

Comparative Analysis of Blockchain Technologies under a Coordination Perspective

Giovanni Ciatto¹

Michael Bosello¹
Andrea Omicini¹

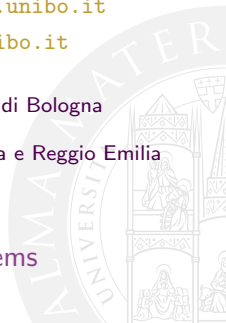
Stefano Mariani²

`giovanni.ciatto@unibo.it` `michael.bosello@studio.unibo.it`
`stefano.mariani@unimore.it` `andrea.omicini@unibo.it`

¹Dipartimento di Informatica – Scienza e Ingegneria—Università di Bologna

²Dipartimento di Scienze e Metodi dell'Ingegneria, Università di Modena e Reggio Emilia

2nd International Workshop on
BlockChain Technologies 4 Multi-Agent Systems
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Outline

- 1 What & Why
- 2 Ok, How?
- 3 Comparison
- 4 Cool, Then?



Next in Line...

- 1 What & Why
 - Coordination
- 2 Ok, How?
 - LINDA as a test-bed
- 3 Comparison
 - Ethereum
 - HyperLedger Fabric (HLF)
 - Corda
- 4 Cool, Then?



Premises

- a lot of BCT have been developed in the recent years
- some are simply aimed at improving **crypto-currencies**
- other are conceived to be **general** and track custom assets
 - through some sort of **programmability**
e.g. by means of smart contracts

Some foundational question arise

- can BCT be used to mediate the interaction of $\left\{ \begin{array}{l} \text{off-chain entities?} \\ \text{on-chain entities?} \end{array} \right.$
- can it be used for coordination?

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What is *Coordination*?

Within MAS

“A framework in which the **interaction** of **active** and independent entities called agents can be **expressed**” [Cia96]

active entities i.e., proactive, computationally autonomous

interaction dependencies among agents activities

- e.g. communication, cooperation, competition, etc.

expressed i.e., explicitly represented, or observed

Takeaway

Coordination studies interaction at the fundamental level

Wait: but *why* Coordination & BCT?

BCT provide highly-desirable properties

- *ordering* of events
- *consistency* among replicated data
- *accountability* of actions
- *identity* management
- (byzantine) *fault tolerance*

Especially in MAS!

Accountable, **trusted** communications, and **consistency** of information are long-standing issues for open MAS [RHJ04, HM15]

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Our test-bed – Tuple-based coordination in LINDA I

LINDA at a glance

Archetypal tuple-based coordination model [Gel85]

4 main elements

- tuples** — structured data chunks
- templates** — pattern language for tuples
- tuple spaces** — blackboards for tuples
- primitives** — put (OUT), or access, i.e. read (RD), or consume (IN)

3 main features

- generative** — tuples independent from agents
- associative** — tuples accessed through templates; no addr. & no ref.
- suspensive** — access attempts suspended if no tuple is available

Our test-bed – Tuple-based coordination in LINDA II

Useful in MAS?

TL;DR Yes! [OZKT01]

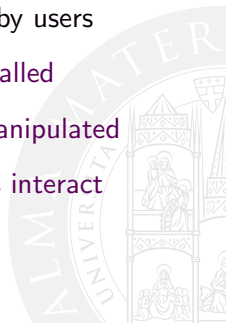
LINDA over BCT

- How can primitives be implemented on BCT?
- Can we reproduce suspensive semantics?
- Does it work for $\left\{ \begin{array}{l} \text{off-chain agents?} \\ \text{on-chain agents?} \end{array} \right.$
- Are there differences among BCT w.r.t. interaction?



Comparison Dimensions for BCT

- openness** — whether they are permissioned or permissionless
- access control** — degrees of freedom in controlling access to assets
- architecture** — main roles for nodes composing the BCT network
- state model** — how (i.e., in which form) the BCT tracks information
 - asset** — which sort of assets may be manipulated by users
- programmability** — how the programmable elements are called
- meta-primitives** — how programmable elements can be manipulated
 - primitives** — operations letting programmable elements interact
- consensus** — how the BCT supports consistency
- termination** — how BCT prevent infinite computations



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Ethereum at a Glance

openness → permissionless

access control → none

architecture → light nodes (clients) + full nodes (miners)

state model → accounts

asset → byte strings

programmability → smart contracts (SC)

meta-primitives → Deploy, Call

primitives → Call (inter-SC), Raise Event (SC-to-client)

consensus → Proof of Work (all miners)

termination → gas



LINDA over Ethereum

Details

| more in [CMO18]

tuple spaces \mapsto smart contracts

coordinated agents \mapsto clients

primitives \mapsto method calls through the Call meta-primitive

suspensive semantics \mapsto listening for events

Peculiarities

- economy of coordination [CMO18]

Shortcomings

- smart contracts cannot be coordinated agents
- no concurrency for primitives

HyperLedger Fabric (HLF) at a glance

openness → permissioned

access control → Membership service, Channels, Endorsement policies

architecture → peers + endorsement peers + ordering nodes

state model → Key-Version-Value (KVV) triplets

asset → KVV triplets

programmability → chaincodes (C)

meta-primitives → Deploy, Invoke, Query

primitives → Invoke (inter-C), SetEvent (C-to-peer)

consensus → pluggable (default: PBFT [CL02])

termination → execute-order-validate architecture [ABB+18]



LINDA over HLF

Details

tuple spaces \mapsto chaincodes

coordinated agents \mapsto peers

primitives \mapsto method calls through the Invoke meta-primitive

suspensive semantics \mapsto listening for events

Peculiarities

- finer control w.r.t. replication, consensus, tuple space access
- some degree of concurrency w.r.t. primitives

Shortcomings

- smart contracts cannot be coordinated agents
- workaround needed for completing multiple primitives at once

Corda at a Glance

openness → permissioned

access control → Doorman service + Flows

architecture → nodes + notary services (notaries)

state model → unspent transaction output (UTXO) + Vaults

asset → states

programmability → contracts

meta-primitives → none (contracts deployed by admins)

primitives → none (validation only)

consensus → pluggable (custom algorithm)

termination → not a problem (contracts are trusted)



LINDA over Corda

Details

tuple spaces \mapsto vaults

coordinated agents \mapsto nodes

primitives \mapsto state creation, or consumption

suspensive semantics \mapsto flows

Peculiarities

- subjective visibility of tuples in tuple spaces
- some degree of concurrency w.r.t. primitives

Shortcomings

- ! tight coupling among coordinated agents

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Takeaways

The good

- BCT can in general be used for coordination **off-chain**
- permissioned BCT allow for a **finer** control w.r.t. tuple **visibility** to off-chain entities

What can be improved

- **on-chain** computational entities may benefit coordination as well
 - because they can be conceived as **agents** [CMMO19]
 - even if this is currently **poorly understood** by the community

The bad

- LINDA-based coordination is **not** fully supported by Corda

Conclusion

Summarising, we

- compared three programmable BCT, namely Ethereum, HLF, & Corda
- w.r.t. the coordination perspective, by implementing LINDA on them
- thus testing capabilities, peculiarities, and limits of BCT
- and showing that smart contracts fall short w.r.t. mutual interaction

In the future, we plan to

- extend our comparison to more technologies
- propose a novel programmable BCT overcoming current limitations

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