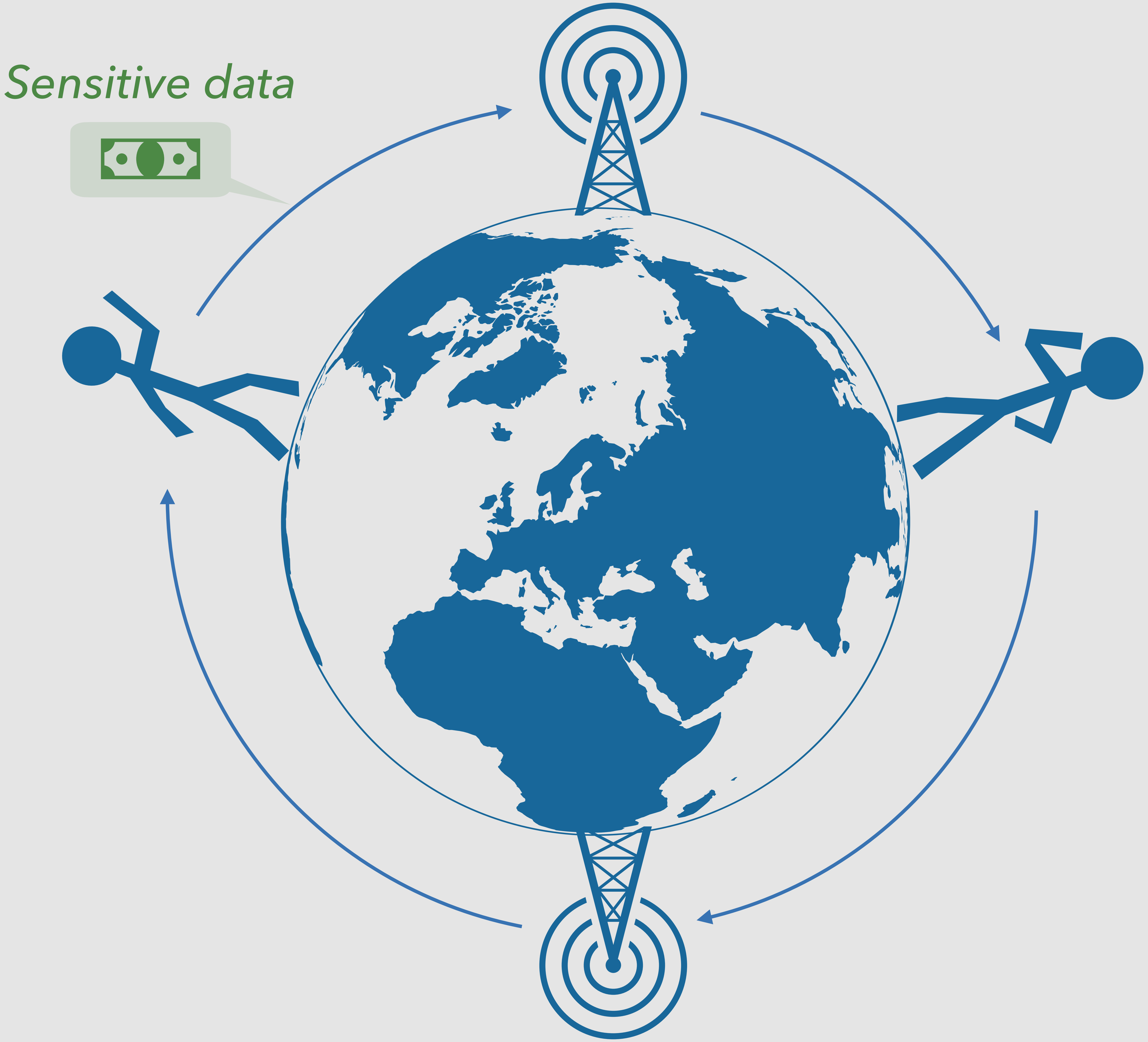
Security Going Live: Verification of Real-Time Components of Security Protocols

