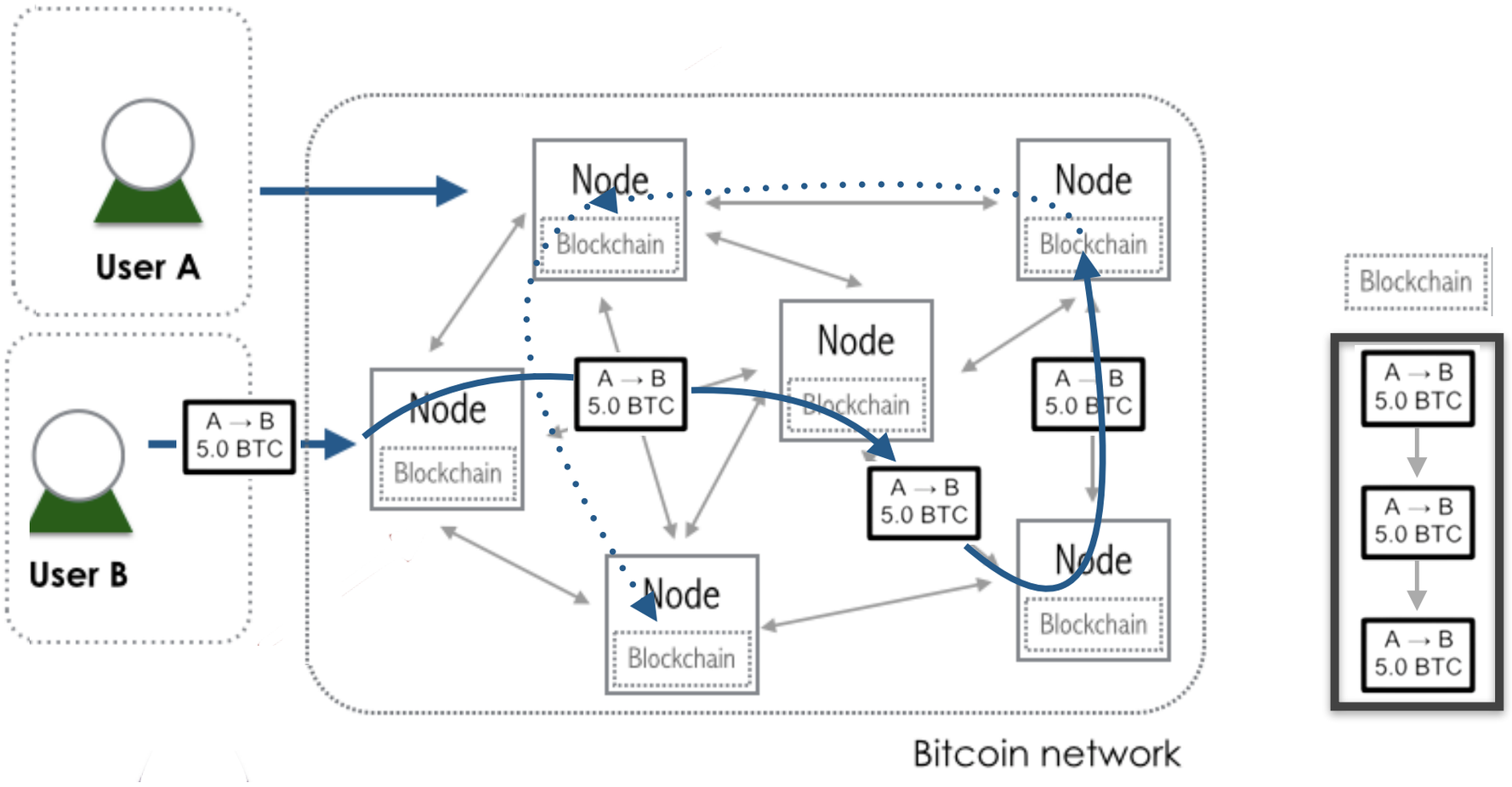
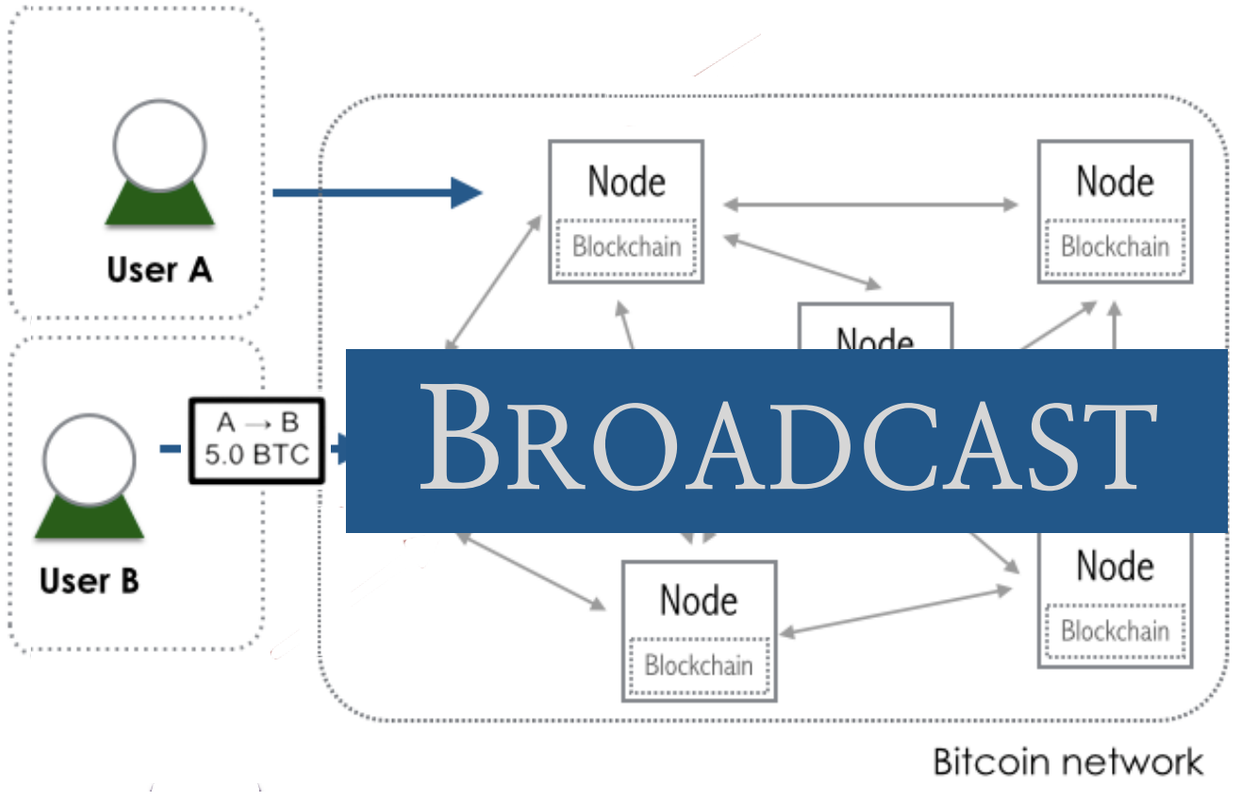


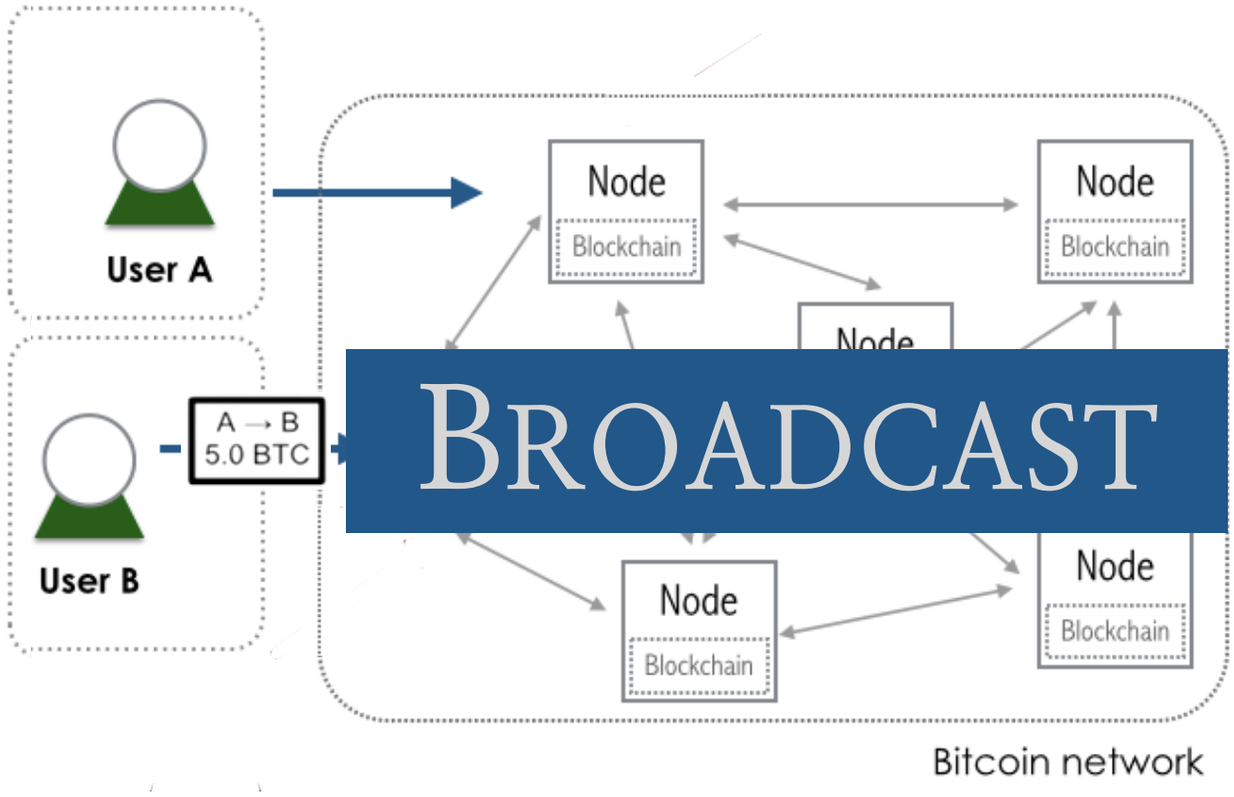
Recognise any abstractions?

