Emerging Technologies for the Circular Economy

Lecture 14: The Machine-to-Everything (M2X) Economy - A step towards the Circular Economy 2.0?

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A Data-Driven Smart Circular Economy Framework

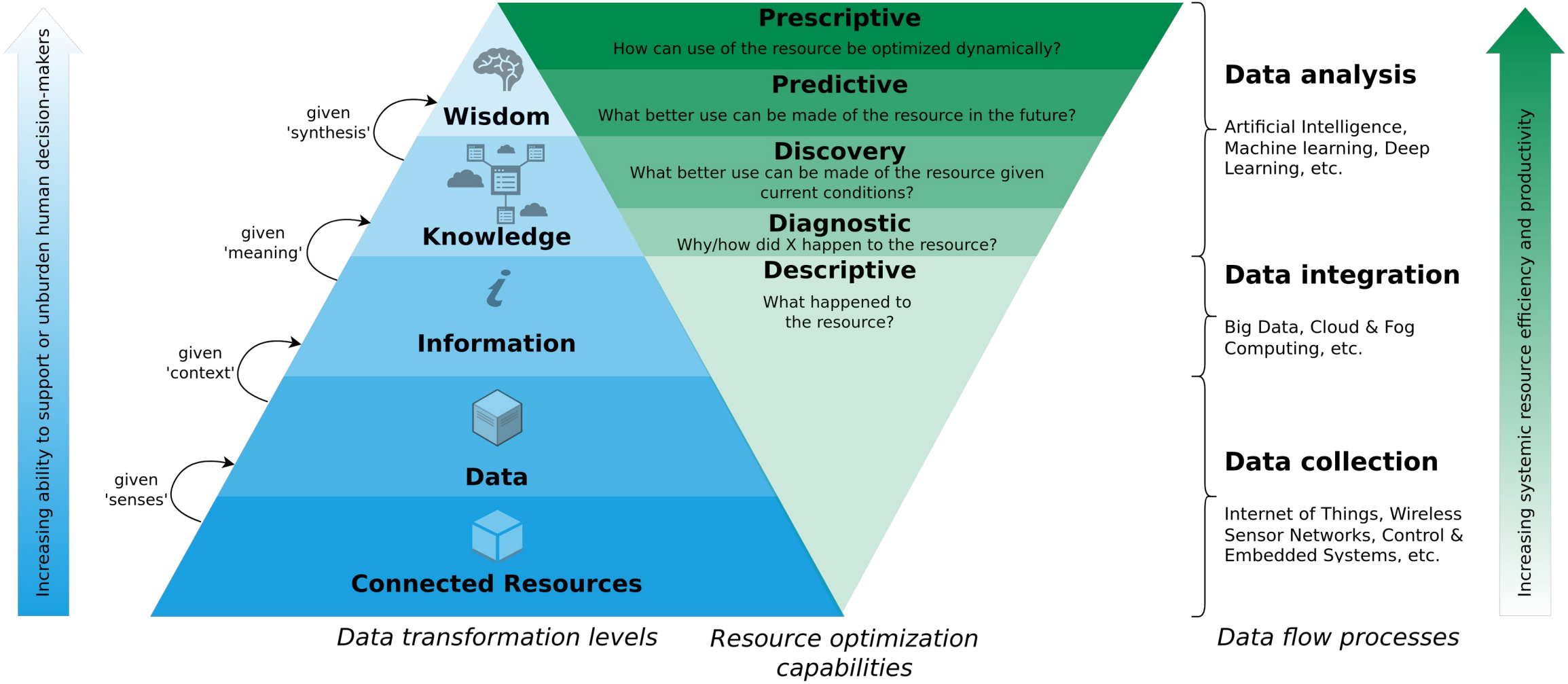


Image recreated based on Kristoffersen et al. (2020) – The smart circular economy: A digital-enabled circular strategies framework for manufacturing companies.

The Nature of Technology

- In the past many new technologies have emerged and disrupted existing economical models.

- B. Arthur stipulates that an *economy is an expression of its technologies*
  - → Thus, it can be argued that the current unsatisfying state of the Circular Economy reflects a lack of sufficiently developed technologies that express themselves within the CE.
  - → Or, more precisely – difficulties of the stakeholders in combining the technologies that are required to enable the CE.

Arthur, Brian (2011) – The Nature of Technology: What It Is and How It Evolves.

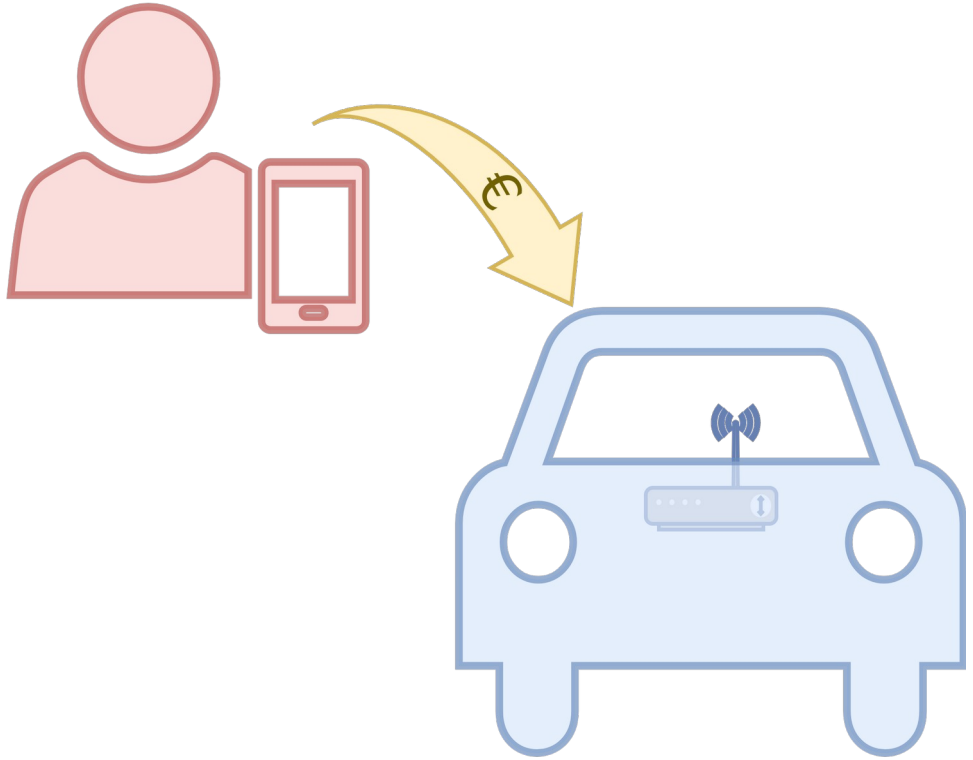
Performance Economy to Sharing Economy

Image recreated based on Walter R. Stahel (2019) – The Circular Economy: A User's Guide.

INTRODUCTION

Machine-to-Human (M2H)

