Towards a Shared Ledger Business Collaboration Language based on Data-Aware Processes

--- or ---

What does it mean for Services Research if all parties Share a single Database?

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And drawing on many discussions with: Yao Liang Chen, Pralhad Deshpande, Yuichi Nakamura, Krishna Ratakonda, Jianwen Su, Noi Sukaviriya, Shin Saito, Takaaki Tateishi

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Version v10

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How do organizations collaborate in today's world?

By exchanging documents, in many cases on paper:

- Trade finance: letter of credit, export documents (eg., SWIFT MT700,…)
- Logistics/Supply Chain: Purchase Order (EDI 850), Load Tender (EDI 204), Tender Response (EDI 990), …
- Mortgage & Loan processing: many scanned PDF's
- …

Are these simply messages exchanged between services?

- No, because they persist, and are referred to at later times

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Blockchain (for businesses) will dramatically streamline data/document sharing

- Blockchain provides a trusted repository for holding persistent data
- Blockchain enables selective privacy
- Blockchain will enable deep efficiencies

How will this seismic shift in business collaboration impact the Services Research Community ?

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One broad area for Services Research contributions:

Business-Level Language and Framework

- Blockchain today is programmed using Turing-complete languages such as GOLANG, Java, ???
- Some domain-specific languages are emerging …

We need

- ***Principled approach*** for data-centered services & collaborations
- ***Domain-specific language*** aimed at business users
- ***Workbenches for business analysts*** to understand, create, test, modify the “smart contracts” that run on Blockchain
- ***Foundational understanding*** of biz-level “smart contracts”

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Agenda

- Blockchain enables a new level of trust & communication
- What is Blockchain, and why is it useful for Business Collaborations?
- Logical separation between Blockchain mechanics and Biz-level programming
- Artifact-centric paradigm as starting point for Business Collaboration Language
- Research challenge areas
  - Language design
  - Reasoning about artifacts
  - Relationship to natural language contracts
- Conclusions

Caveat

This field is still in its infancy

This talk is mainly raising questions

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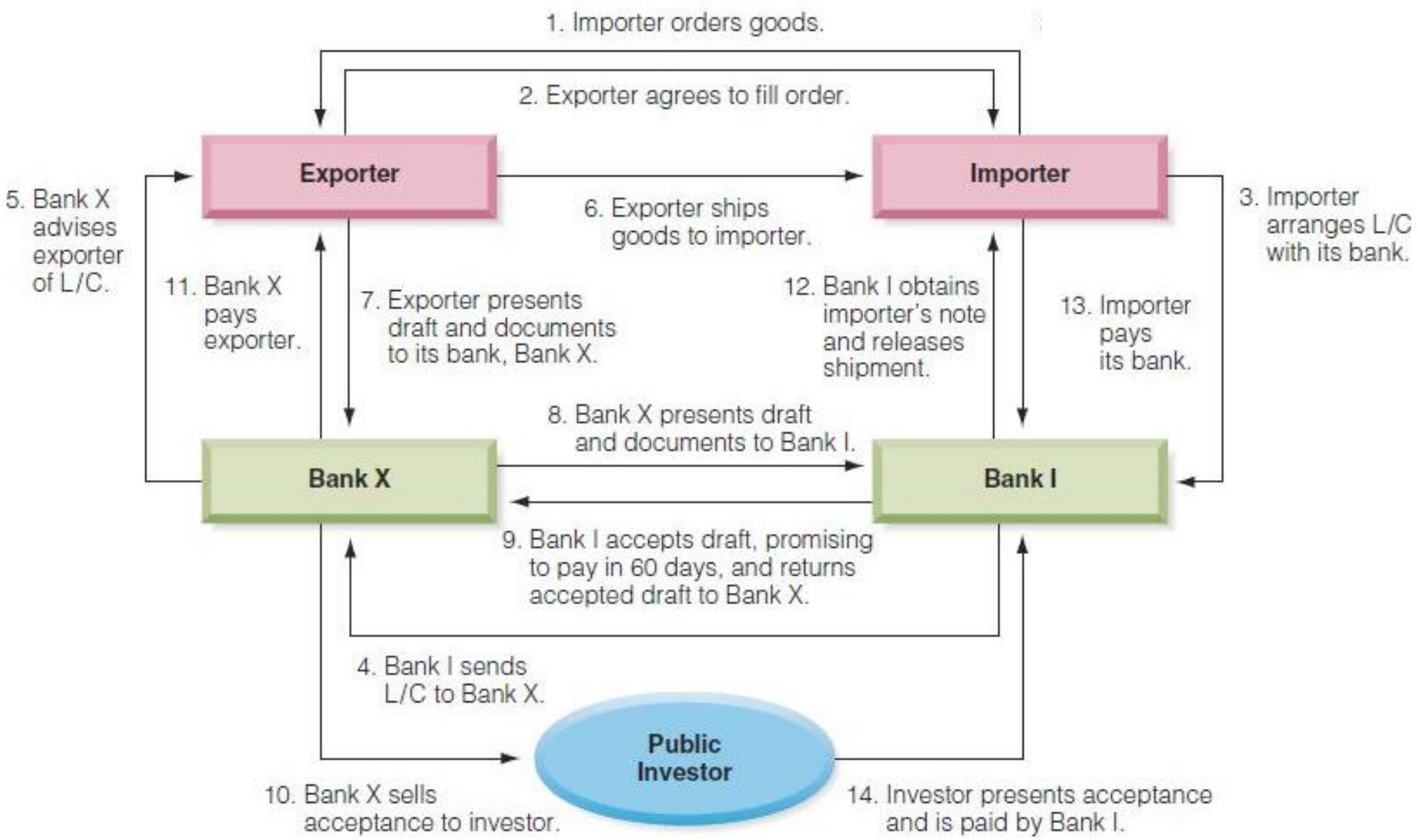
Example from International Trade Finance