High-level interactions



What kind of broadcast?

High-level interactions

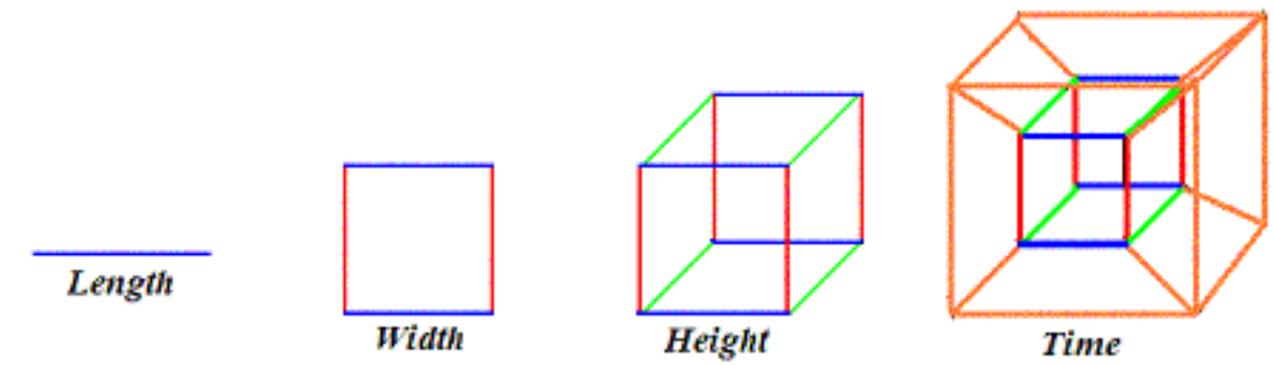


What kind of broadcast?

PROPERTIES (guarantees)

PERFORMANCE

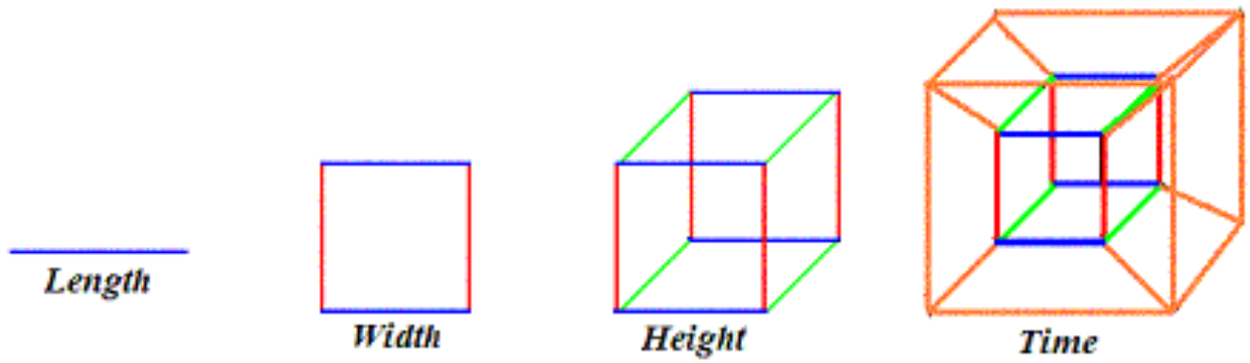
PROPERTIES



PROPERTIES

Analogy
(not formal)

The Four Dimensions *of a cube*



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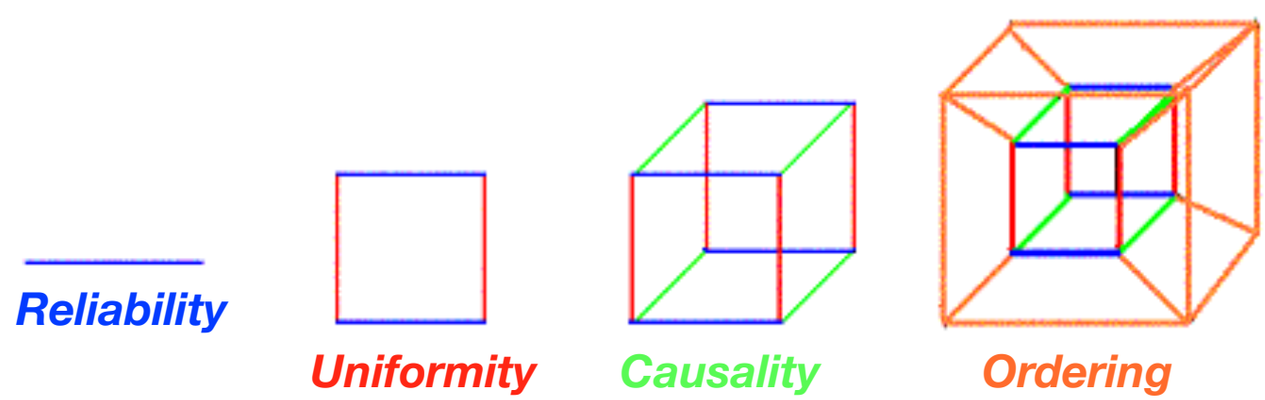
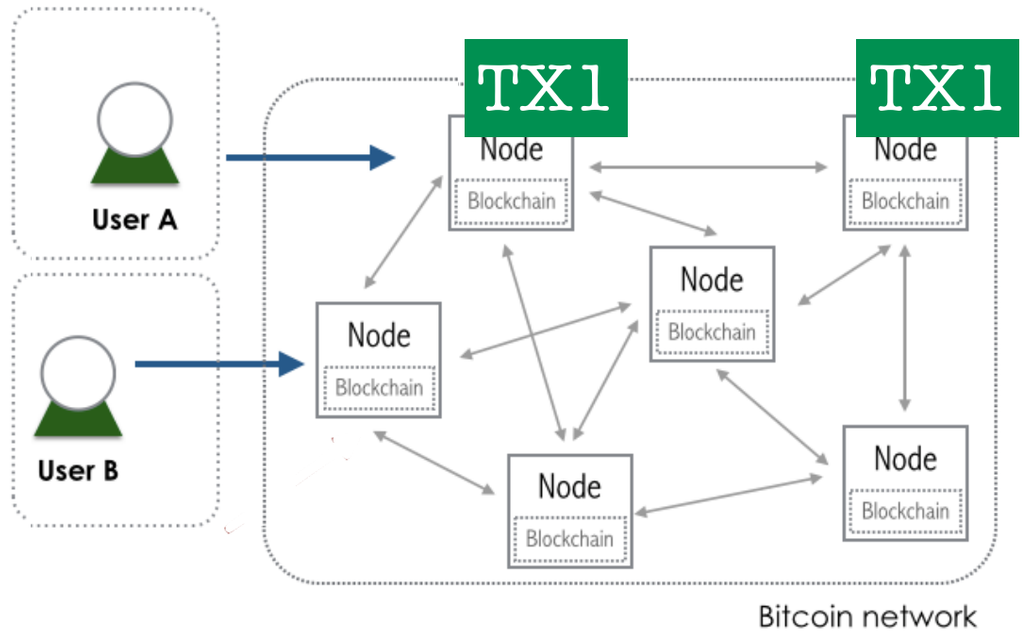


PROPERTIES

Do we need Reliability?