- Machine-to-Human (M2H)
- For example → Transportation-as-a-Service



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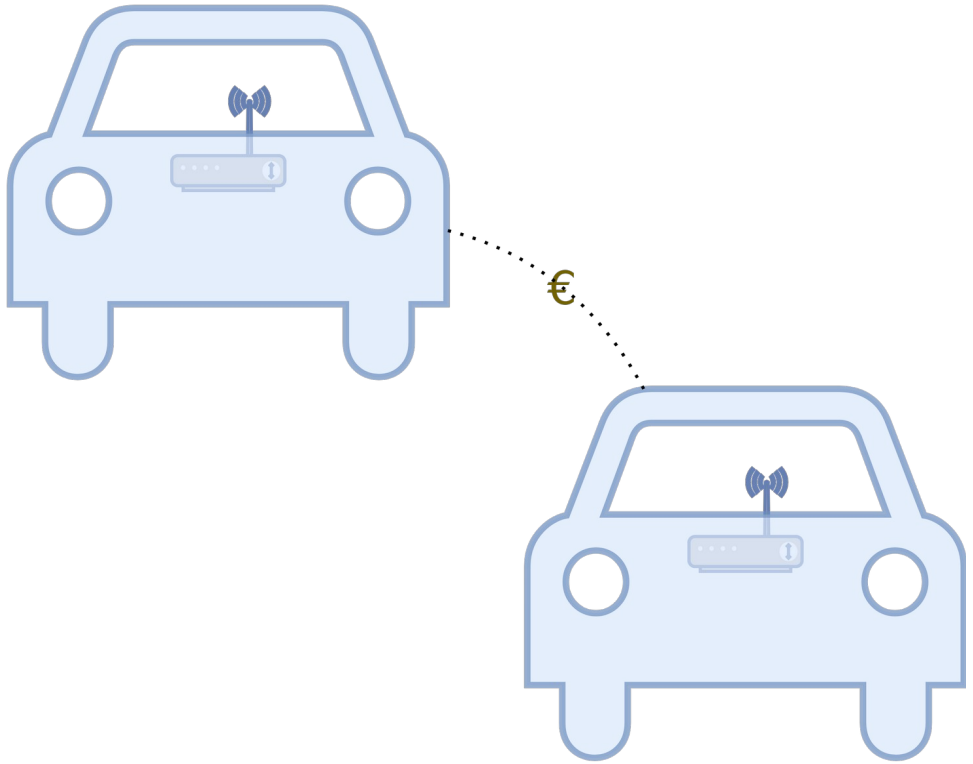
Machine-to-Machine (M2M)

- Machine-to-Machine (M2M)
- For example → Road space negotiations



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Machine-to-Infrastructure (M2I)

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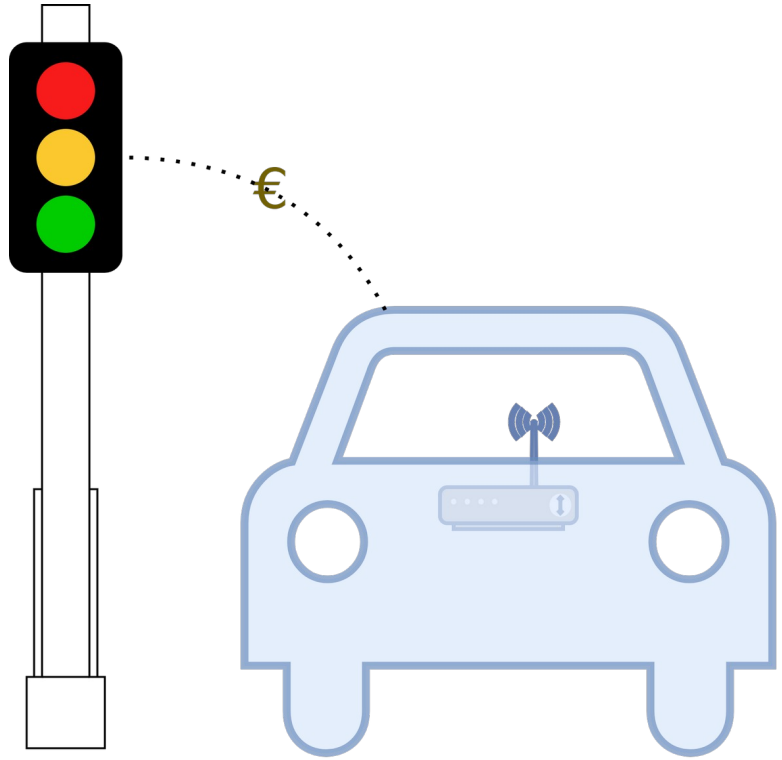
- For example → Smart parking, electric vehicle charging or traffic information



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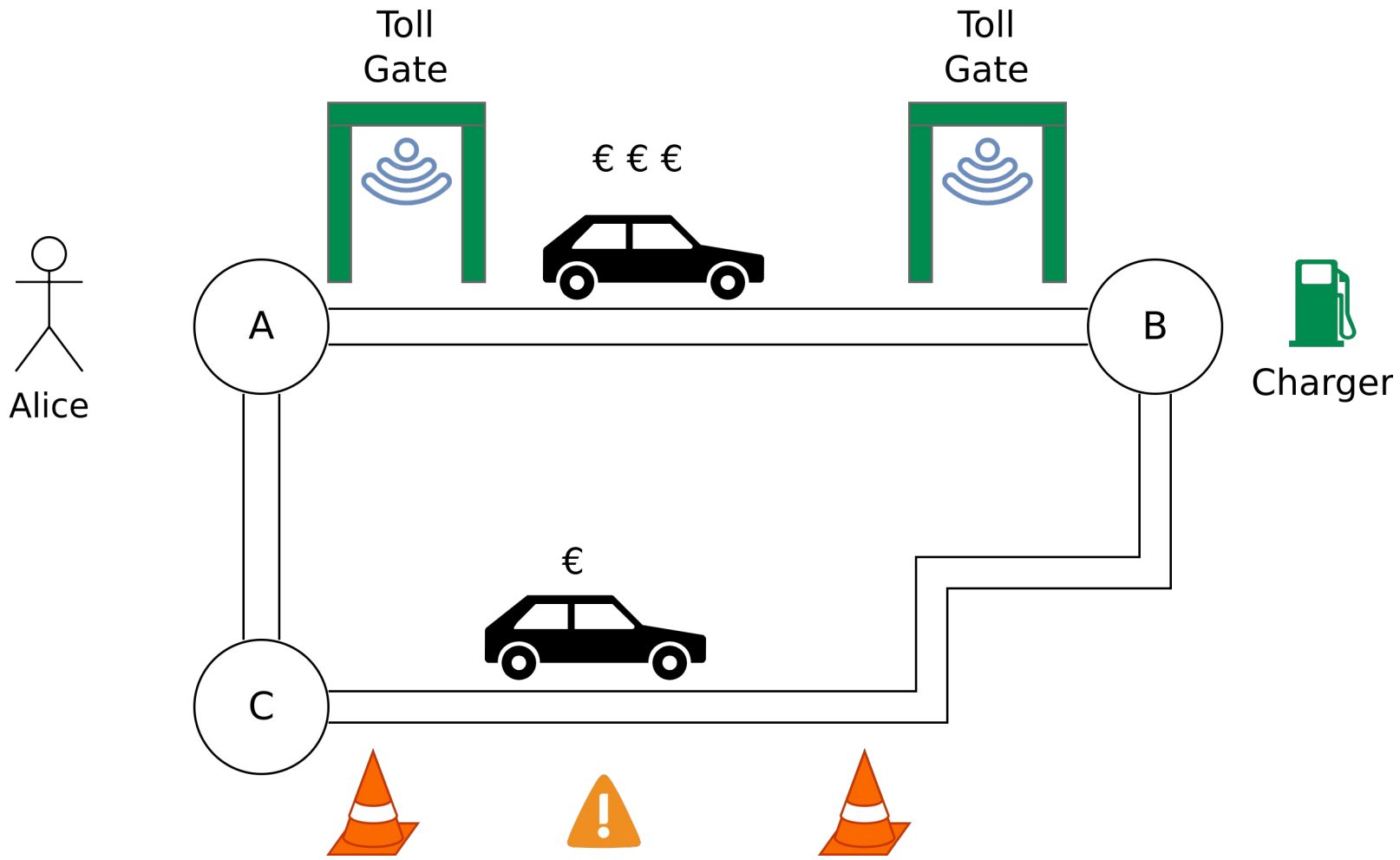
Running Case



MOBI Grand Challenge 2019 – Chorus Mobility

Transforming Urban Mobility

MOBI Grand Challenge Submission Video

THE M2X ECONOMY

M2X Economy

Machine-to-Human (M2H)

+

Machine-to-Machine (M2M)

+

Machine-to-Infrastructure (M2I)

=

Machine-to-Everything (M2X)

M2X Economy

Machine-to-Human (M2H)
+
Machine-to-Machine (M2M)
+
Machine-to-Infrastructure (M2I)
=
Machine-to-Everything (M2X)

M2X Economy → Is the result of business interactions, transactions and collaborations among entities of the M2X ecosystem.

M2X Economy – Definition

"The M2X Economy is the result of interactions, transactions, collaborations and business enactments among humans, autonomous and cooperative smart devices, software agents, and physical systems.