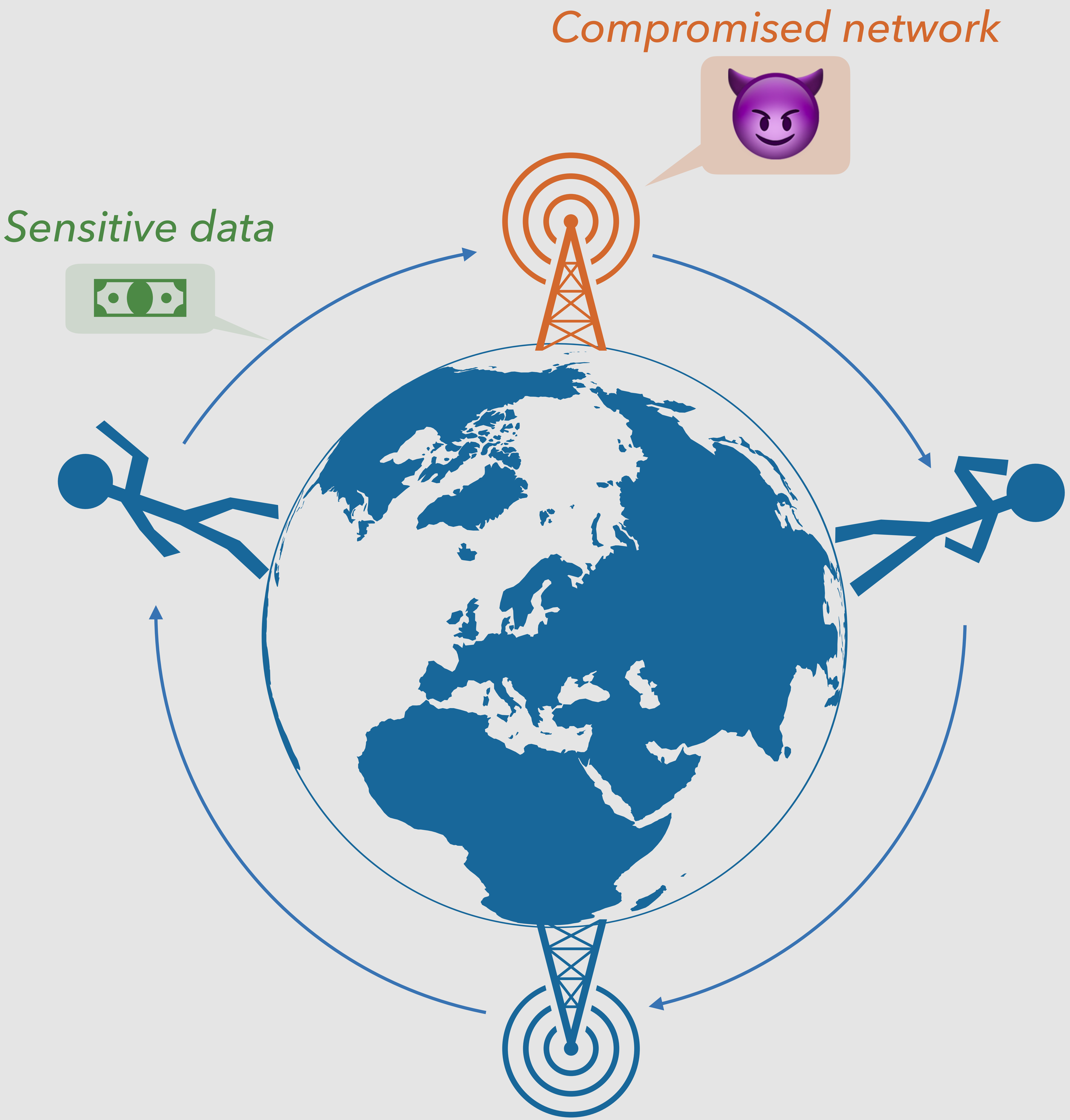
Work in progress with

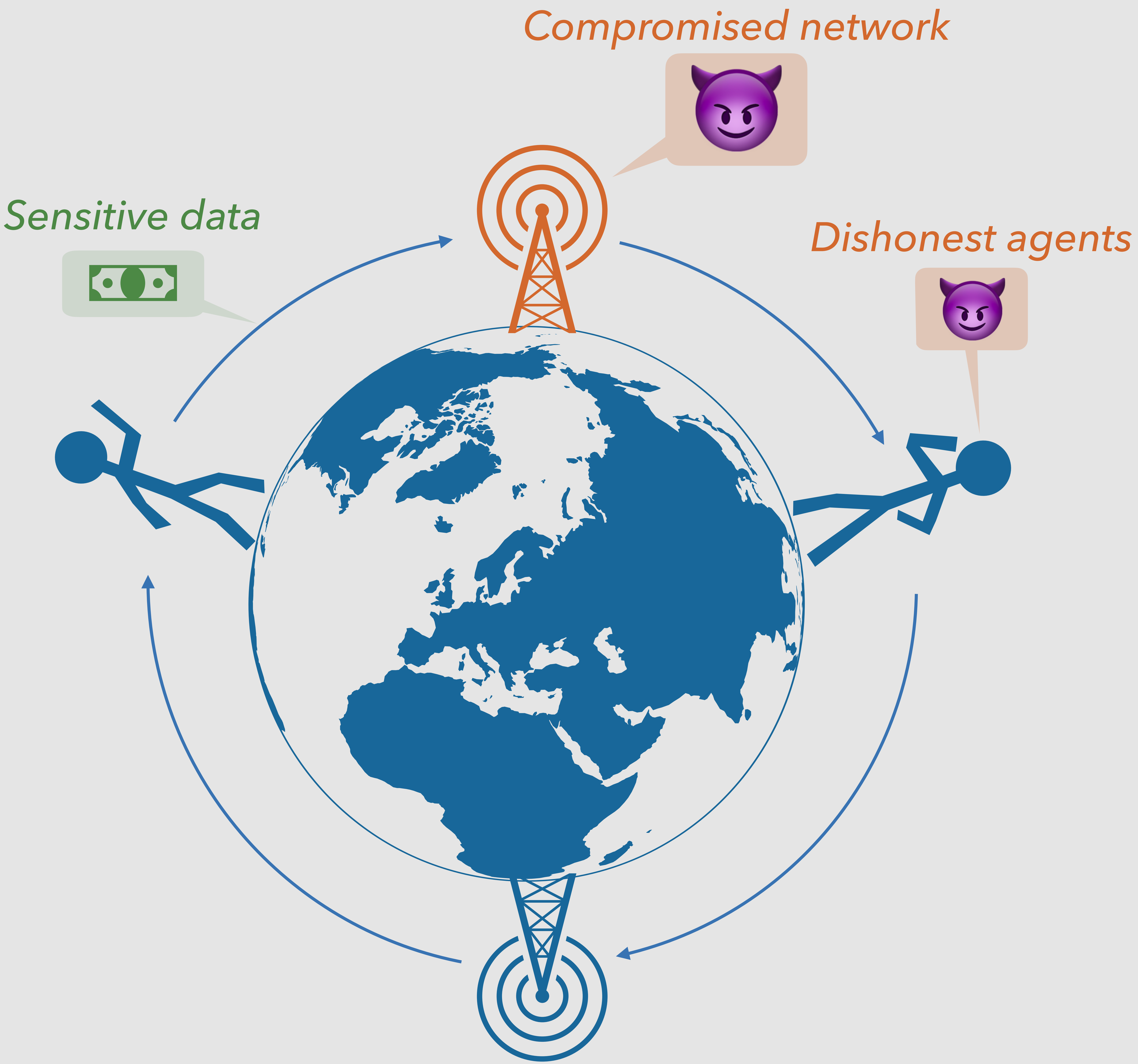
Pedro Moreno-Sanchez[1], Itsaka Rakotonirina[2], Clara Schneidewind[2]

[1] IMDEA Software Institute

[2] MPI-SP


Sensitive data


Compromised network
Sensitive data


Compromised network
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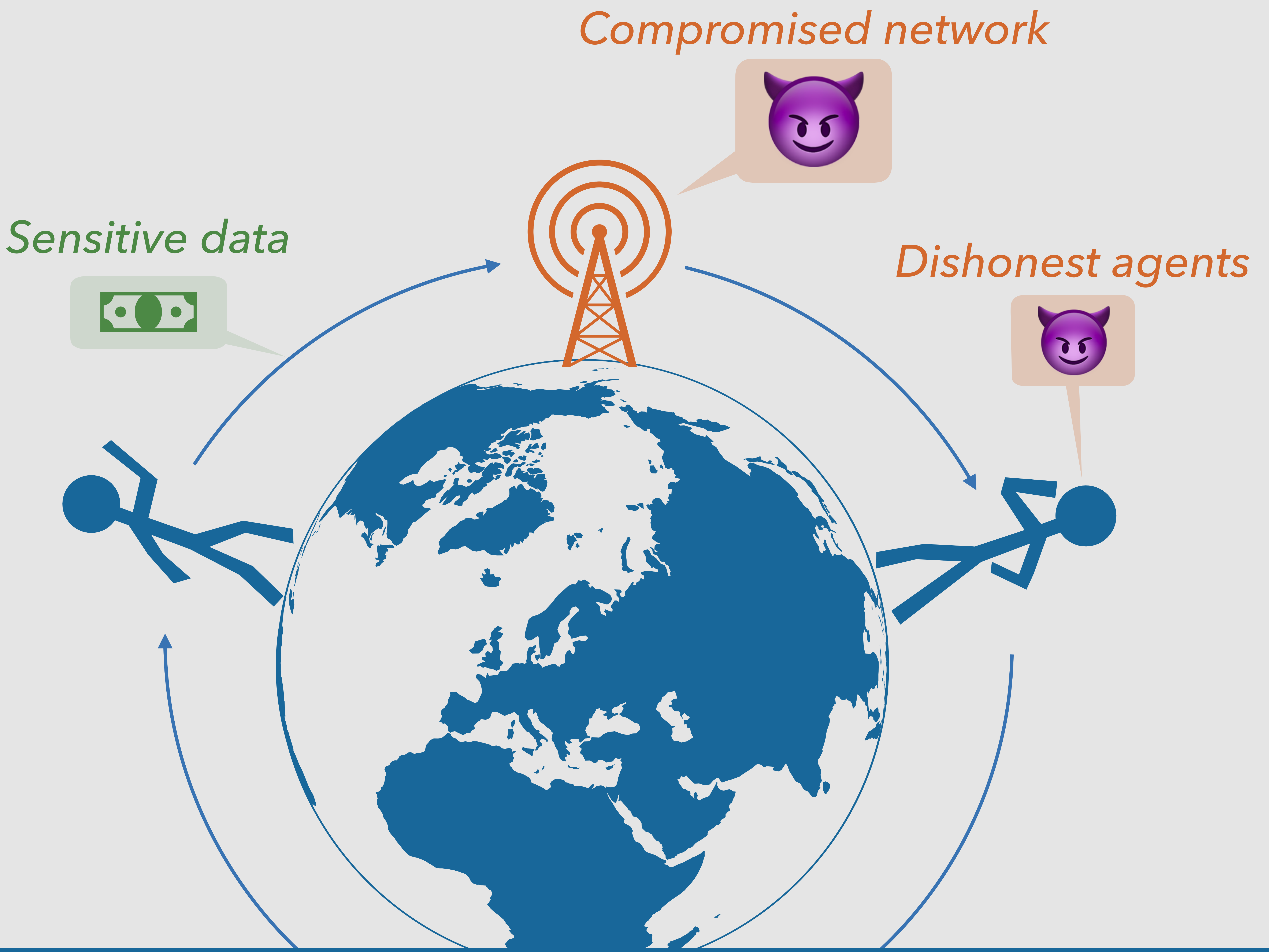
Dishonest agents



Fairness: can one stall the protocol after having gained an "advantage"?

Theorem

Asynchronous communications are unfair.