- Consider the following:
  - User A starts `TX1`
  - Use best-effort broadcast
    - Validity + !Duplication + !Creation
    - “the burden of reliability is on the sender”
    - Lacks Agreement ⇒ Nodes diverge

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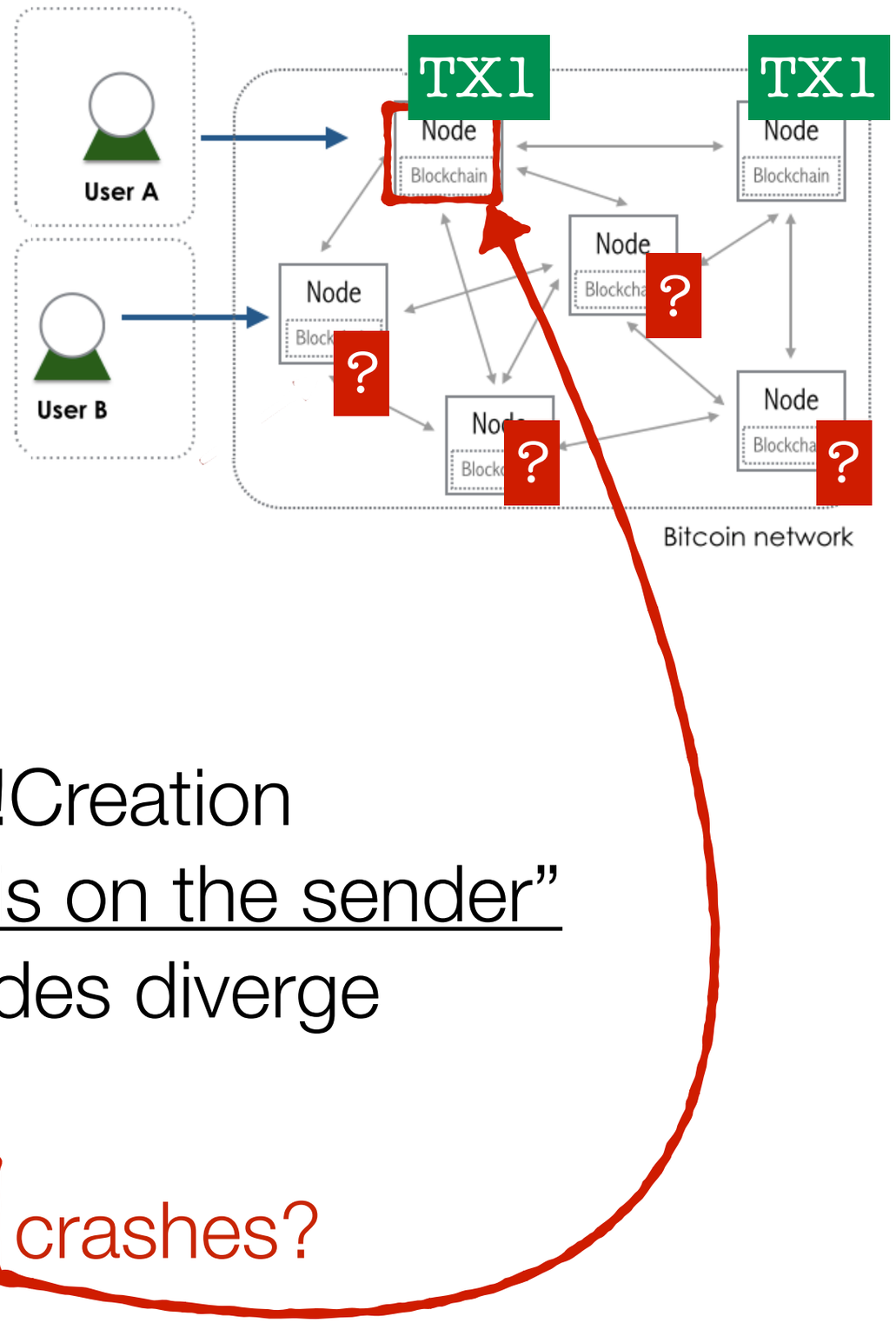
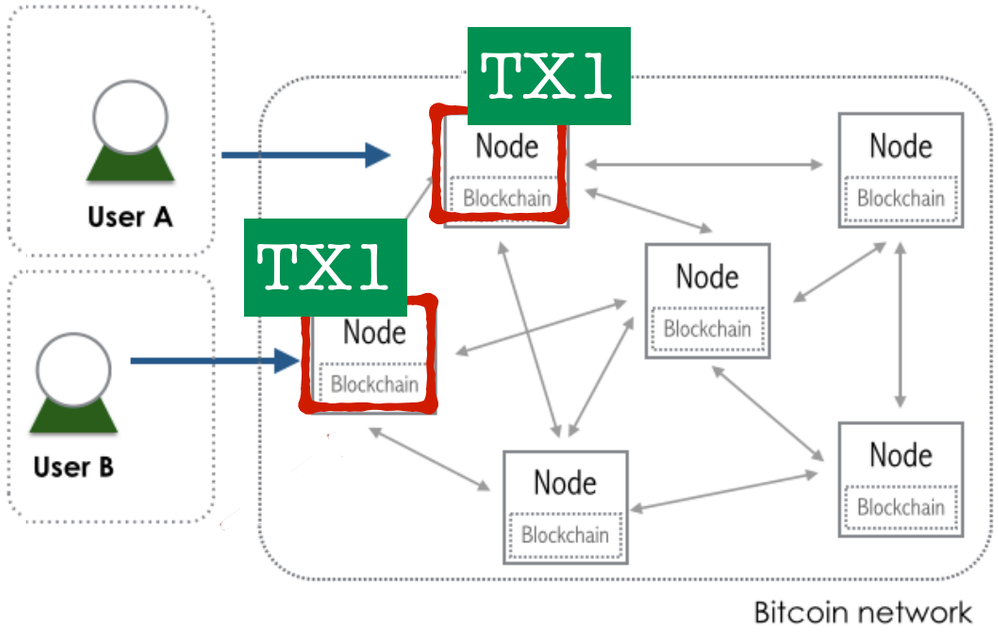


PROPERTIES

Do we need Uniformity?

- Consider the following:
  - User A starts `TX1`
  - Use regular reliable broadcast
    - Validity + !Duplication + !Creation + Agreement for correct nodes
  - Is it OK to deliver and crash?



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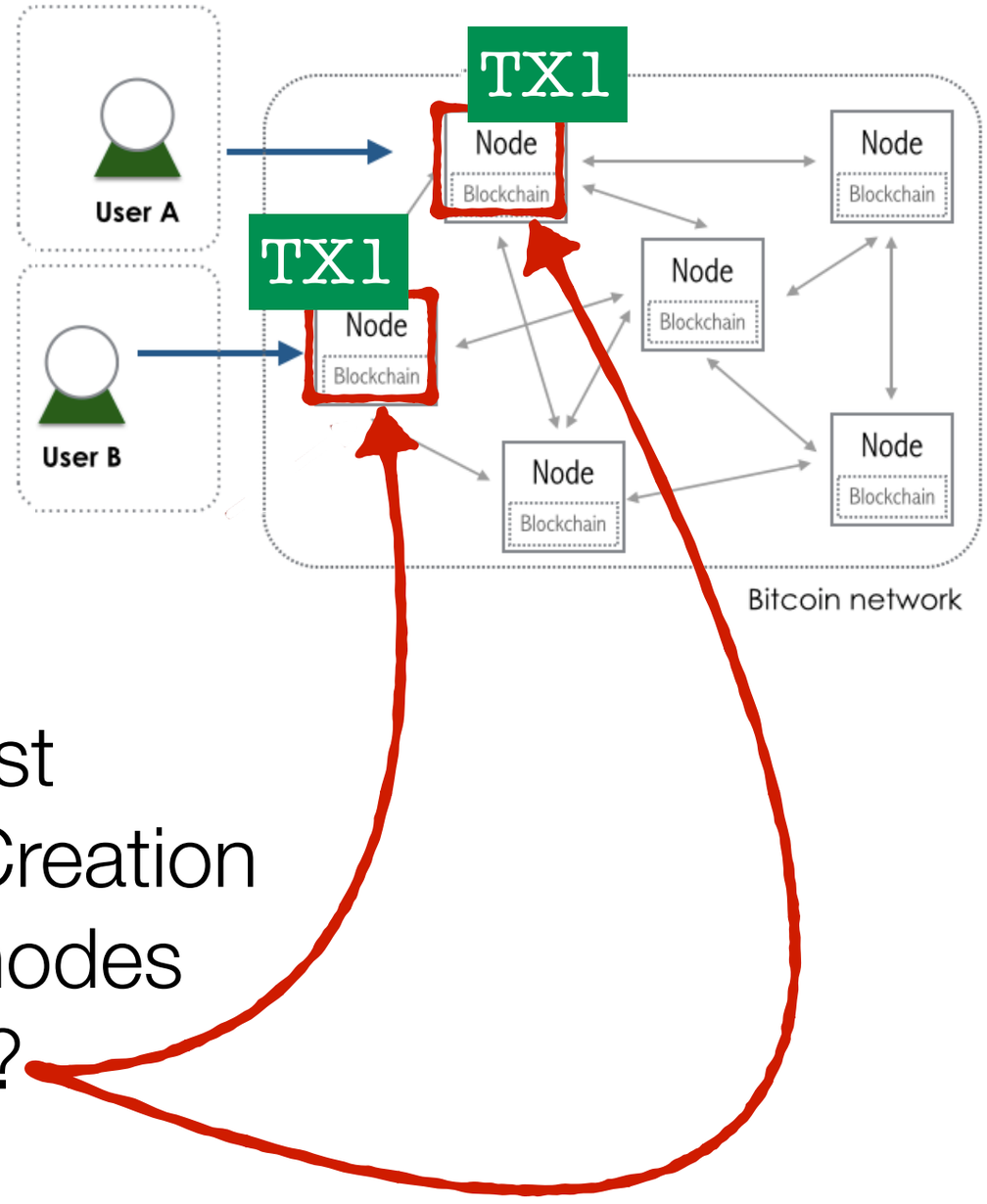