The corresponding ecosystem is formed by automated, globally-available, heterogeneous socio-technical e-governance systems with loosely coupled, P2P-resembling network structures and is characterized by its dynamic, continuously changing, interoperable, open and distributed nature. Thereby, the M2X Economy employs concepts such as cyber-physical systems, the Internet of Things, and wireless sensor networks."

B. Leiding, P. Sharma, A. Norta, "The Machine-to-Everything (M2X) Economy: Business Enactments, Collaborations, and e-Governance", Future Internet 13.12 (2021): 319.

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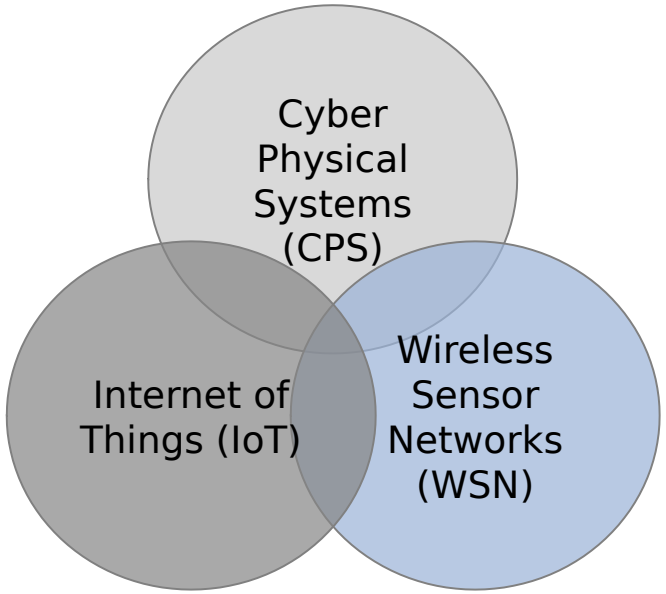
State of the Art – IoT, CPS, WSN, etc.



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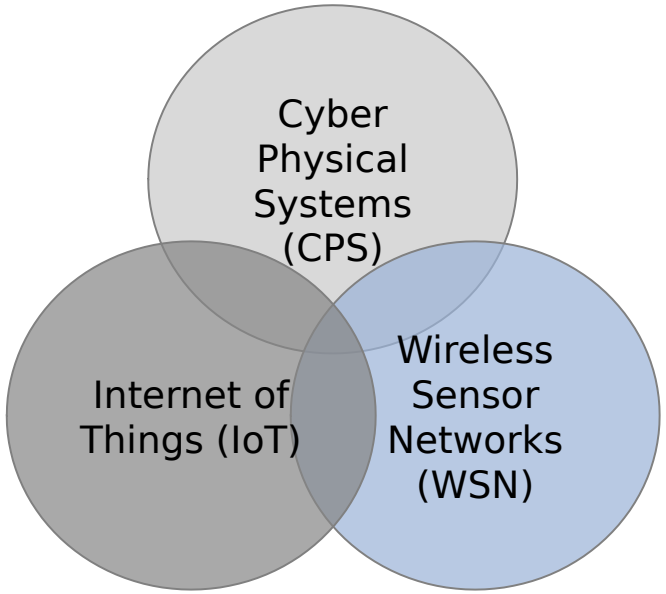