- S. Even, Y. Yacobi, 1980. *Relations among public key signature system*
- R. Cleve, 1986. *Limits on the security of coin flips when half the processors are faulty*

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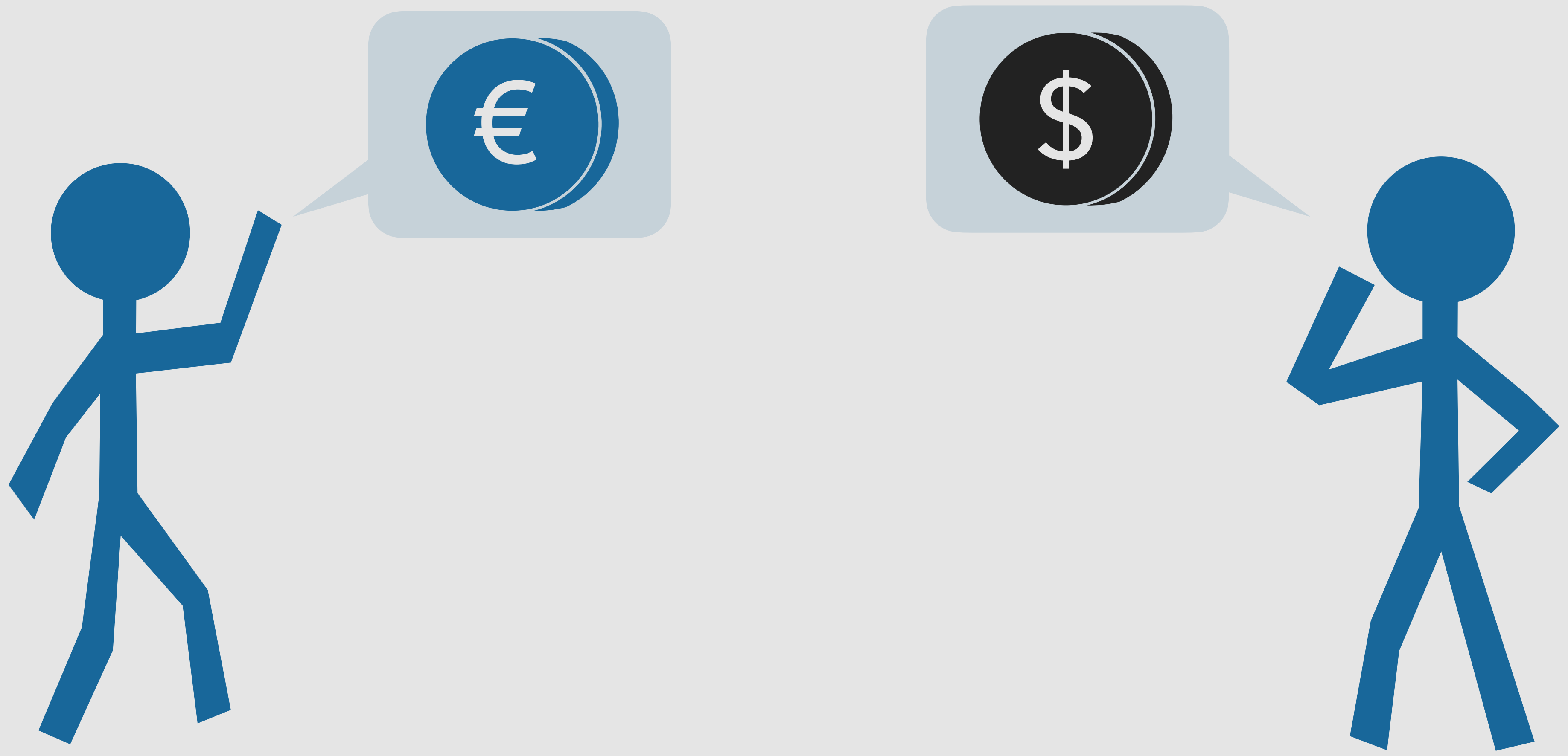
Example: *asynchronous coin swapping*



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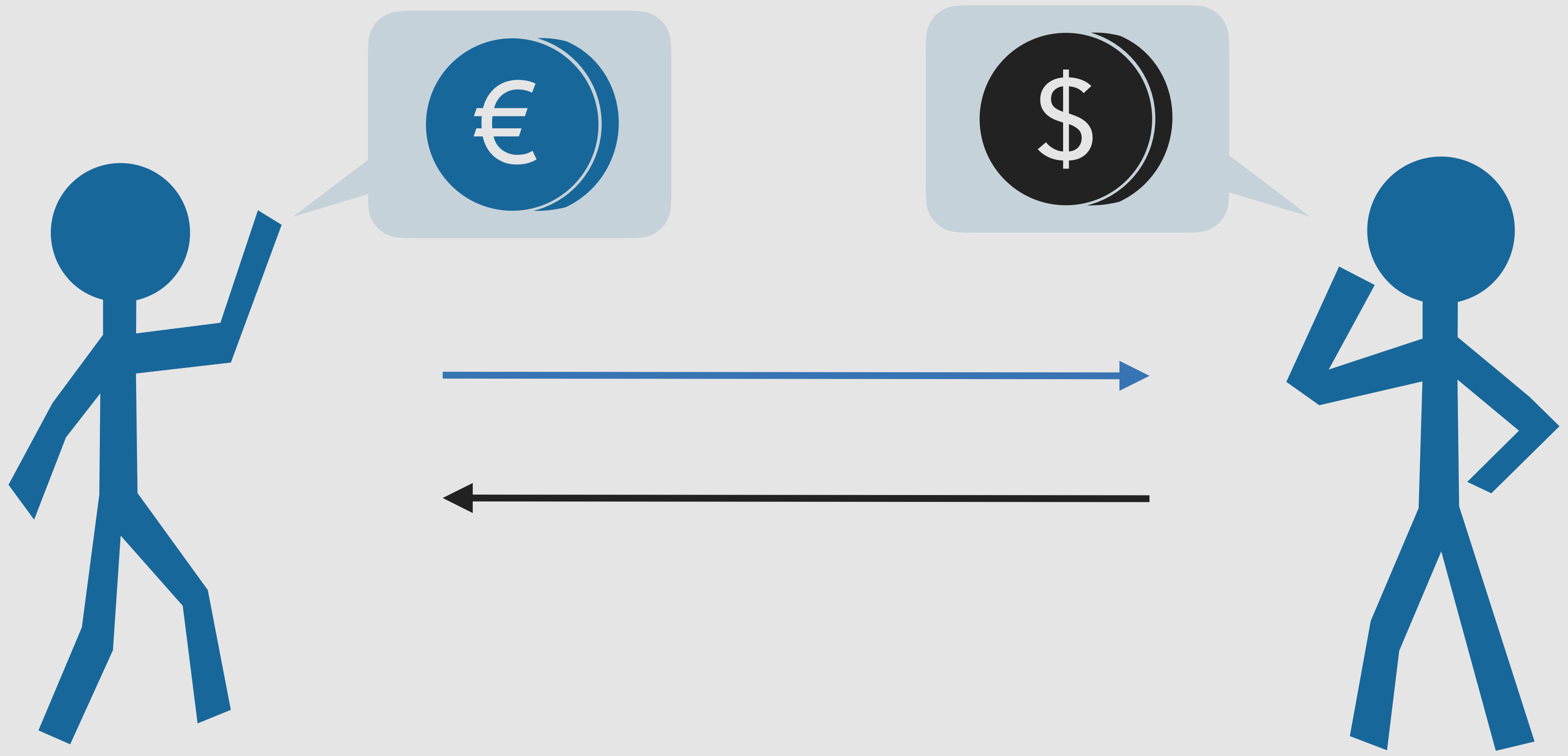