"Uniformity is important if nodes interact with the external world"

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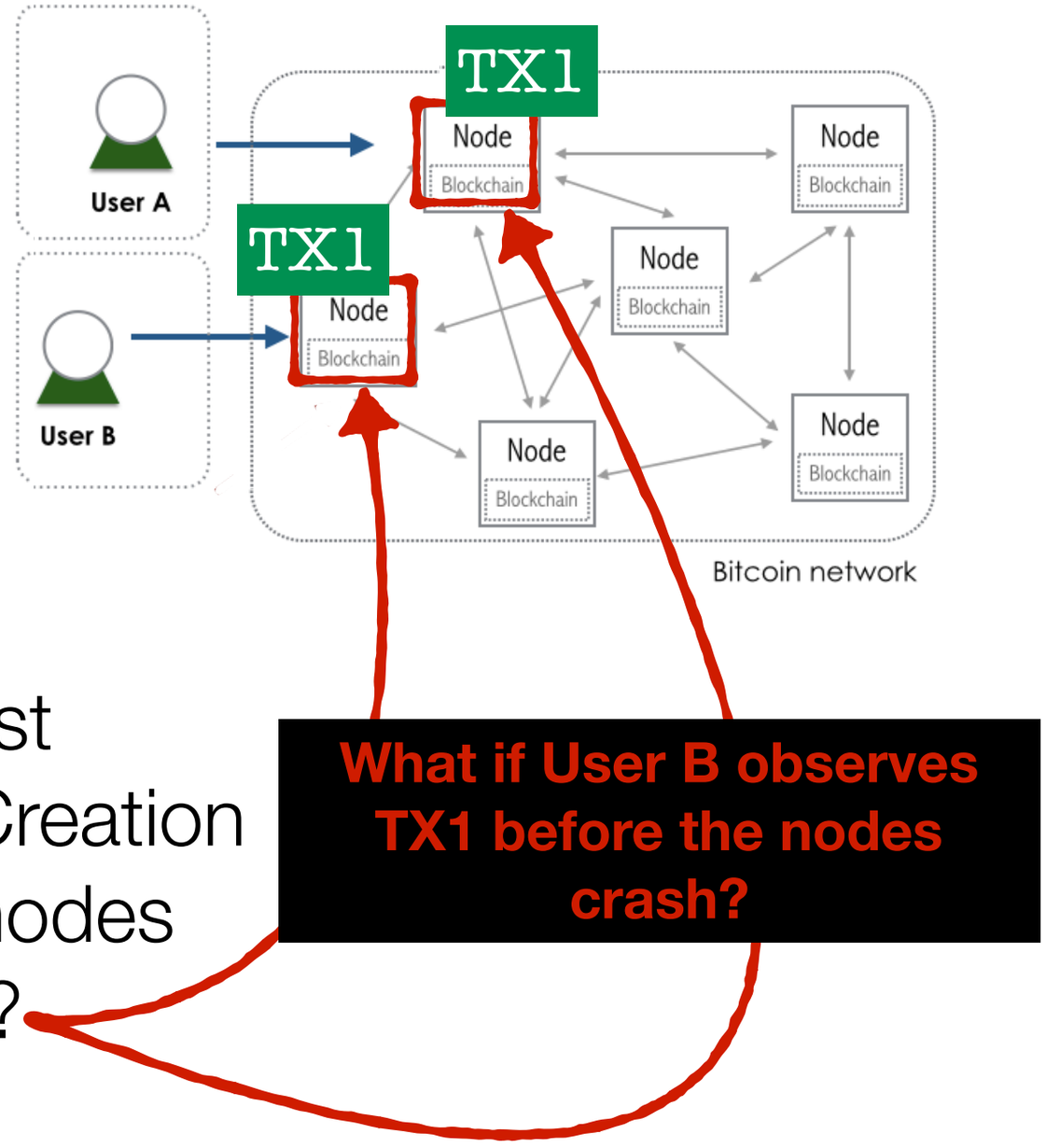
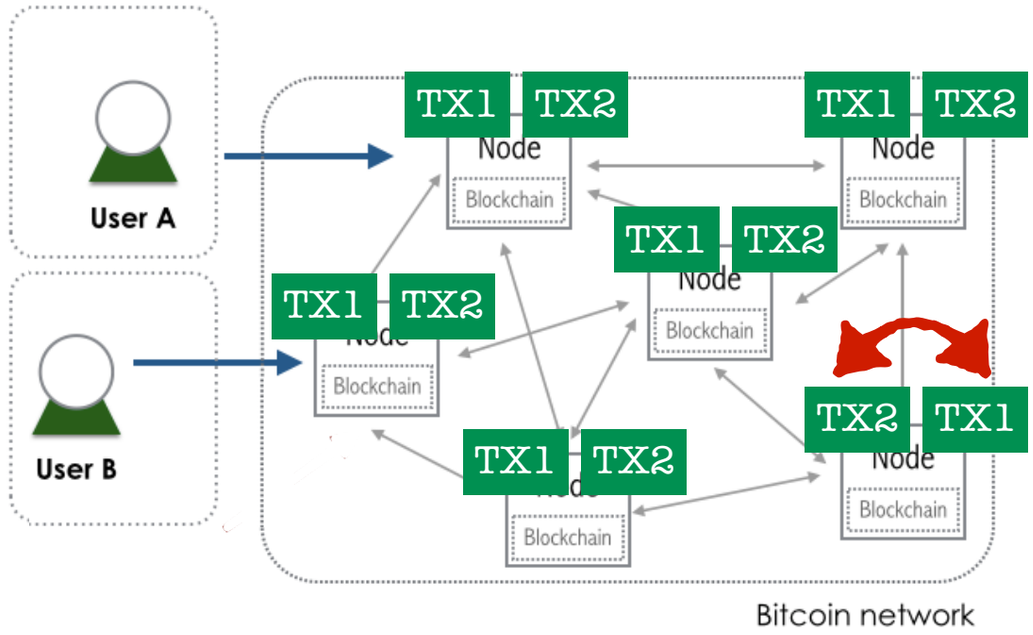


"Uniformity is important if nodes interact with the external world"

PROPERTIES

Do we need Causality? (partial ordering)

- Consider the following:
  - User A starts `TX1` and `TX2`
  - Use uniform reliable broadcast
    - Validity + !Duplication + !Creation + Uniform Agreement
      ⇒ Applies to all nodes
  - All nodes deliver both TX, but the order may differ