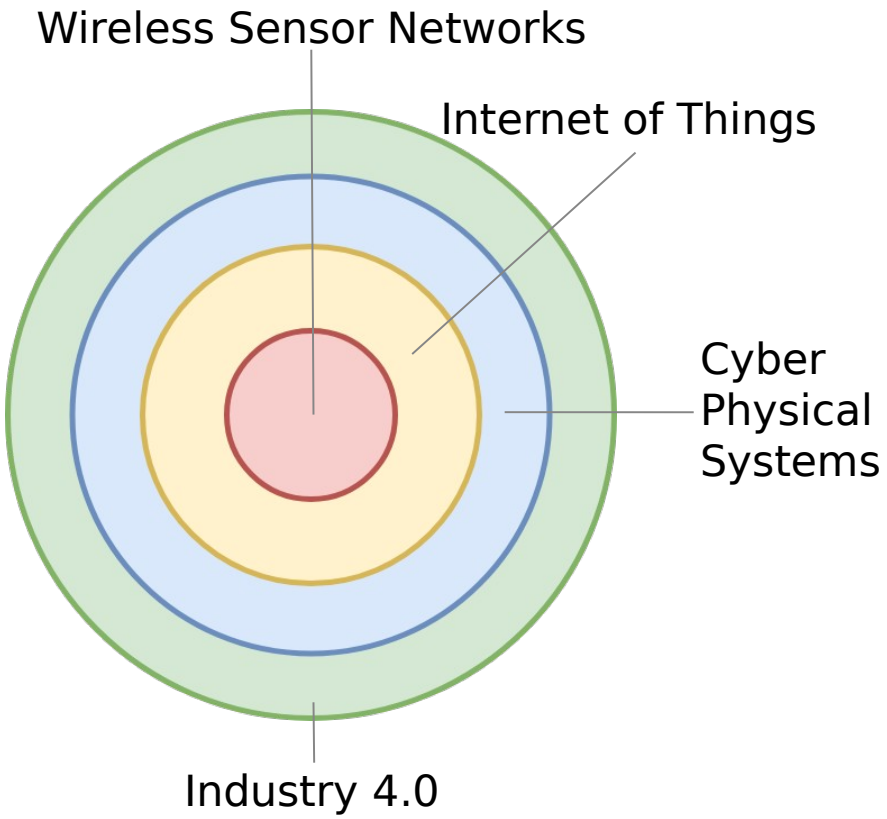

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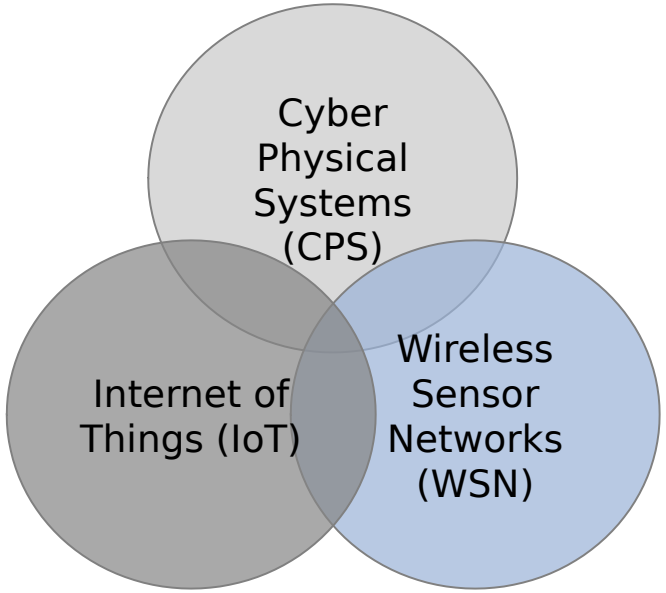
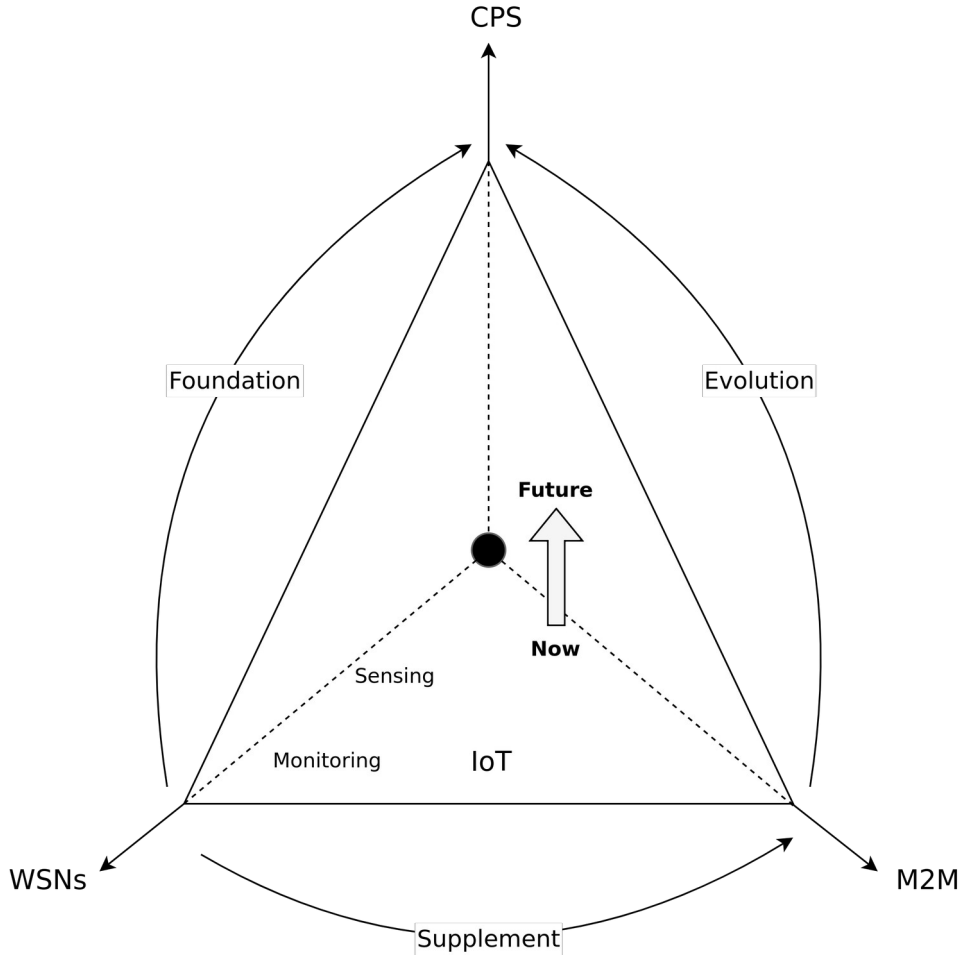
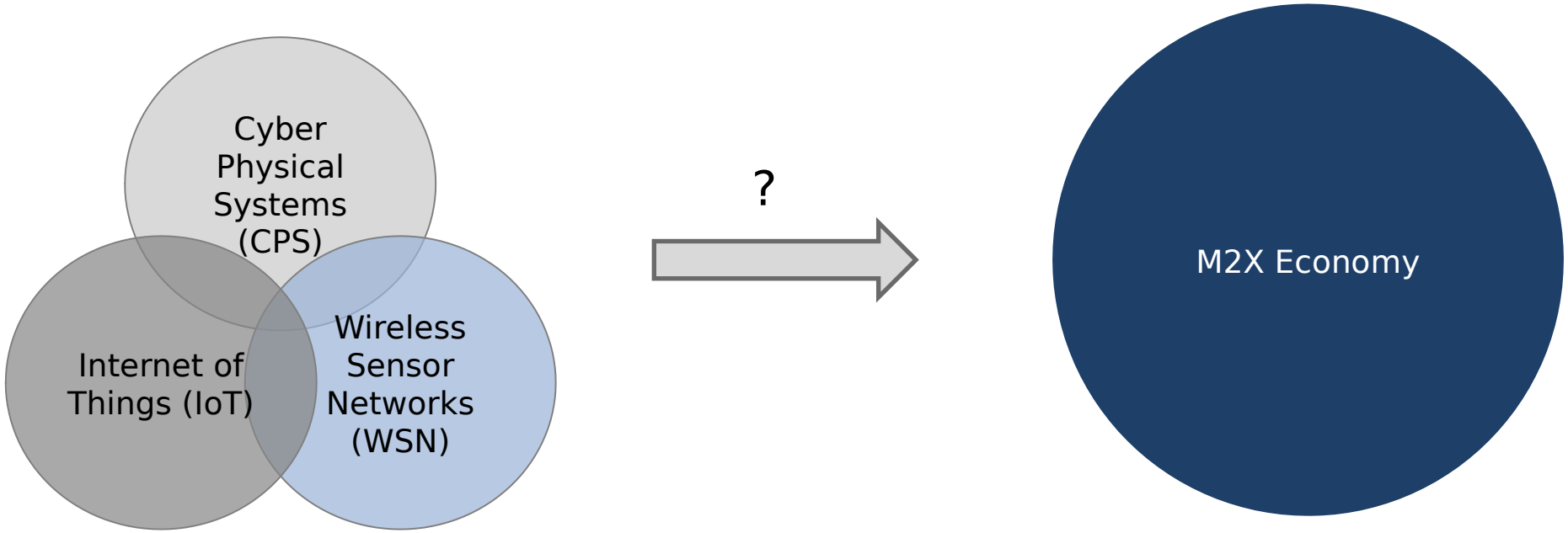




Based on: Misic and Misic (2014) – Machine-to-Machine Communications: Architectures, Technology, Standards, and Applications.

What is missing?



What is missing?

The M2X Economy

—

Concepts for Business Interactions, Transactions and Collaborations Among Autonomous Smart Devices

Dissertation
for the award of the degree
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within the Doctoral program Ph.D. Programme in Computer Science (PCS)
of the Georg-August University School of Science (GAUSS)

Submitted by
Benjamin Leiding

from Rostock (place of birth)
Göttingen 2019

THE M2X ECONOMY – BUILDING BLOCKS

Everything is a Contract

- TaaS, road space negotiations, smart parking, electric vehicle charging, toll gate payments, etc.
  → Roughly the same process

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- Abstraction towards a general lifecycle for value exchange, collaborations, and business enactments of the M2X Economy

→ We stipulate that all M2X-related interactions, transactions, collaborations, and further enactments can be governed and represented using a blockchain-based smart contract.

Contracts

- Traditional understanding of a contract:
  - Written or spoken agreement enforceable by law
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  - Written or spoken agreement enforceable by law
  - Parties involved voluntarily engage to establish a consensus

- In most business cases, contracts:
  - are documents
  - identify the contracting parties uniquely
  - describe service that is offered for some form of compensation
  - list a set of additional clauses such as service-delivery dates, penalties, etc.

Contracts

- But traditional contracts:
  - are often underspecified → does not work for machines
  - do not provide sufficient details about the actual transaction process
    → friction between the contracting parties, e.g., one party assumes a specific product certificate before delivering a partial compensation and the other party assumes the opposite

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- Deadlocks lead to costly conflict resolutions, or even a collapse of the entire contract transaction.
- Enforcement of traditional contracts proves to be either too complicated, time consuming, or impossible, certainly in international circumstances.

Electronic Contracts

So what is the solution?

Electronic Contracts

So what is the solution?

- Electronic smart contracts
  - Enable and govern business transactions using a computerized transaction protocol such as a blockchain
  - Smart contracts are computer programs for the consistent execution by a network of mutually distrusting nodes where no arbitration of a trusted authority exists
  - Readable/processable by machines and humans alike

→ Fact tracking, non-repudiation, auditability, and tamper-resistant storage of information in a distributed multi-stakeholder setting, e.g., the M2X Economy.

Blockchain Technology

- Append-only data structure secured by interconnected hashes
- Distributed and decentralized data storage with a global consensus mechanism
  - Neutral territory between stakeholders
  - Immutability
  - Non-repudiation and auditability