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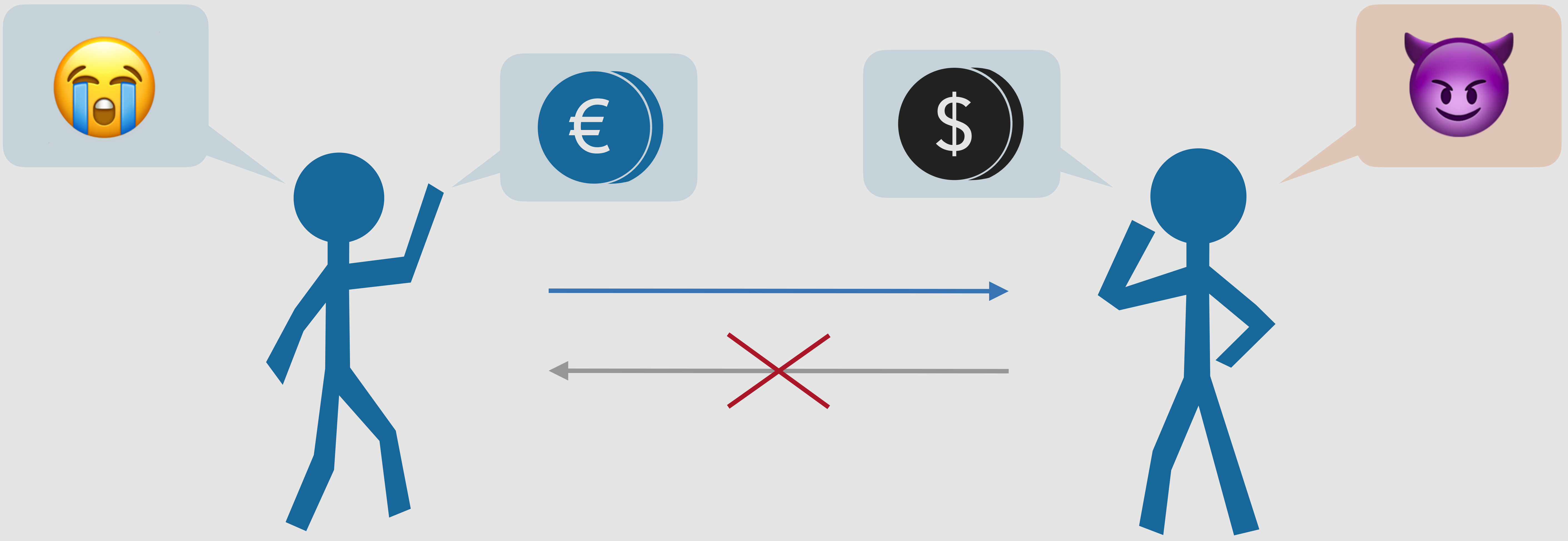
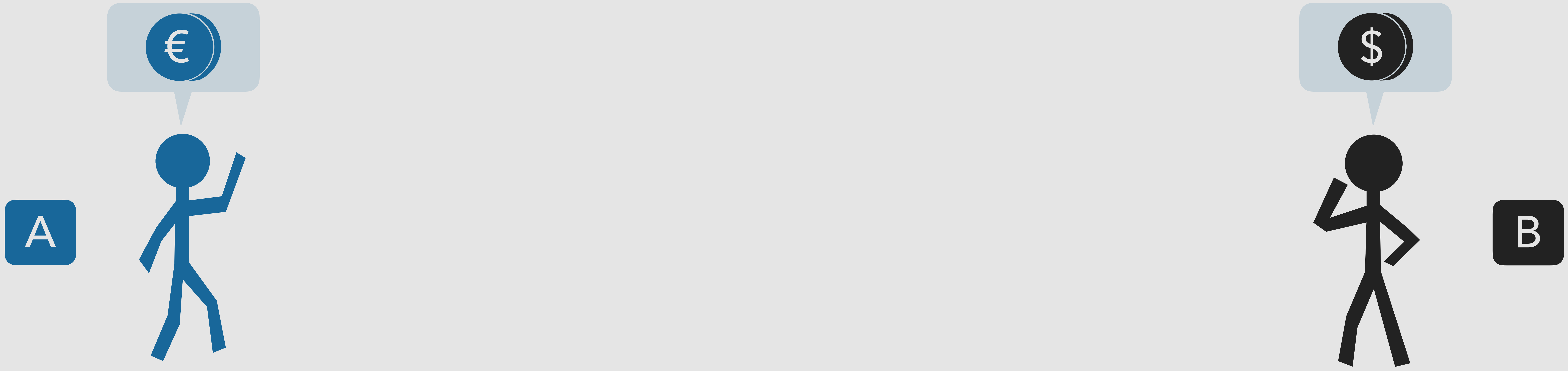


Practical solutions



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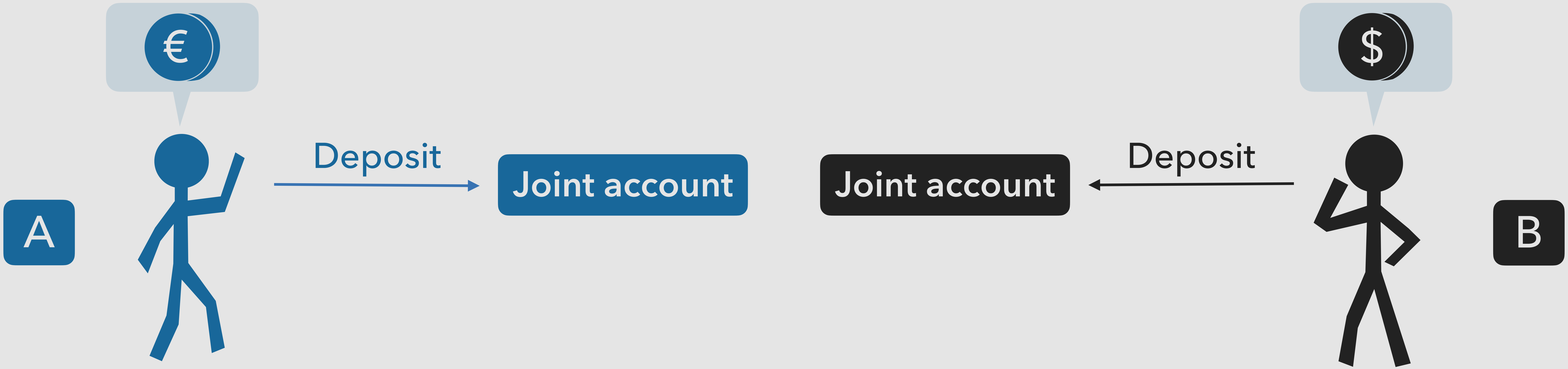

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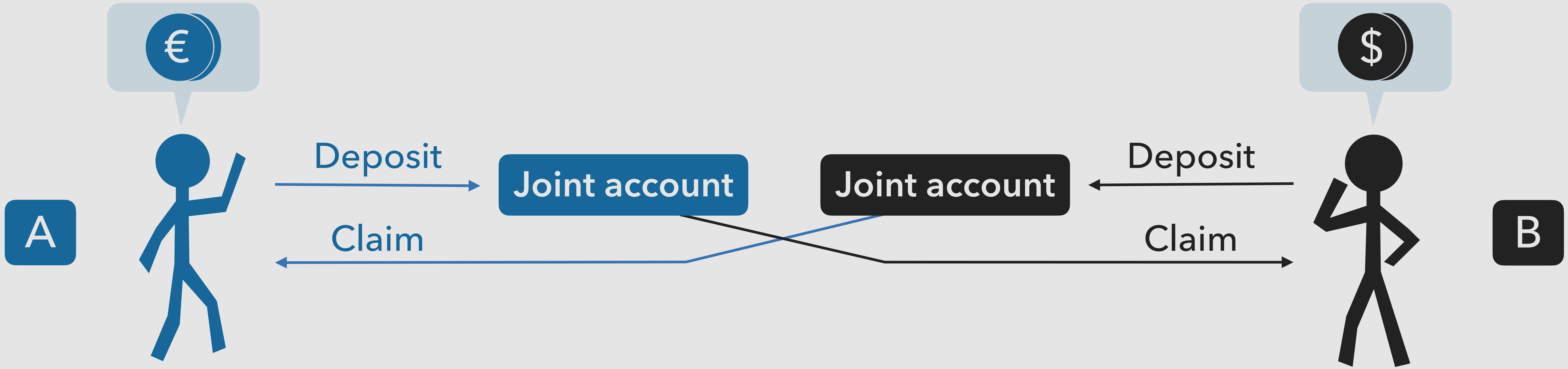