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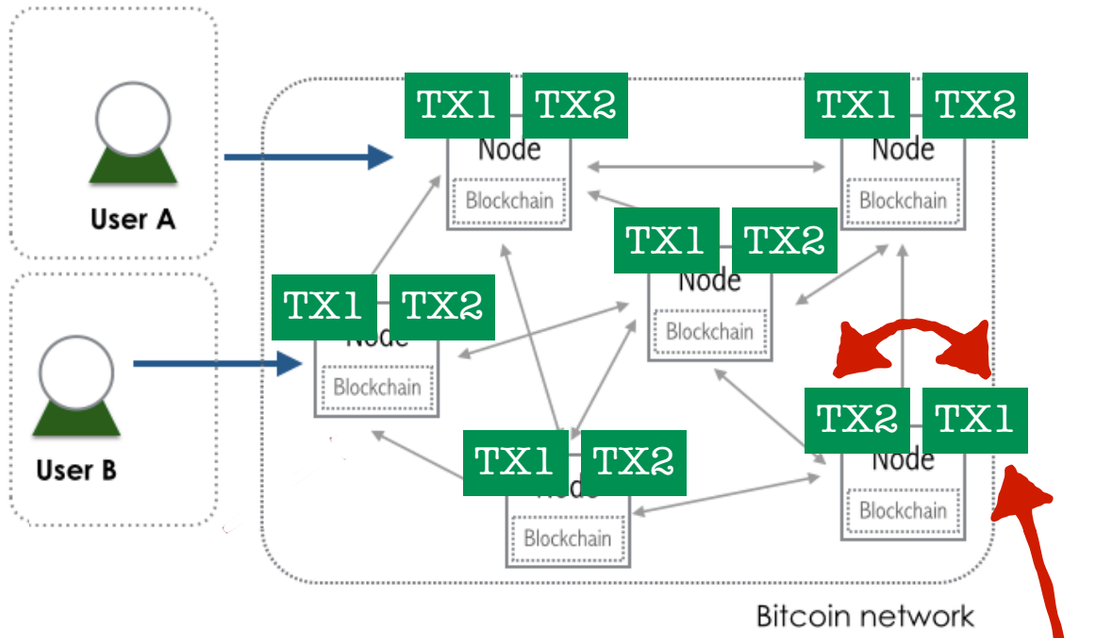
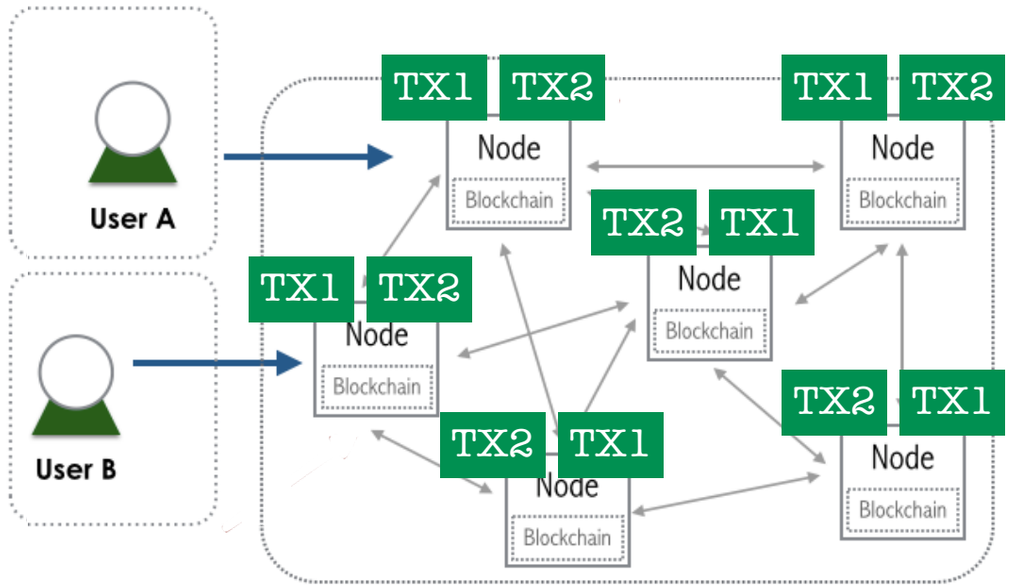


What if `TX2` depends on money from `TX1` ?

PROPERTIES

Do we need (Total) Ordering?



- Consider the following:
  - User A starts TX1
  - User B starts TX2

  No dependency among these two
  - Use causal-order uniform reliable broadcast
    - Validity + !Duplication + !Creation + Uniform Agreement + Causality
      ⇒ Respect causal dependencies among TXs
  - All nodes deliver both TX, but the order may differ

PROPERTIES

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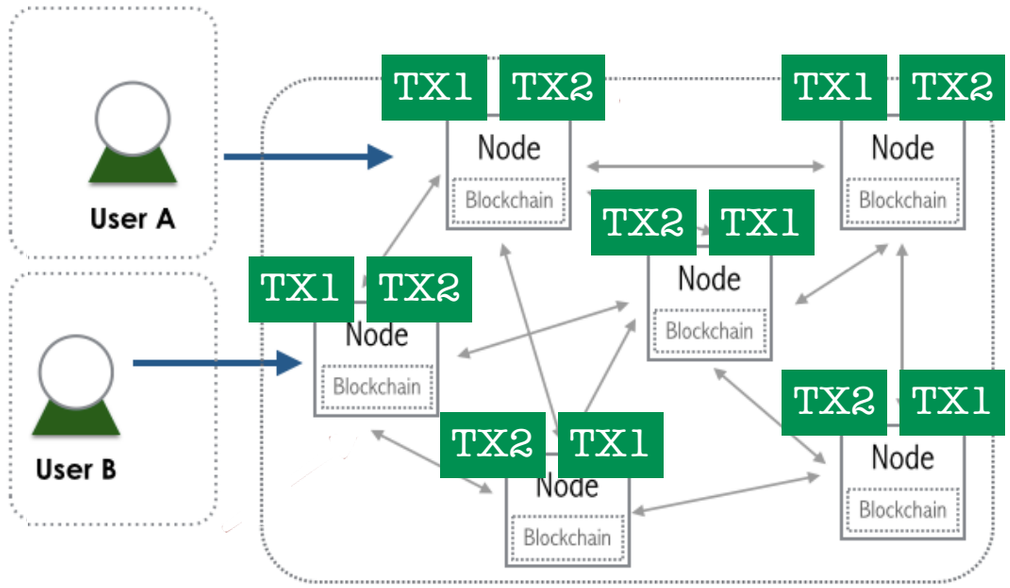

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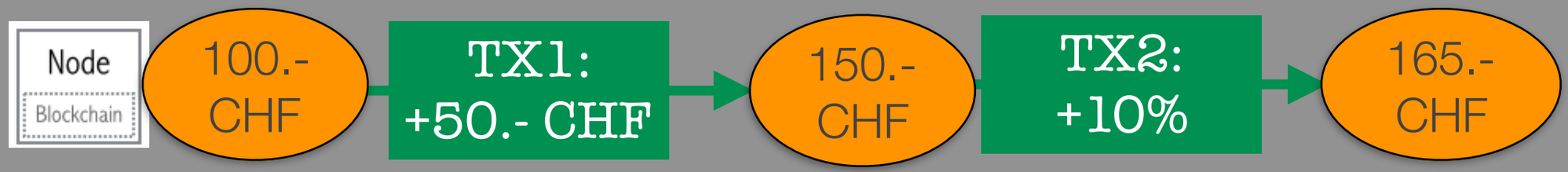
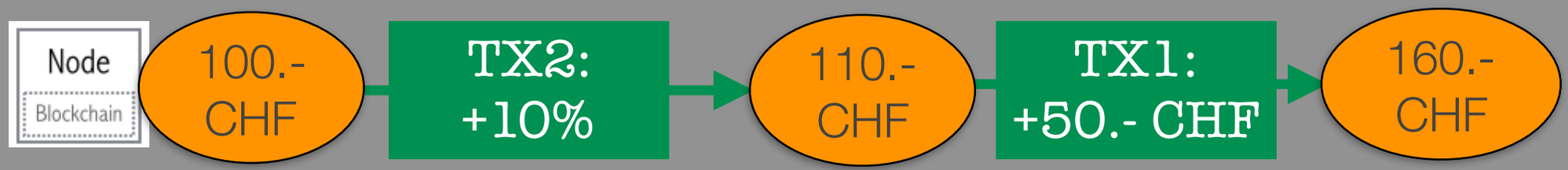
What if TX1 and TX2 are not commutative?