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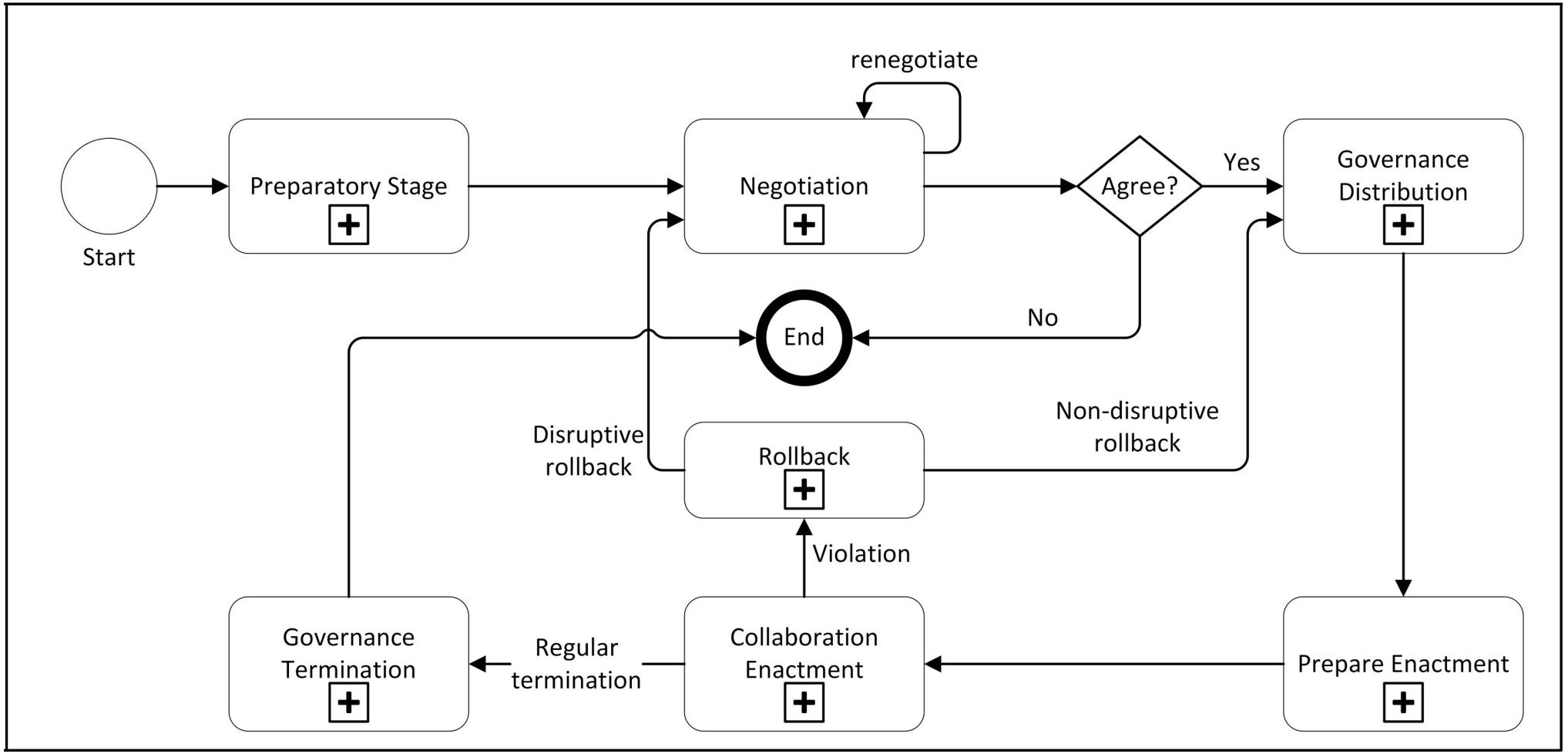
- Append-only data structure secured by interconnected hashes
- Distributed and decentralized data storage with a global consensus mechanism
  - Neutral territory between stakeholders
  - Immutability
  - Non-repudiation and auditability
- Enables Smart Contracts:
  - On-chain programs → State changes stored on-chain
  - Autonomous, deterministic and auditable execution of programs

Digital Contract Lifecycle



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Lifecycle – Preparatory Stage

- Select contract based on pre-configured templates provided by a corresponding business hub, e.g., blockchain
- Collect entity-related information:
  - Identifiers
  - Wallet addresses
  - Location
  - Jurisdiction
- Specify contract conditions:
  - Departure location
  - Final destination
  - Vehicle size
  - Departure/arrival time

Lifecycle – Negotiation

- Negotiate an agreement among the involved stakeholders
- Essentially:

Needs of the client (get from A to B) vs. needs of the service provider (compensation for service)

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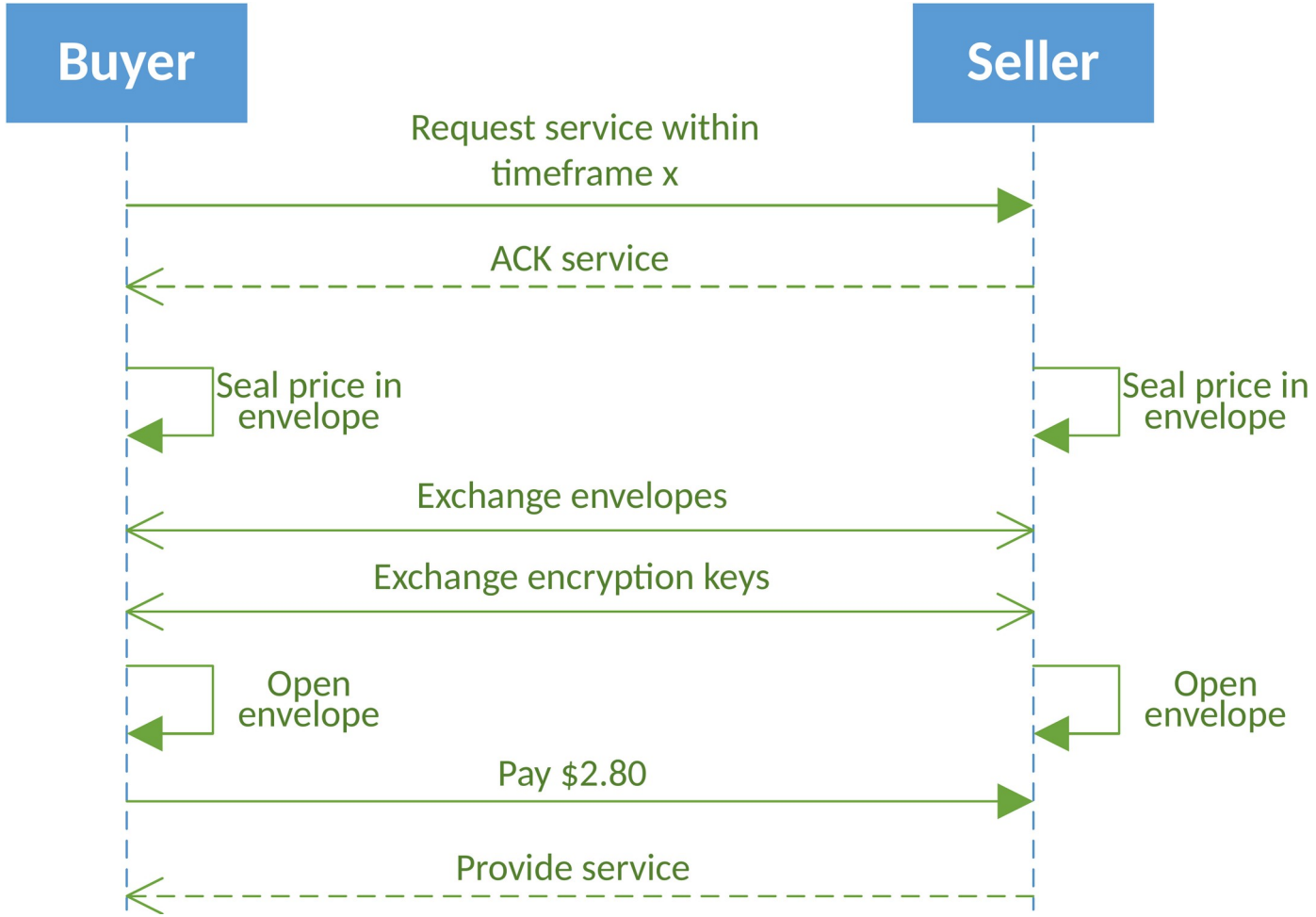
Needs of the client (get from A to B) vs. needs of the service provider (compensation for service)

- In case the entities agree on the negotiated conditions → All involved parties sign the contract and express their approval
- In case no agreement is reached → Trigger contract rollback