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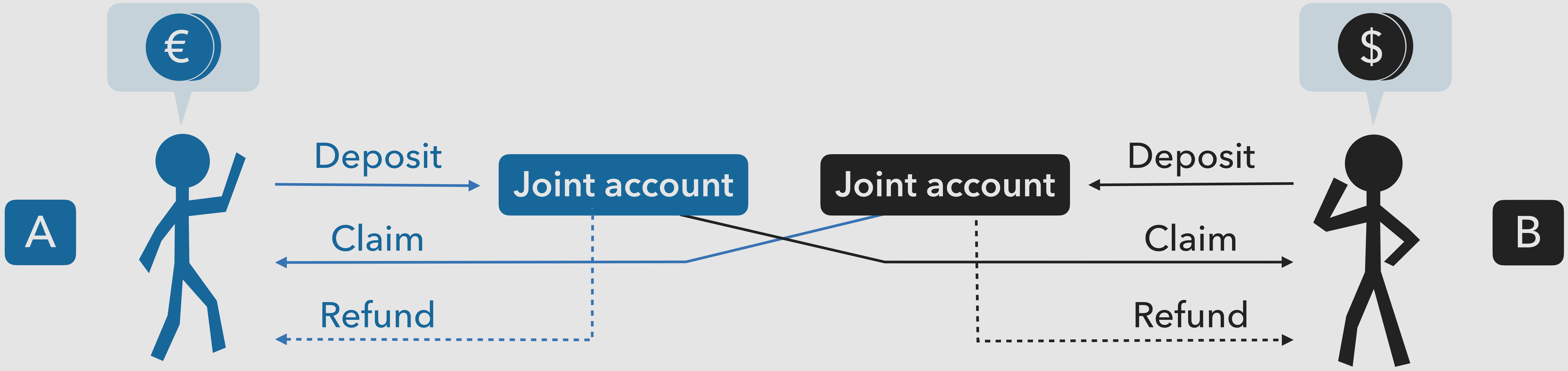

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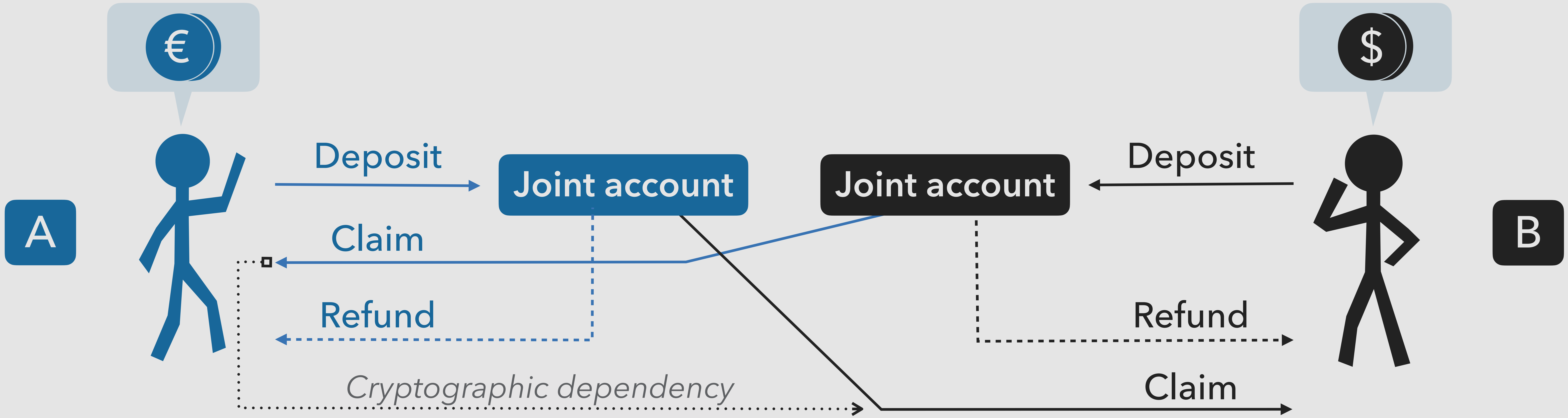

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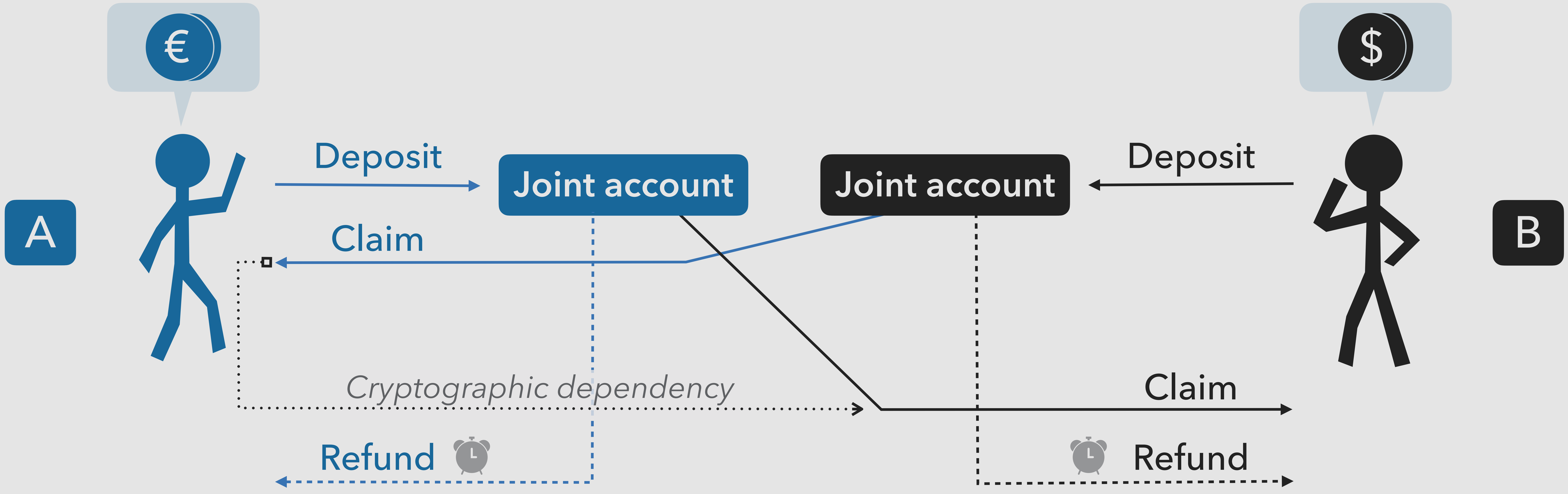
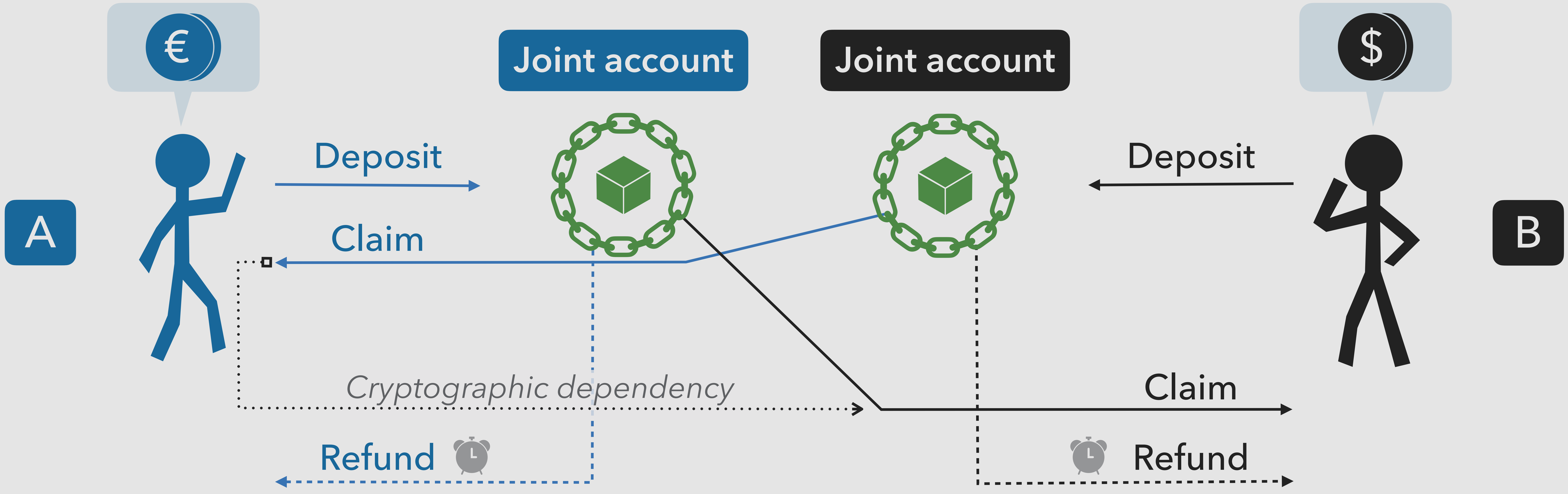