Commutativity
counter-example





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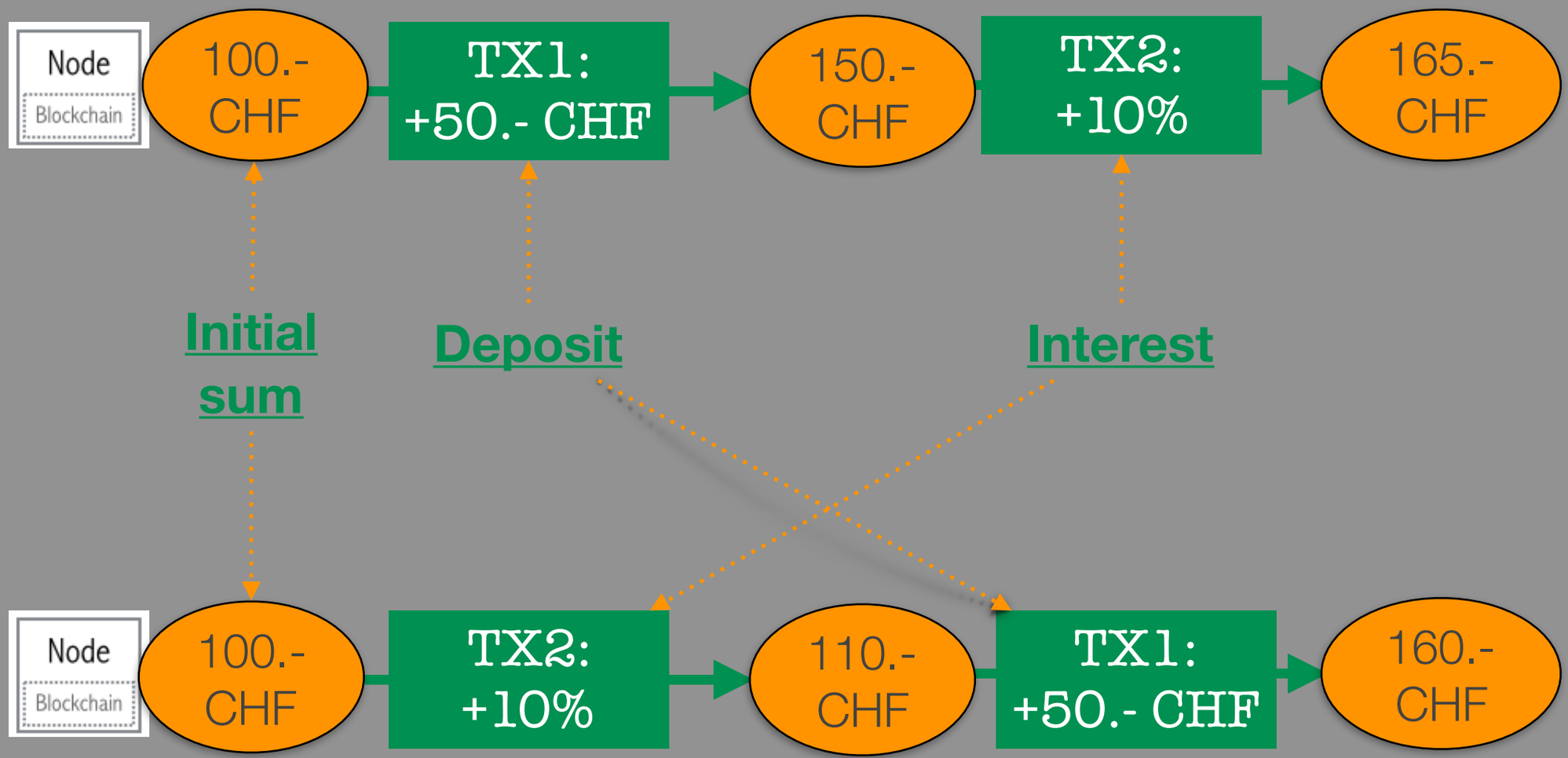

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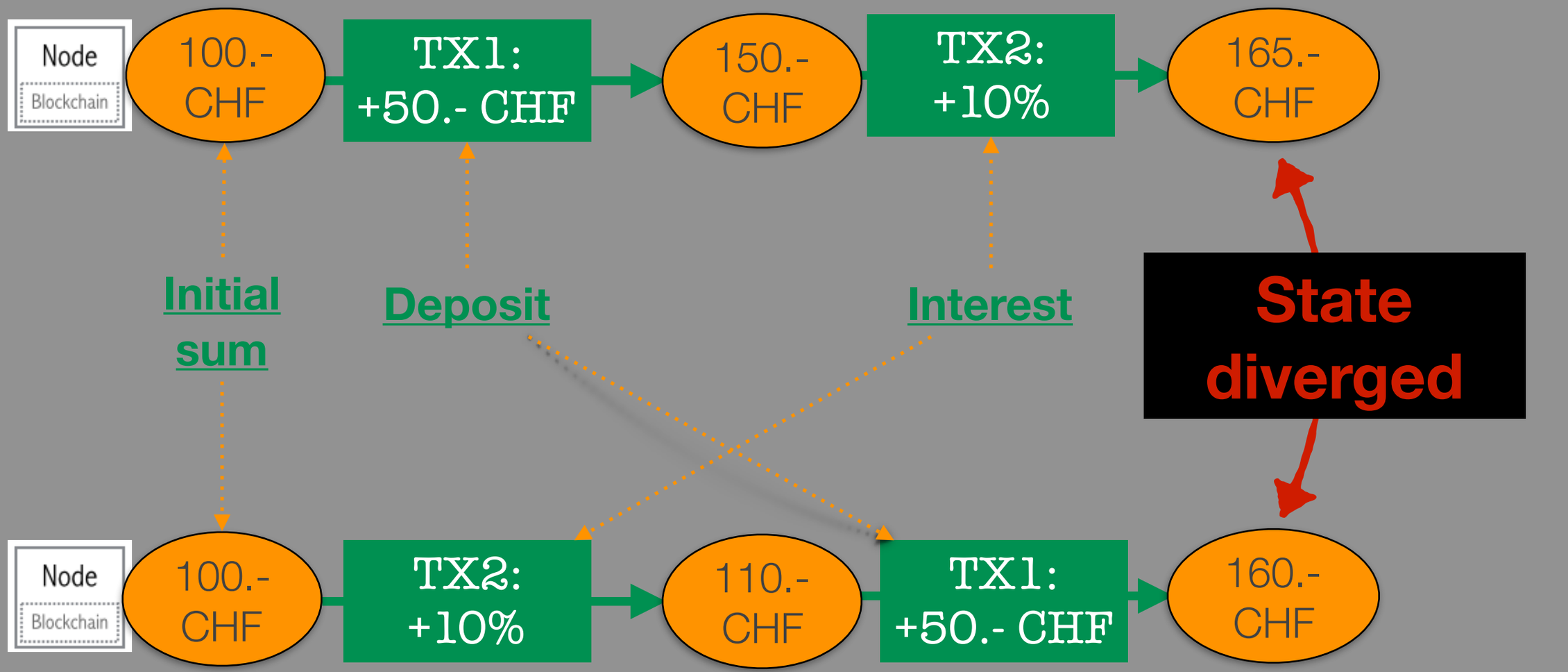
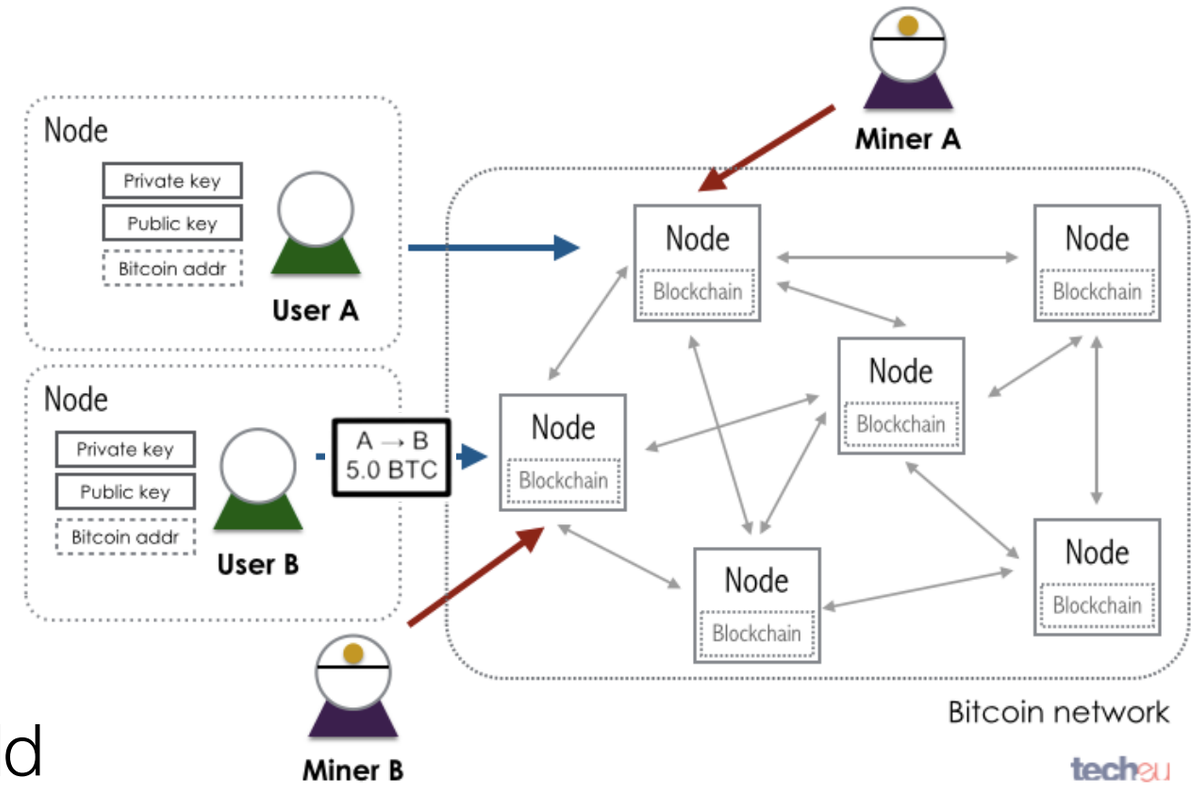


PROPERTIES

- Reliability
  - Sender crashes
  - Agreement
- Uniformity
  - Again, crashes
  - Interaction with outside world
- Causality
  - Partial order
  - Dependencies among TXs
- Total order
  - Commutativity