Auctions and Negotiations – 1-to-1



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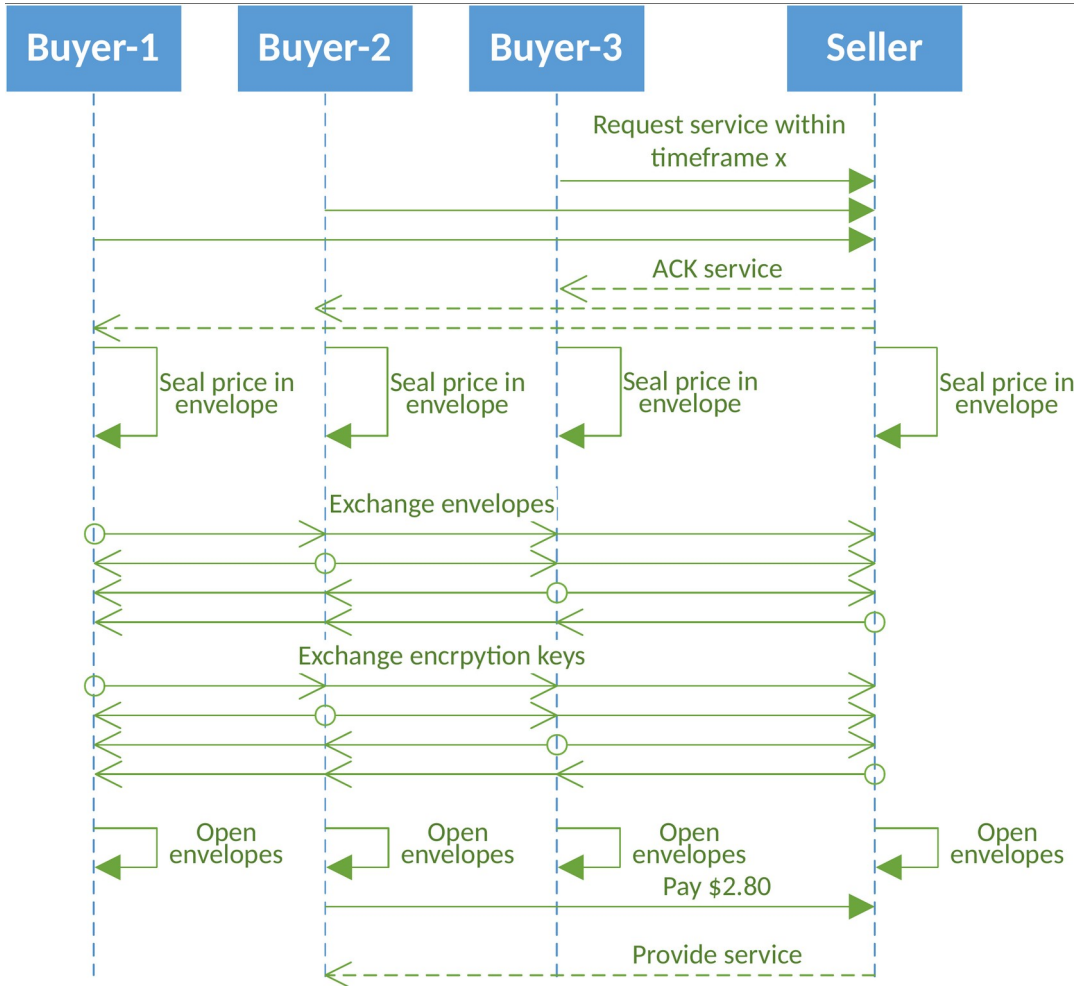
Auctions and Negotiations – 1-to-Many



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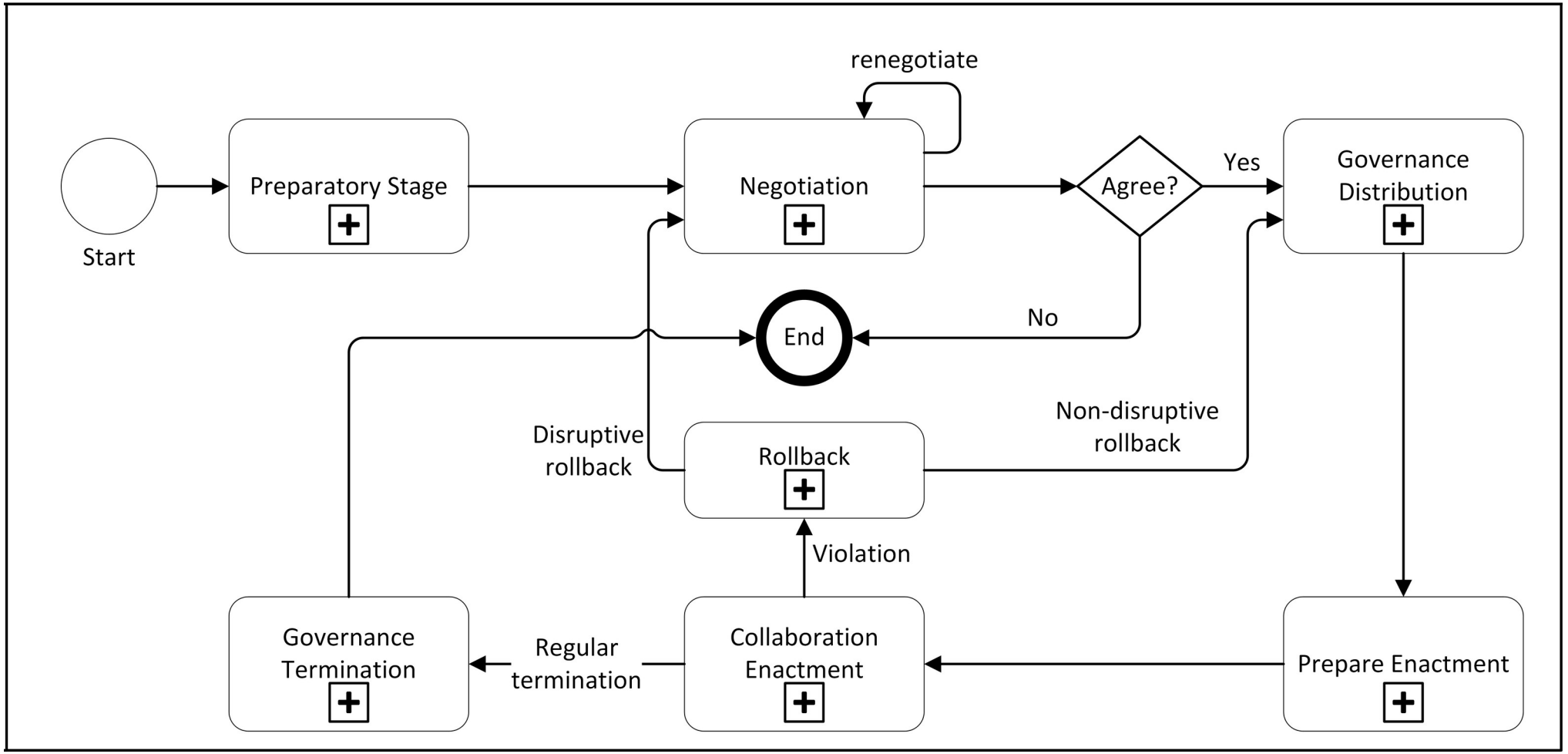