Practical solutions

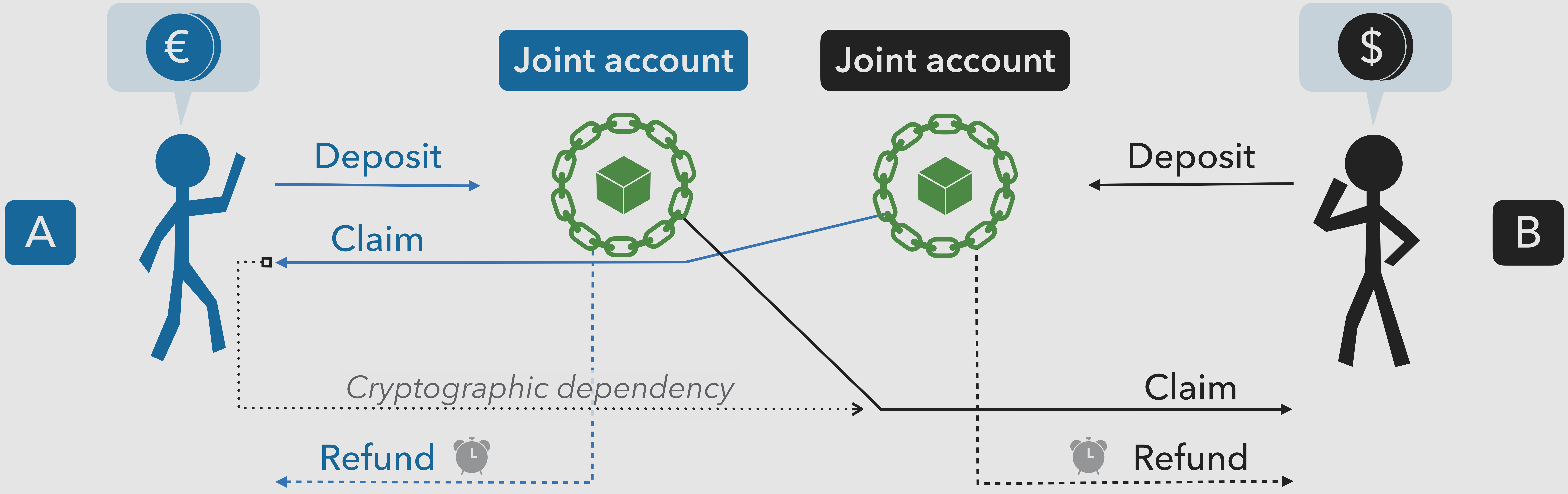
Blockchain(s): trusted public ledger(s) publishing transactions regularly



Practical solutions

Blockchain(s): trusted public ledger(s) publishing transactions regularly

Time lock: lower bound on the publication time of a transaction



Takeaway message

Enforcing fairness often requires:

Complex cryptographic interactions with a third party

Intricate real-time mechanisms

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✔ Good support from existing verification techniques

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Intricate real-time mechanisms

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Specifying real-time protocols