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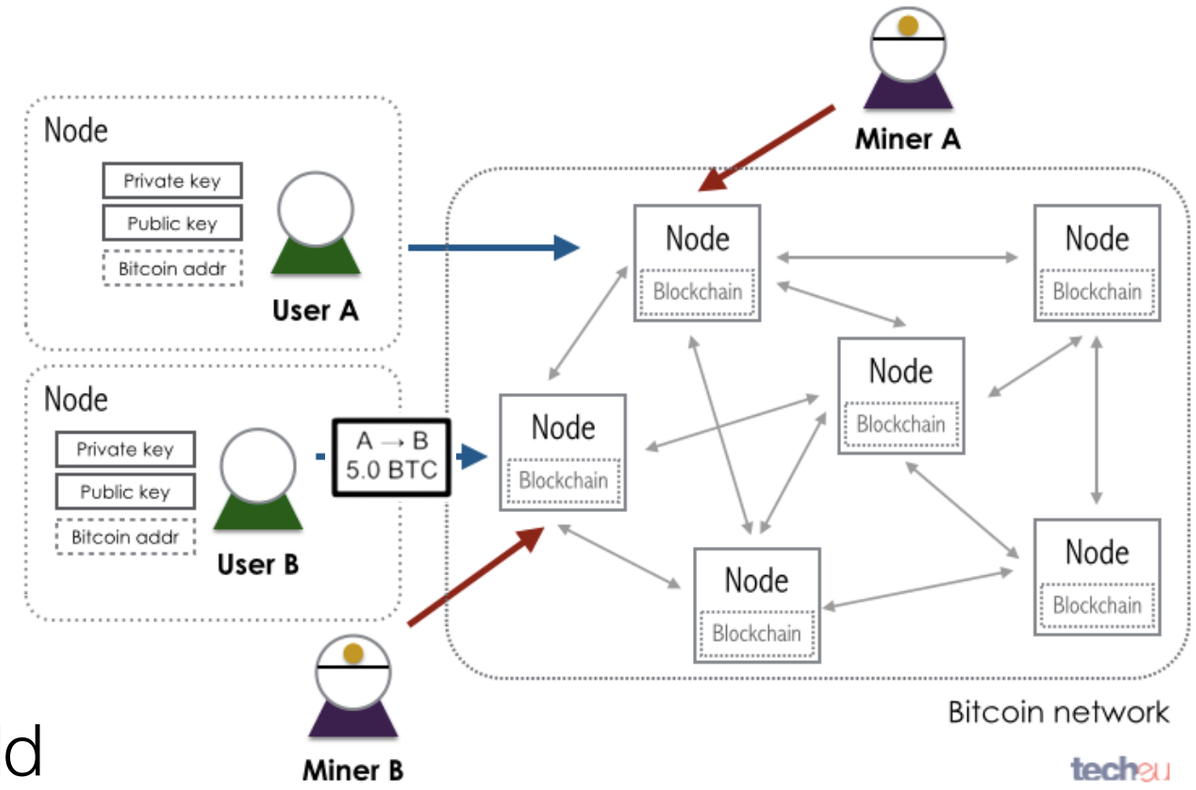

Contrast:

- Canonical Bitcoin requires best-effort broadcast
- Allows temp. inconsistencies
- Makes up with crypto

PROPERTIES

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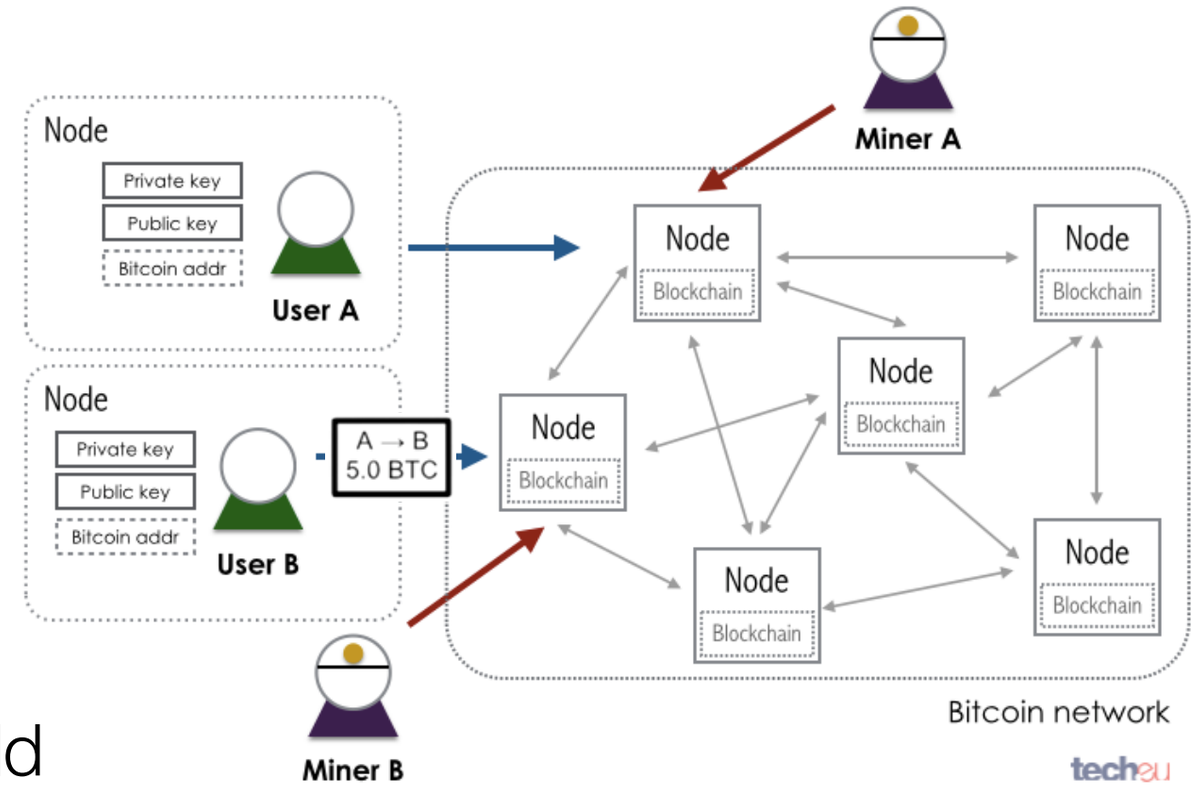

Contrast:

- Canonical Bitcoin requires best-effort broadcast
- Allows temp. inconsistencies
- Makes up with crypto

All properties are desirable

PERFORMANCE

Goals:

1. Replace traditional CAMIPRO
2. Make banks obsolete

AN INFORMAL COMPARISON…

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CANONICAL BITCOIN

- Best-effort broadcast
- Optimized for Internet (WAN)
- **TX~10 minutes**

How useful would that be?
(in the lunch queue)

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CANONICAL BITCOIN

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How useful would that be?
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CAMIPRO BITCOIN

- CAMIPRO-Bitcoin-Broadcast
- Optimized for small network (EPFL LAN)
- TX~1second (back of the envelope)
- Acceptable latency & throughput

Specification

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Module:

Name: CAMIPRO-Bitcoin-Broadcast, **instance** *cbit*

Properties:

- **URB1, URB2, URB3, URB4**
- **Causal Order (CO)**
- **Total order (TO)**

What's left ????

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Events:

Request: ⟨*cbit, Start* | TX⟩:
Attempts to commit TX

Indication: ⟨*cbit, Status* | TX, s⟩:
Indicates the status s∈{“Abort”,“Commit”} of TX

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CAMIPRO-Bitcoin

Request **Indication**

CAMIPRO-Bitcoin-Broadcast

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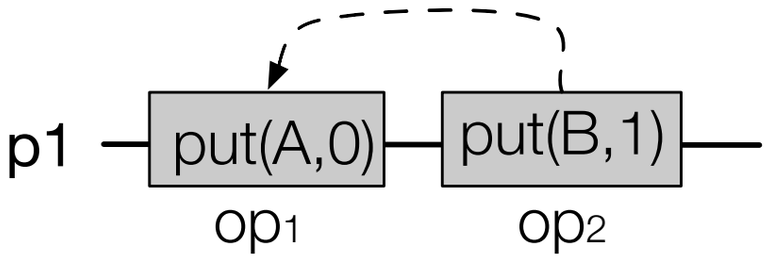
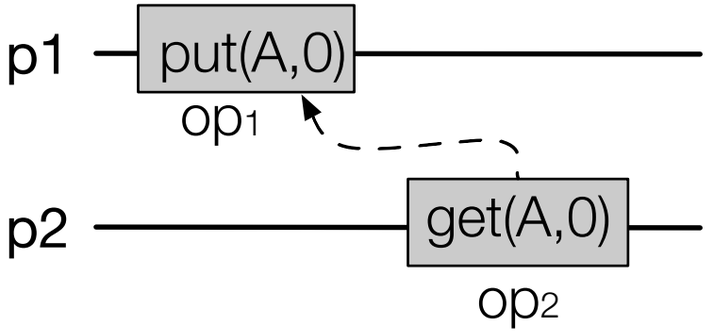
Causal consistency — one last look