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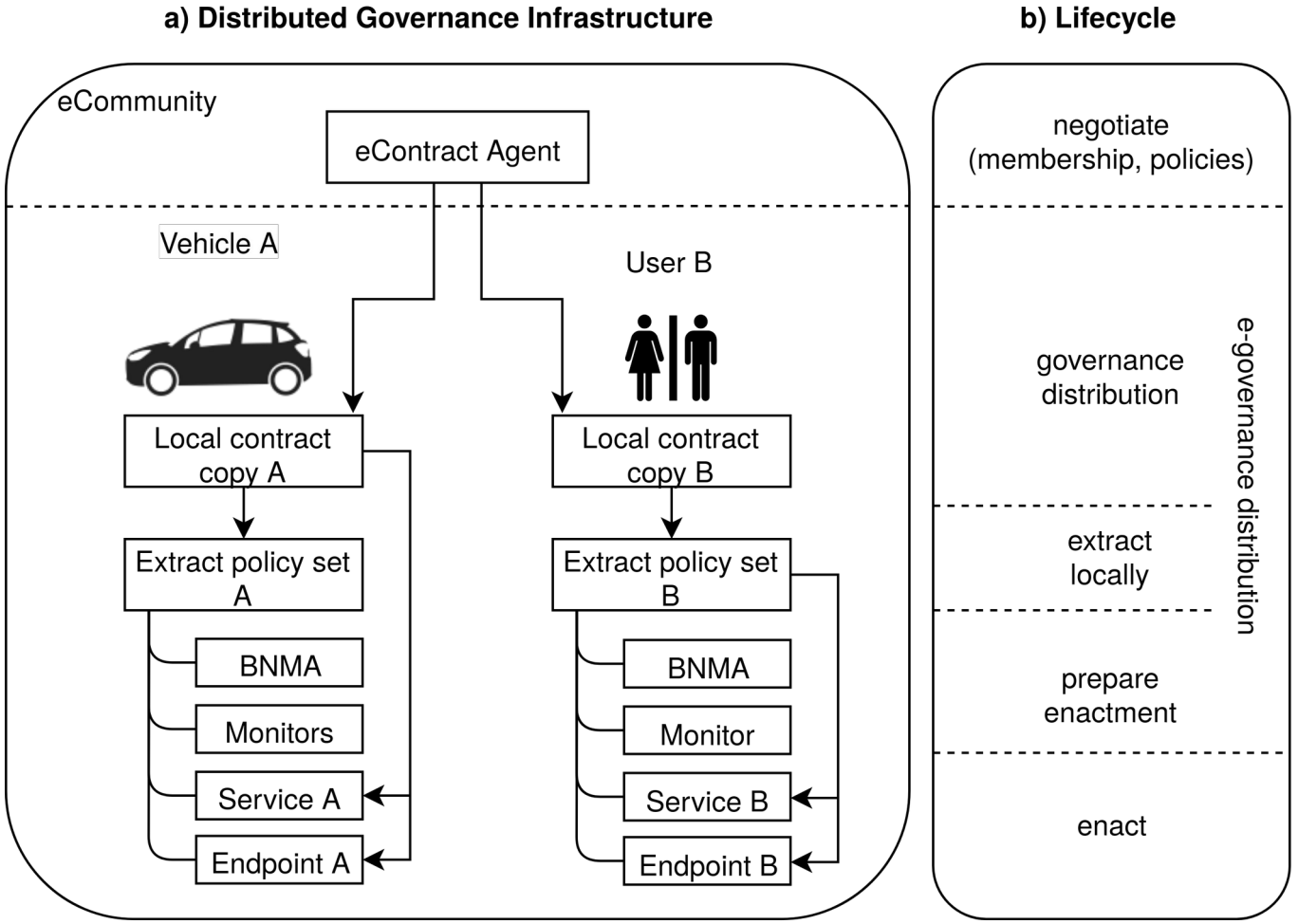
Lifecycle – Governance Distribution

- A smart contract between the involved parties is established and serves as a DGI (distributed governance infrastructure)-coordinating agent
- Each participating entity receives a local contract copy containing the rights and obligations of each party
  - e.g., transporting the user to the correct location
- Obligations are observed by monitoring services or monitors, e.g., IoT-sensors

Lifecycle –Prepare Enactment

- Prepare and provide concrete required process endpoints, e.g., for payment processing
- Creation of communication endpoints so that the services of the partners are able to communicate with each other
- Liveness check of connected services

Governance



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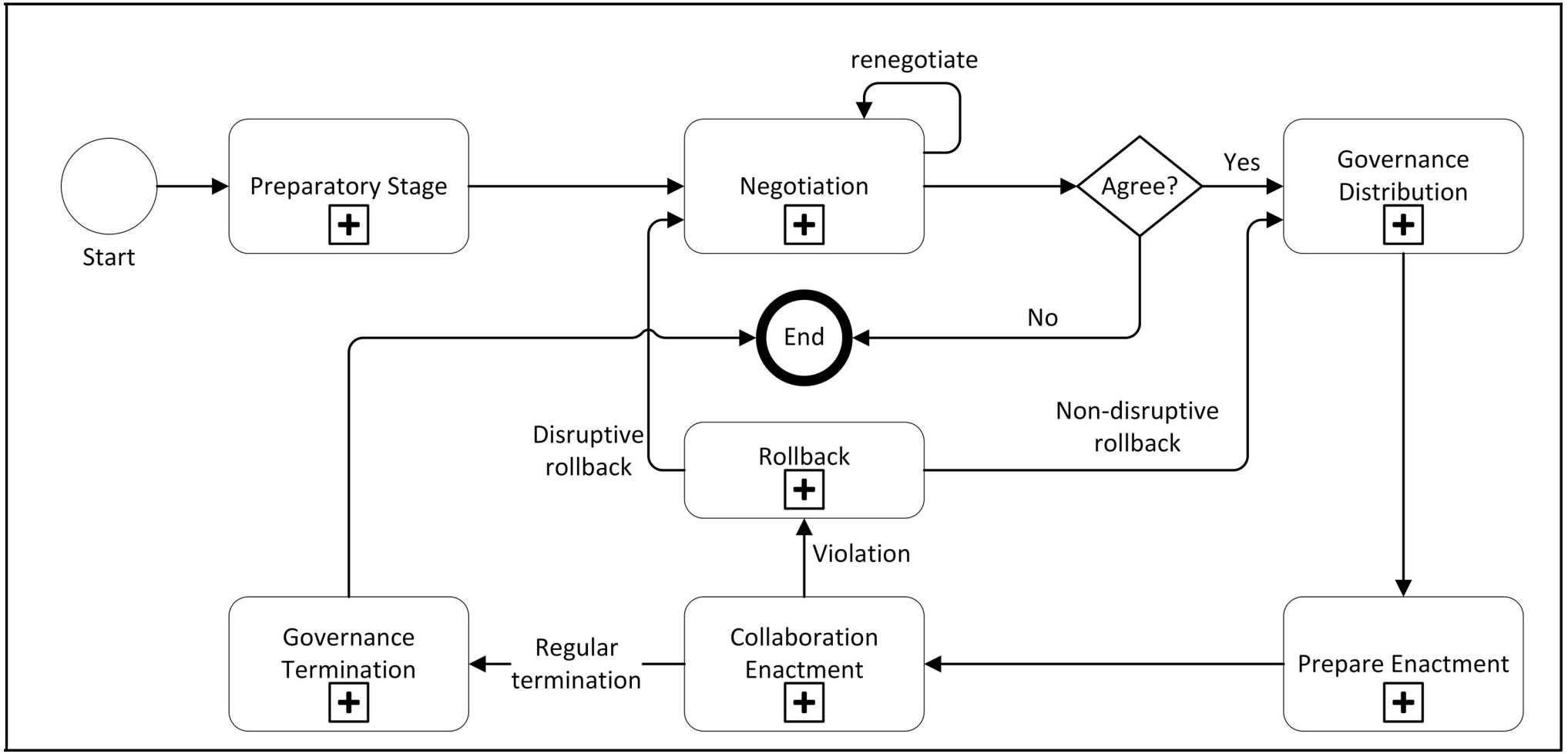
Kutvonen et al. (2012) – Inter-Enterprise Business Transaction Management in Open Service Ecosystems

Lifecycle – Enactment

- Pick up the user and transport the user to the final destination
- Monitor contract obligations and check for violations

Digital Contract Lifecycle



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Lifecycle – Conflict Resolution and Rollback

What if something goes wrong?
(failing to transport the user to the agreed-upon destination)