- Suppose that a company in Kenya is exporting pineapples to an importer in Rotterdam …



- At least 4 parties, often more
  - Exporter
  - Exporter's Bank
  - Importer's Bank
  - Importer
  - There may be 10's of parties
- Kinds of documents
  - Order
  - Letter of Credit
  - Export documents
  - Draft
  - …
- Today
  - Some documents communicated electronically
  - Other documents sent by air courier

From "International Financial Management" by Jeff Madura

Example from International Trade Finance

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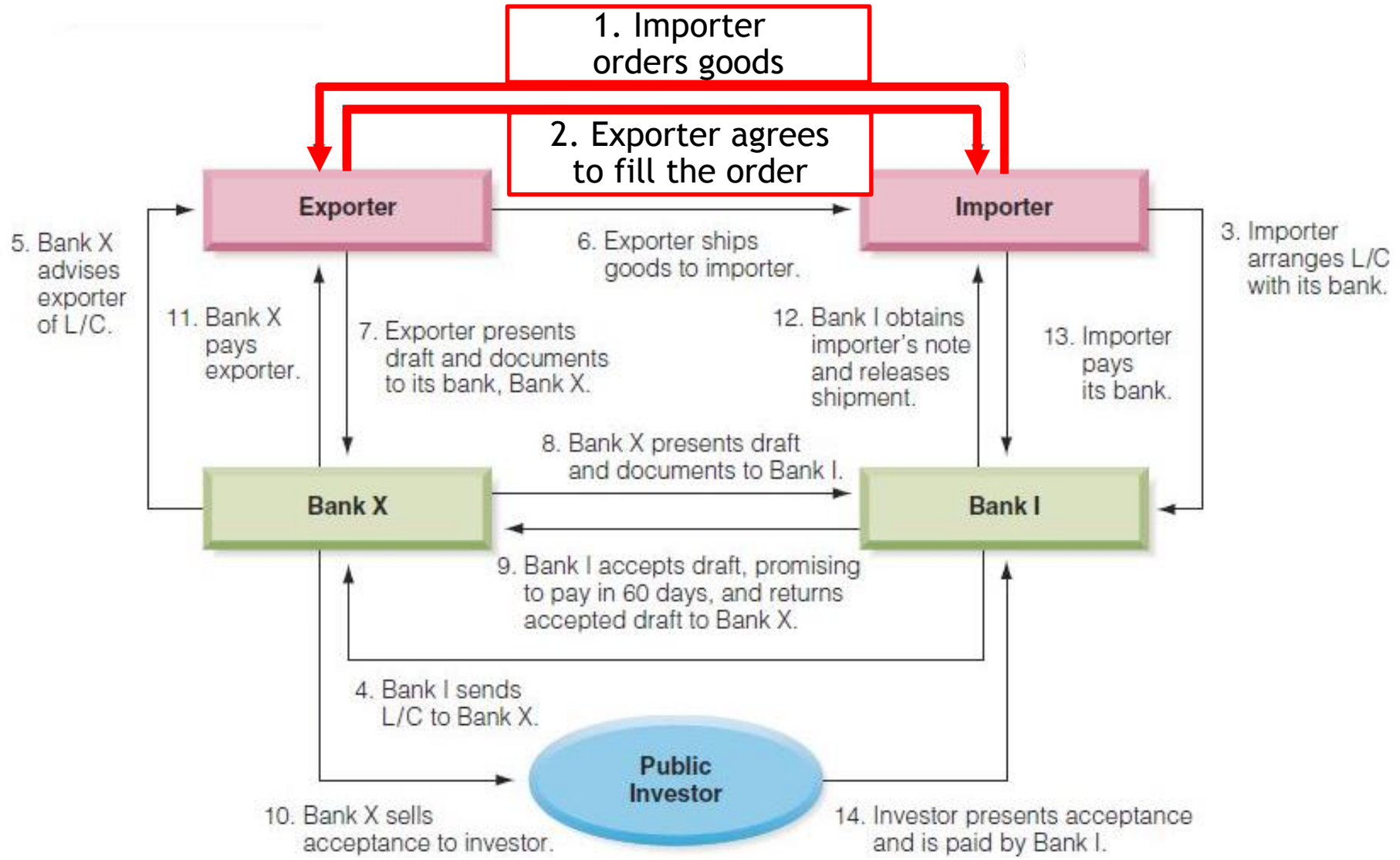