- Given two operations, op1 and op2

- op1 → op2 (causally precedes)
  if any of the following three cases applies:

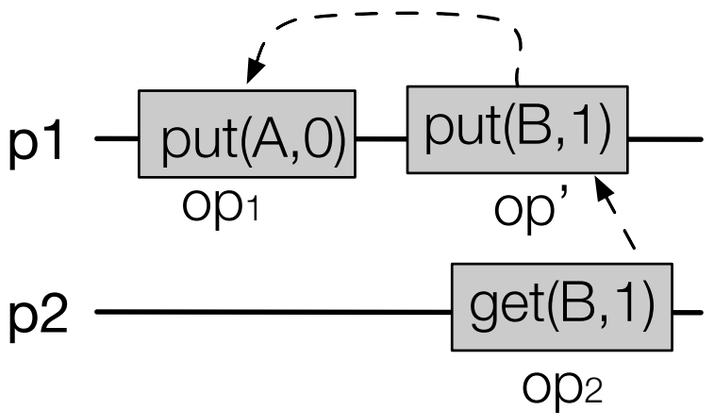


(a) FIFO: A process invokes op1 and then invokes op2



(b) Local: A process invokes the PUT operation op1 and another process invokes the GET operation op2, where op2 observes the written value of op1

(c) Transitivity: There exists an intermediate operation op′ such that op1 → op′ and op′ → op2.



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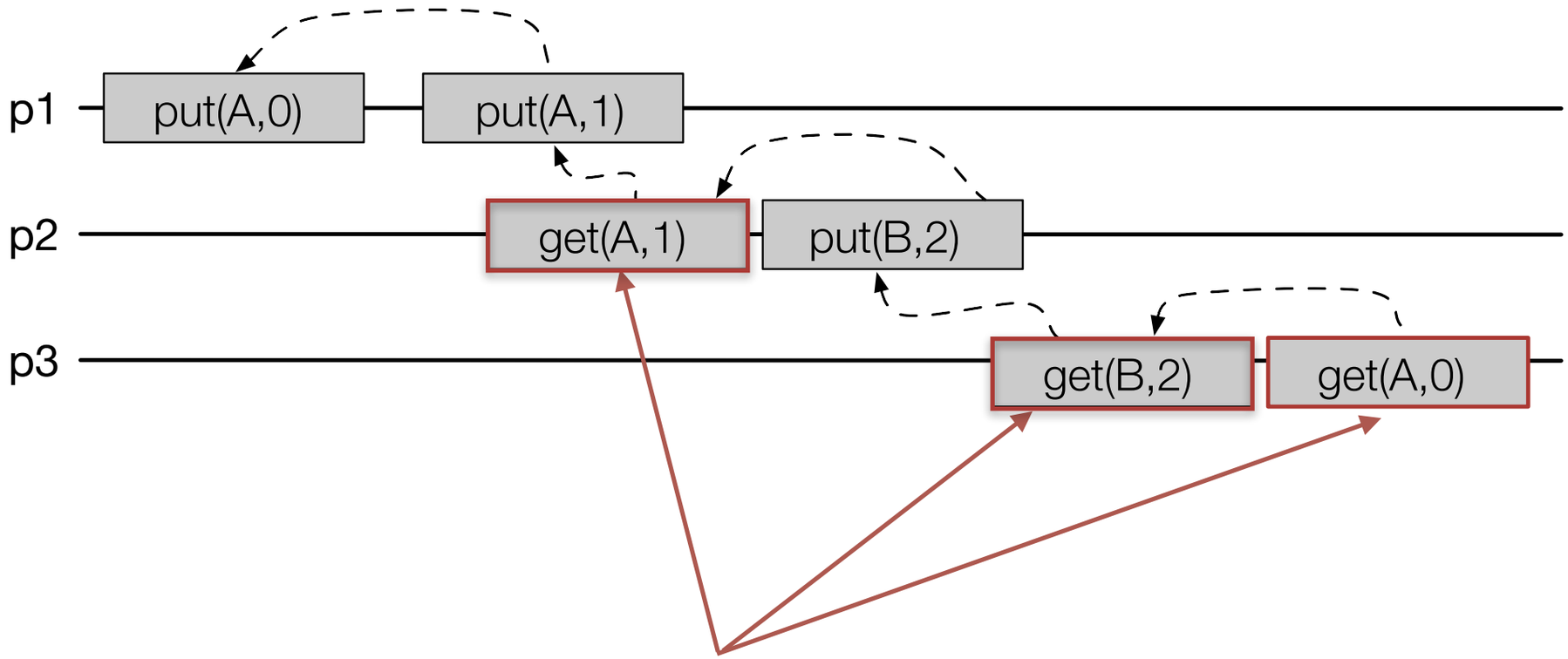
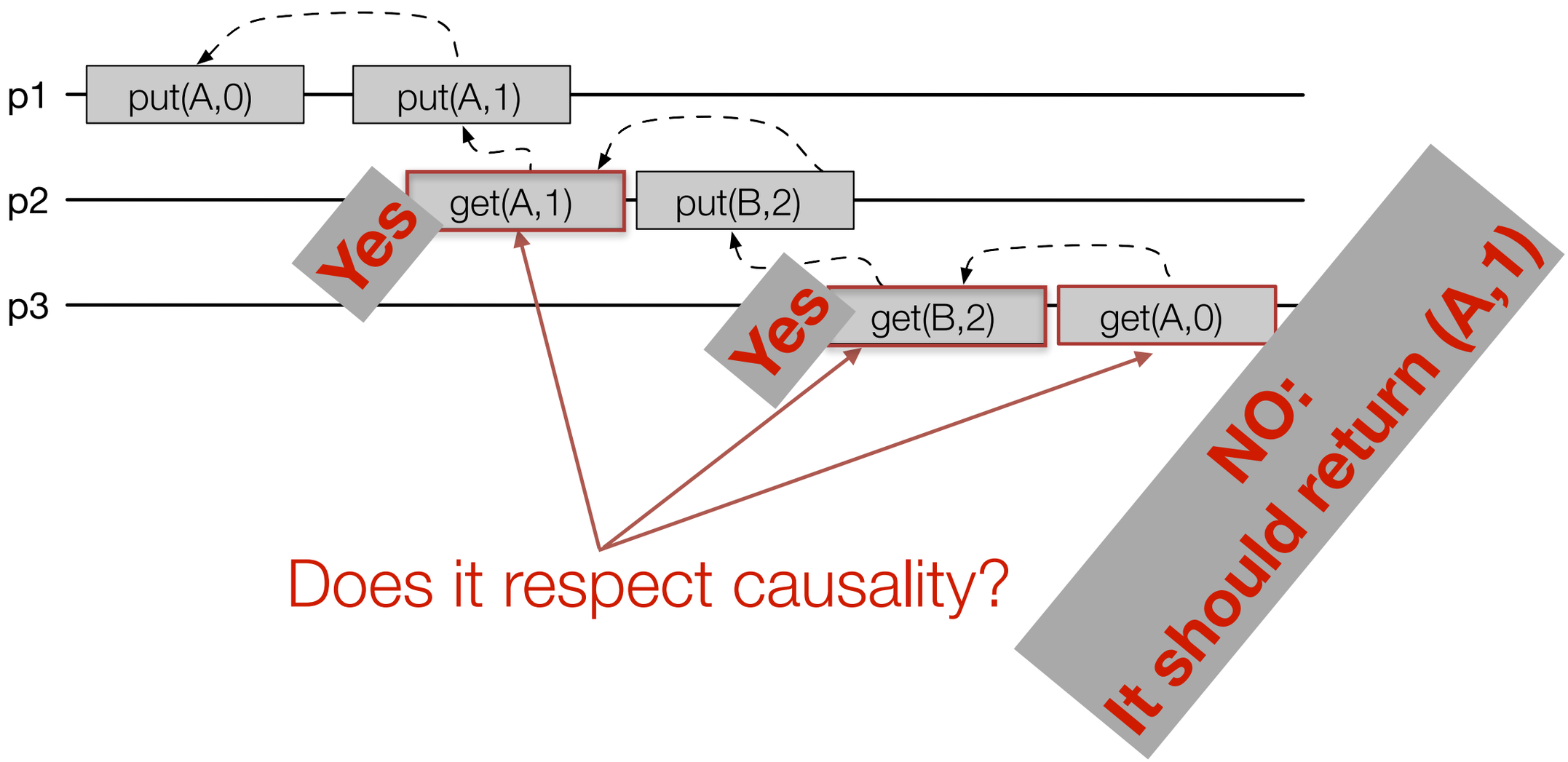


Does it respect causality?

Causal consistency — one last look



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