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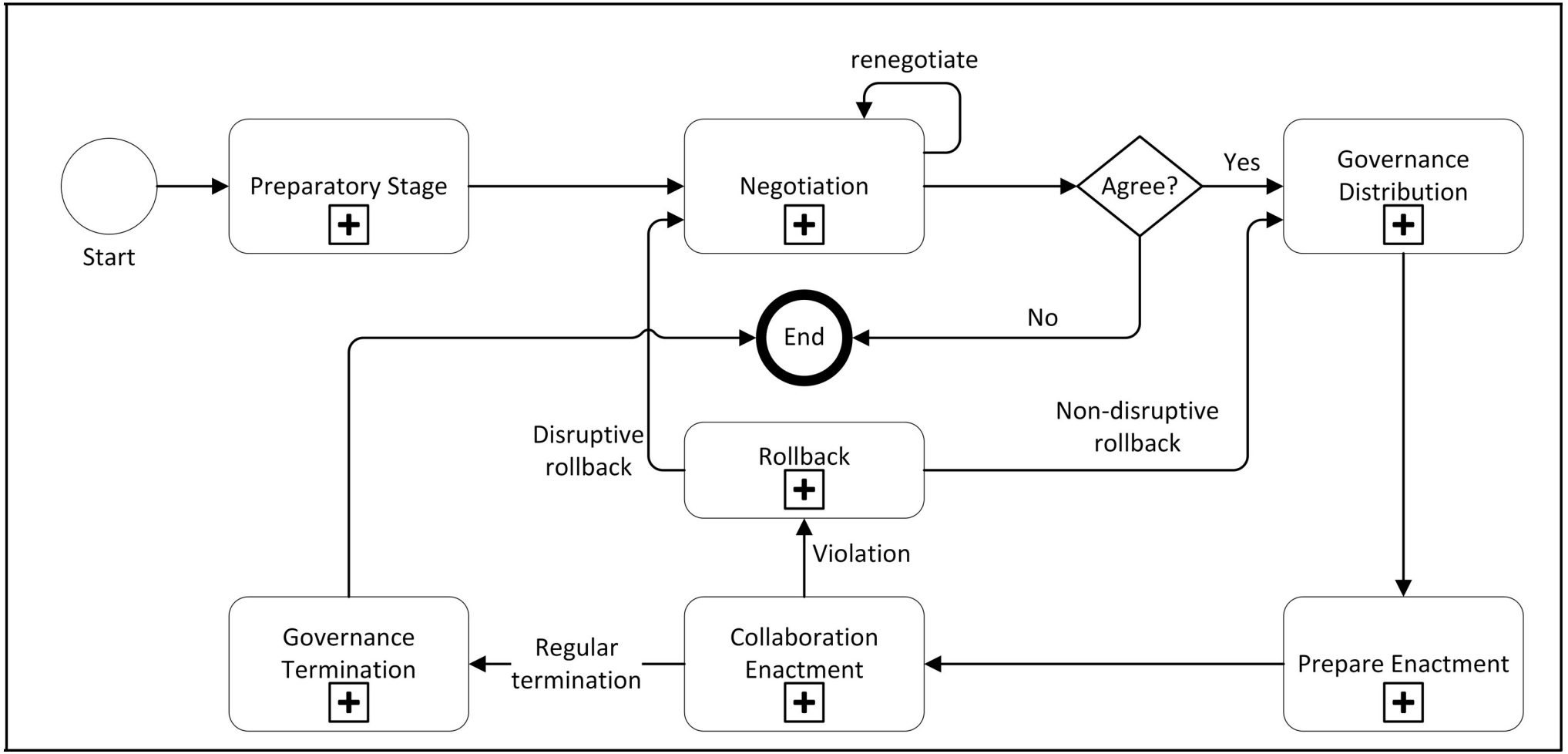
What if something goes wrong?
(failing to transport the user to the agreed-upon destination)

- Two options:
  - Immediate rollback
  - Mediation process that is supervised by a conflict resolution escrow service
- Can be calming or disruptive

Lifecycle – Governance Termination

- Contract terminates, or expires either after the user arrives at the final destination, or when the contract is prematurely terminated
- Dismantle DGI and everything that was setup before the enactment

Digital Contract Lifecycle



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M2X Modalities

- Environment integrity
- Accountability and logging
- Privacy
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- Market behavior

WHY BLOCKCHAIN TECHNOLOGY?

Why Blockchain Technology?

- Smart contracts
  - Enable and govern business transactions/interactions and collaborations
  - No need for arbitration via a trusted authority
  - Readable/processable by machines and humans alike
  - Fact tracking, non-repudiation, auditability, and tamper-resistant storage of information in a distributed multi-stakeholder setting

Why Blockchain Technology?

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- Automation and economy of scale via computerized transaction protocol
- Decentralized, distributed, open and interoperable ecosystem without lock-in effects instead of silo-like oligopoly structures

M2X ECONOMY → CIRCULAR ECONOMY (2.0)

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Performance Economy

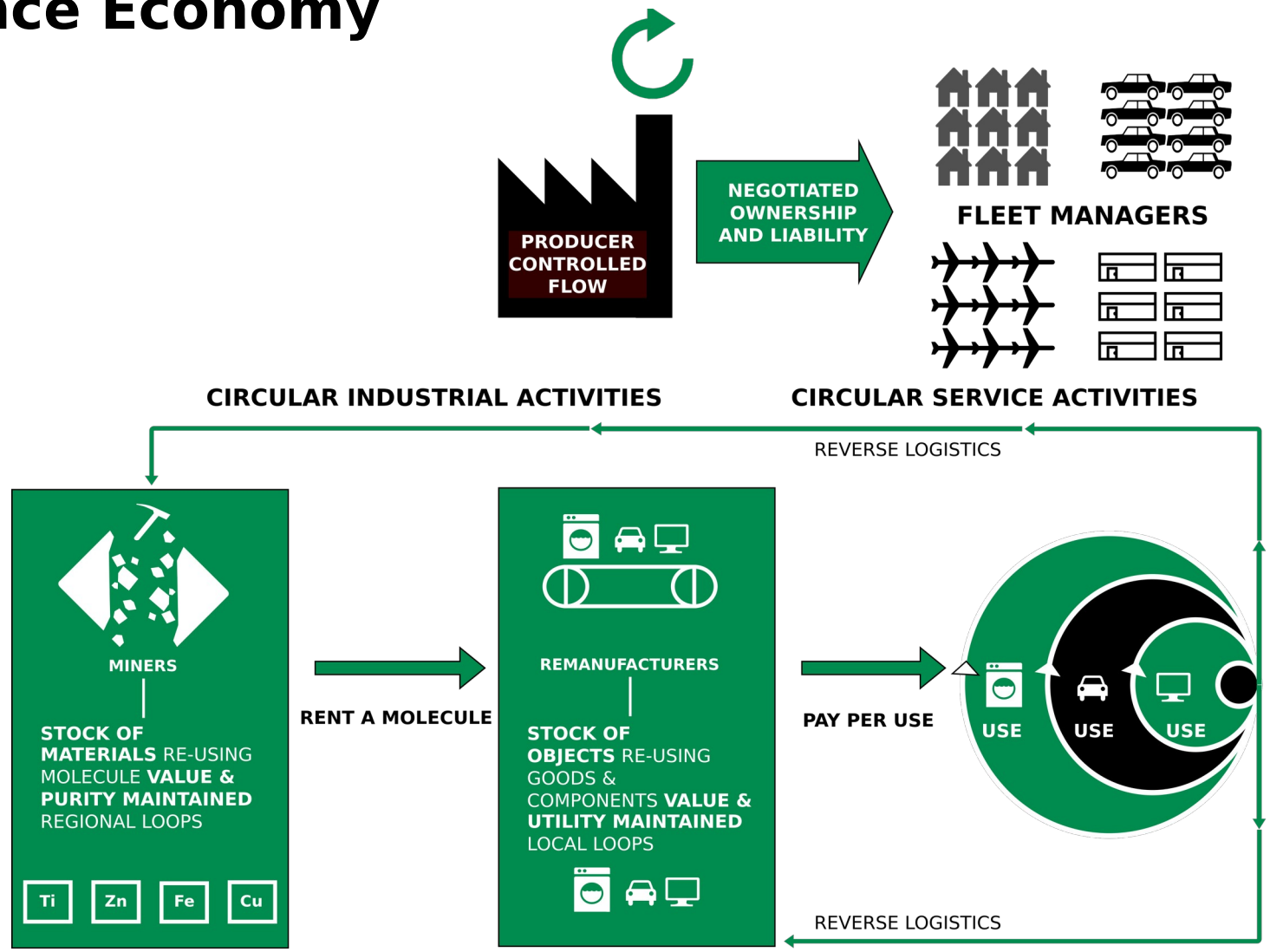

Image adapted from Walter R. Stahel (2019) – The Circular Economy: A User's Guide.

WHAT'S NEXT?

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- Circular Economy ✓

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- IoT ✓

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- Vision of M2X as a potential enabler for the PE/CE2.0 ✓

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Missing building block → Blockchain Technology

Questions?

Further Resources

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- B. Leiding, “The M2X Economy – Concepts for Business Interactions, Transactions and Collaborations Among Autonomous Smart Devices”, PhD Thesis, University of Göttingen, Göttingen, Germany, 2020. – Link.