Planned features

```
// case 1: B also locked its coin within time Delta: continue
@t : t < t_start + Delta : inLedger(BLock) :

  // pre-sign. of A's payment
  let gx = st(x) in
  let in_ptx_APay = { nSequence = 0 ; id = id_ALock ; index = 0 } in
  let out_ptx_APay = { CLTV = 0 ; CSV = 0 ; pub = pkB' } in
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fixed-size array?

reduction to the binary case?

Be careful of standard frameworks!

When modelling fairness, the ability to perform some action or not has *consequences*

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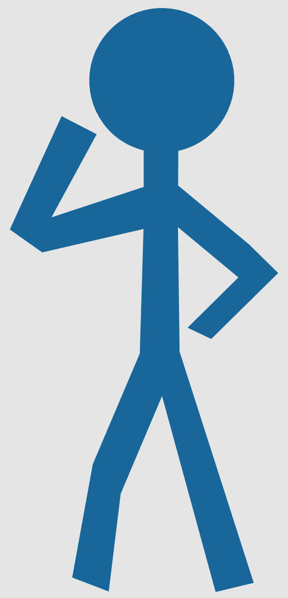
Option 1:
Wait for a transaction until time t

Option 2:
Fallback solution



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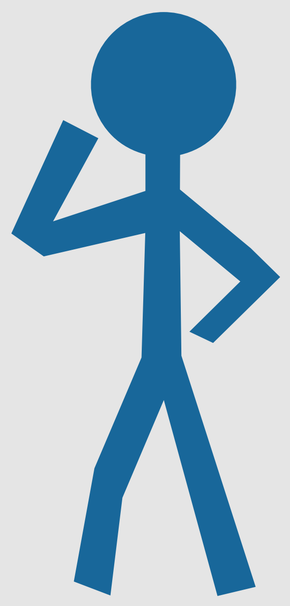

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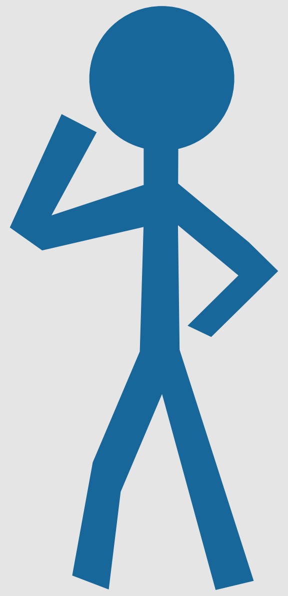

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Atomicity: certain operations should be done "*simultaneously*"

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Progress: one option should be chosen, if possible

Atomicity: certain operations should be done “*simultaneously*”

Process syntax

Parallel

P | Q

Replication

! P

Choice

P + Q

nil

0

tic

tic : P

output

out(u) : P

input

in(x) : P

event

Ev(ũ) : P

time stamp

@ t : P

time condition

when b : P

Process syntax

Structural operators

Parallel	Replication	Choice	nil
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Communications · *Security prop.*

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Time management

time stamp	time condition
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Atomicity

$$\mathit{instr} \,;\, \mathrm{P} \;=\; \mathit{instr} : \mathbf{tic} : \mathrm{P}$$

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Specifying temporal properties

*Security properties: tidy CTL**

G. Barthe, U. Dal Lago, G. Malavolta, I. Rakotonirina, 2022.
Tidy: symbolic verification of timed cryptographic protocols

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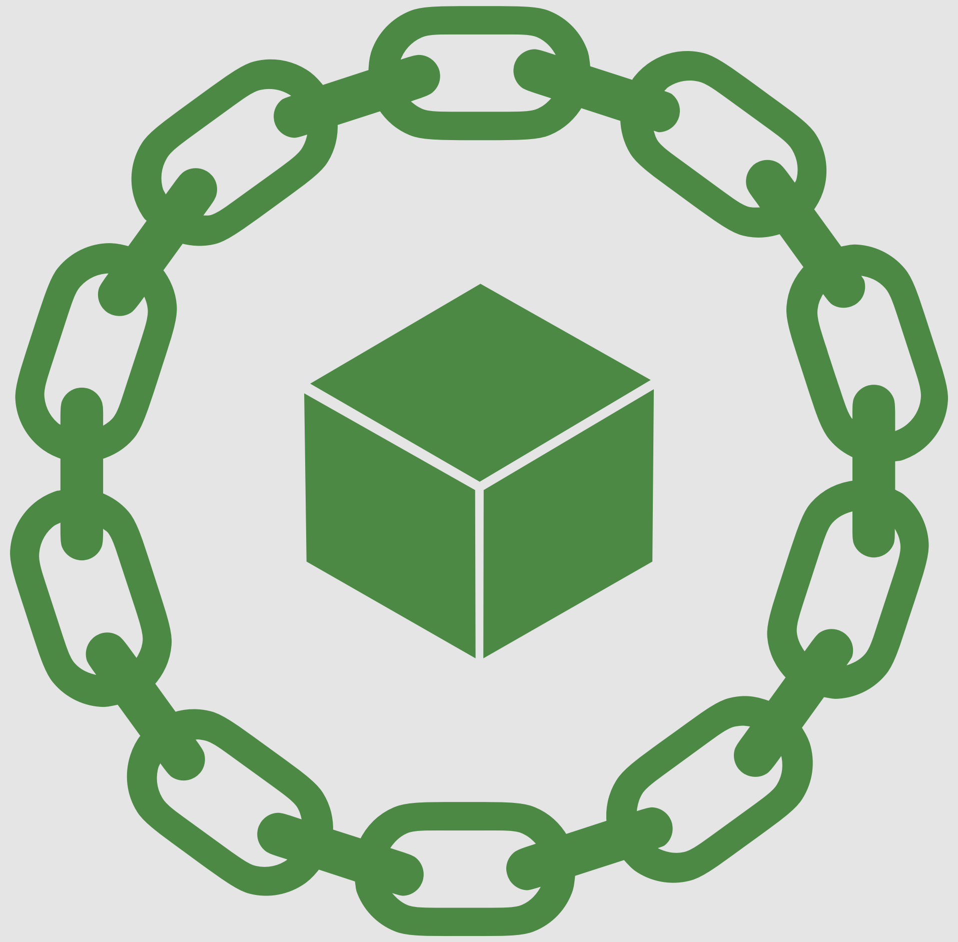

axiomatisation of a blockchain with time locks

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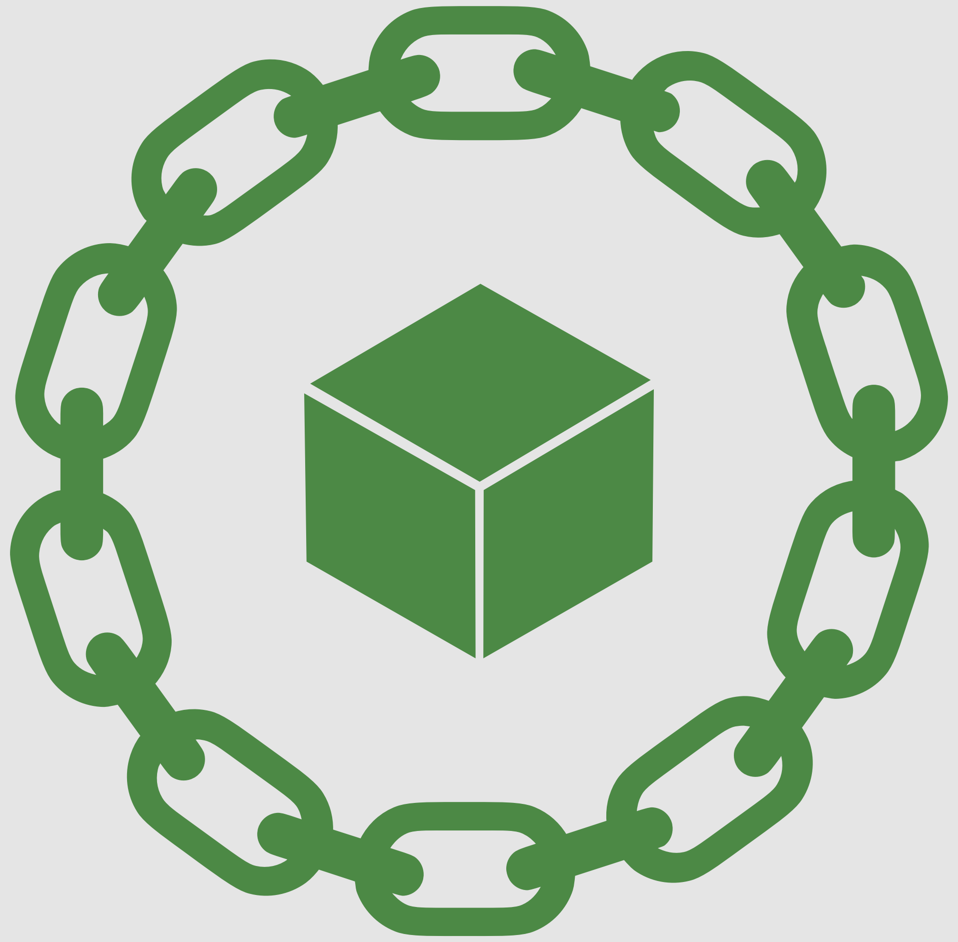

axiomatisation of a blockchain with time locks

Examples:

$$\mathbf{G}(\forall\, tx.\ \mathbf{Publish}(tx) \Rightarrow \mathbf{F}\ \mathit{doubleSpend}(tx) \Rightarrow \bot)$$

"at any point in the future"

"at some point in the future"

$$\forall\, tx.\ \mathbf{F}_{\mathrm{timeLock}(tx)}\ \mathbf{Publish}(tx) \Rightarrow \bot$$

"at some point in at most timeLock(tx) units of time"

Verifying real-time protocols?

(work in progress)

Verification chain

Calculus of concurrent processes

Proof / Attack

Verification chain

Calculus of concurrent processes

Sapic

Multiset rewrite rules

Proof / Attack

Verification chain

Calculus of concurrent processes

↓ ***Sapic***

Multiset rewrite rules

↓ ***Tamarin prover***

Proof / Attack

Verification chain

Calculus of concurrent processes

+ atomicity

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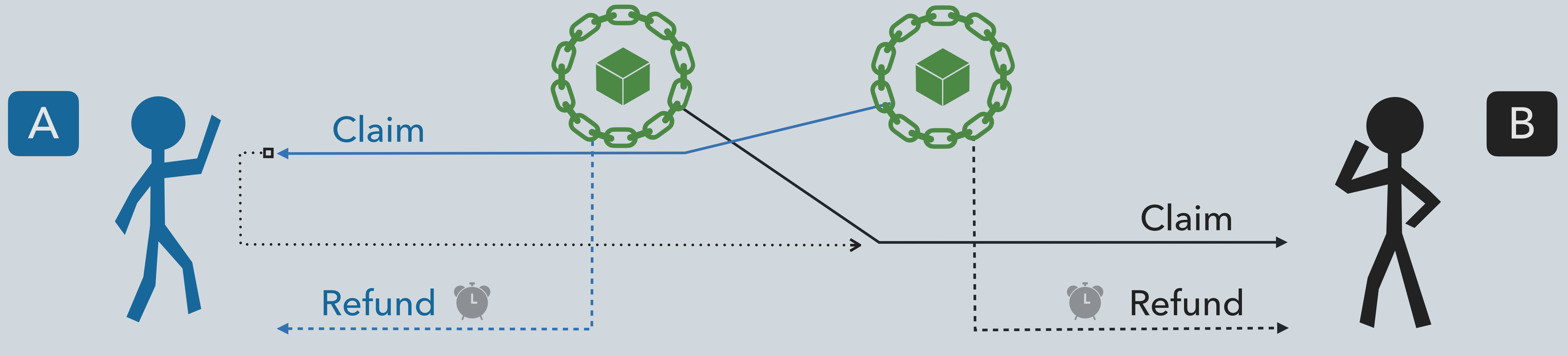
Proof / Attack

refinement if unsound attack

Typical unsound attacks



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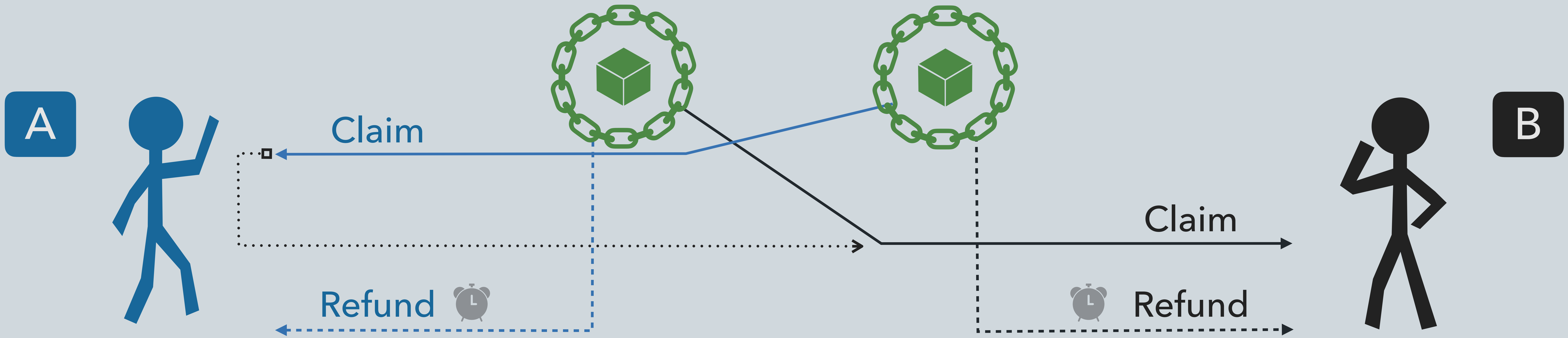

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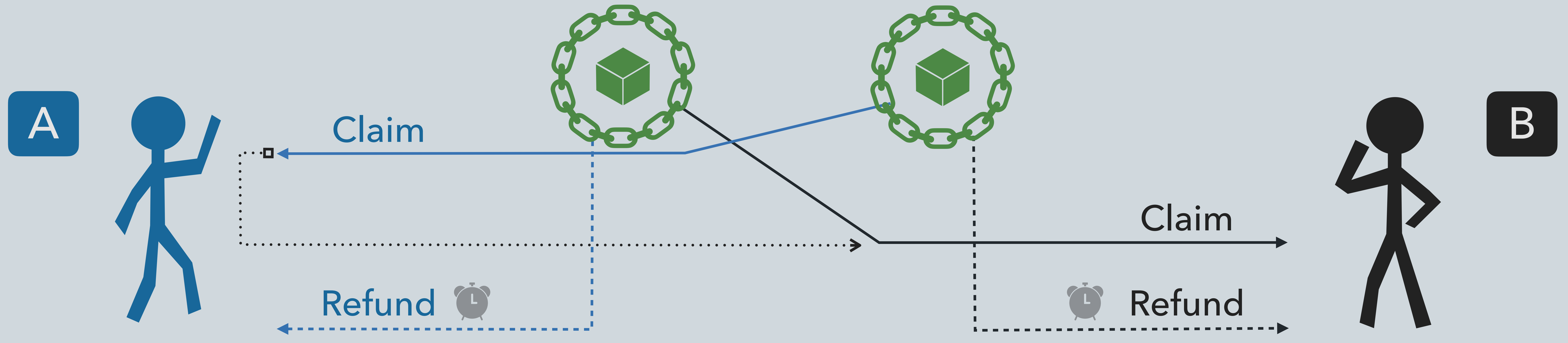

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⚠ *A's Refund timelock*

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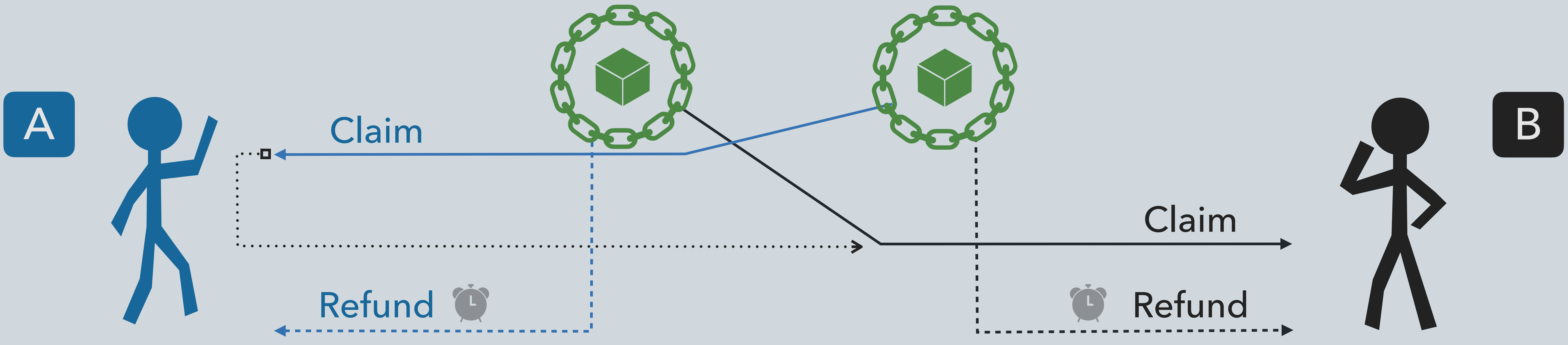

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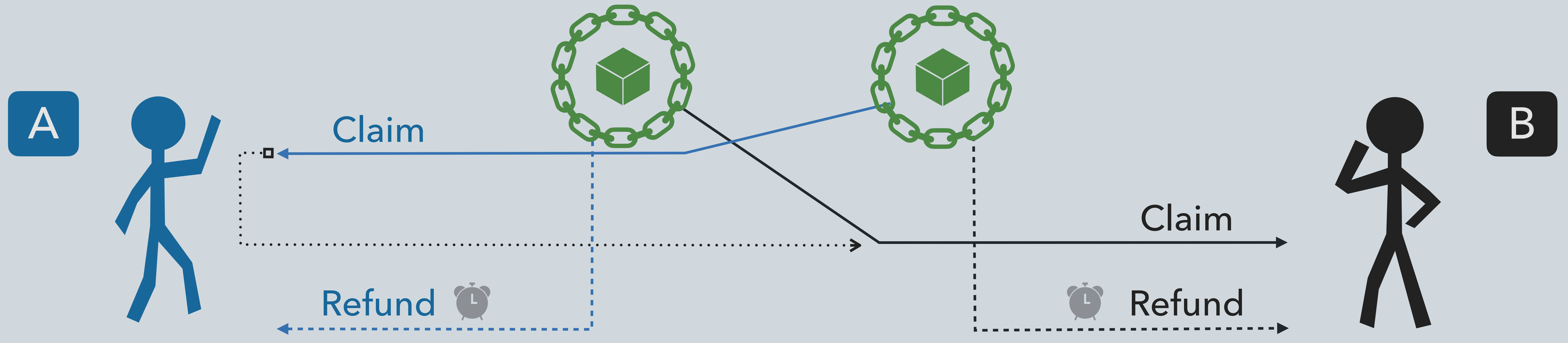

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⚠ *B's fast reactiveness*

Conclusion

A calculus supporting real time and atomicity

Formalisation of a Blockchain with time locks

In progress: extending/adapt Sapic to fit the workflow