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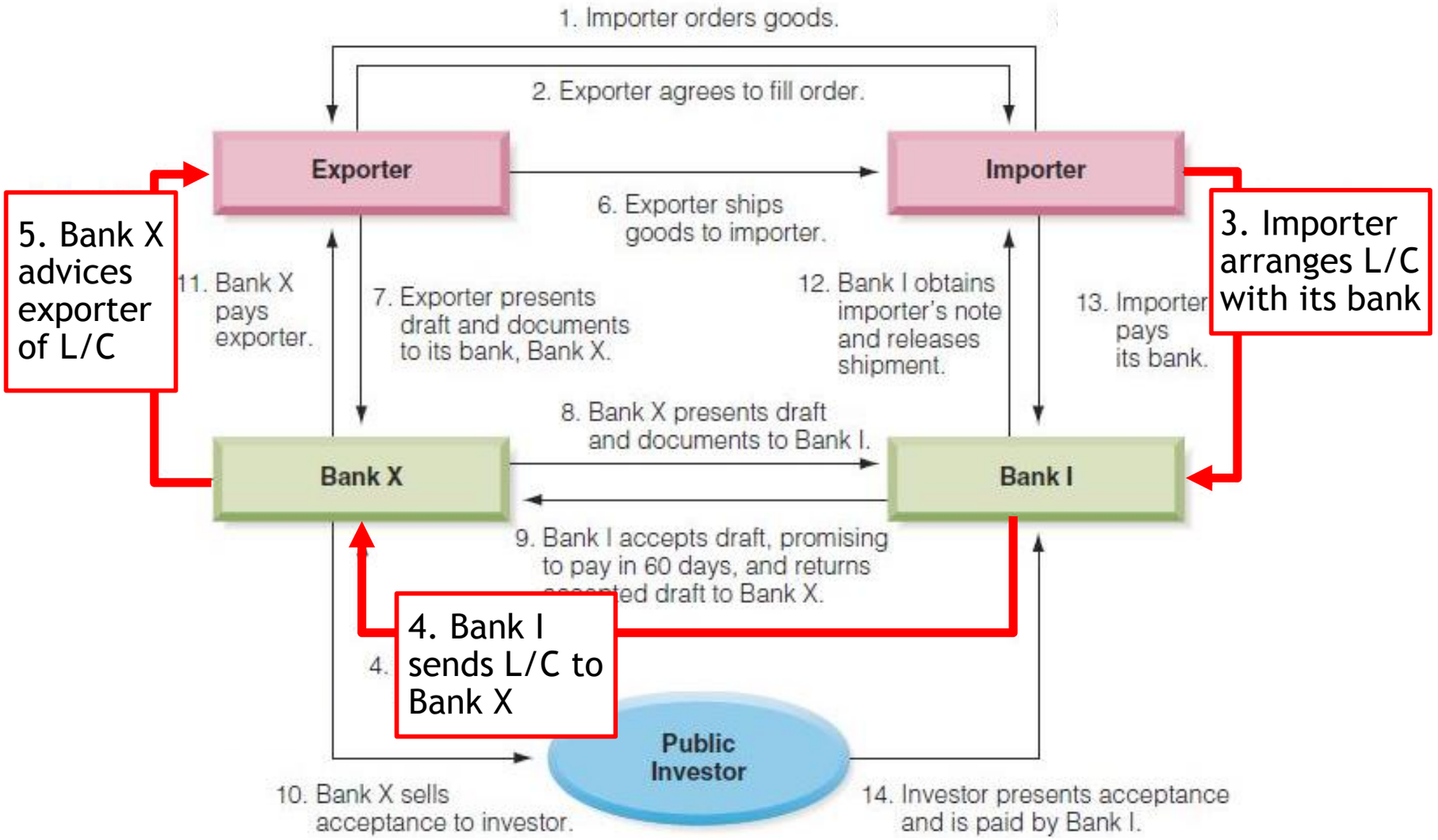

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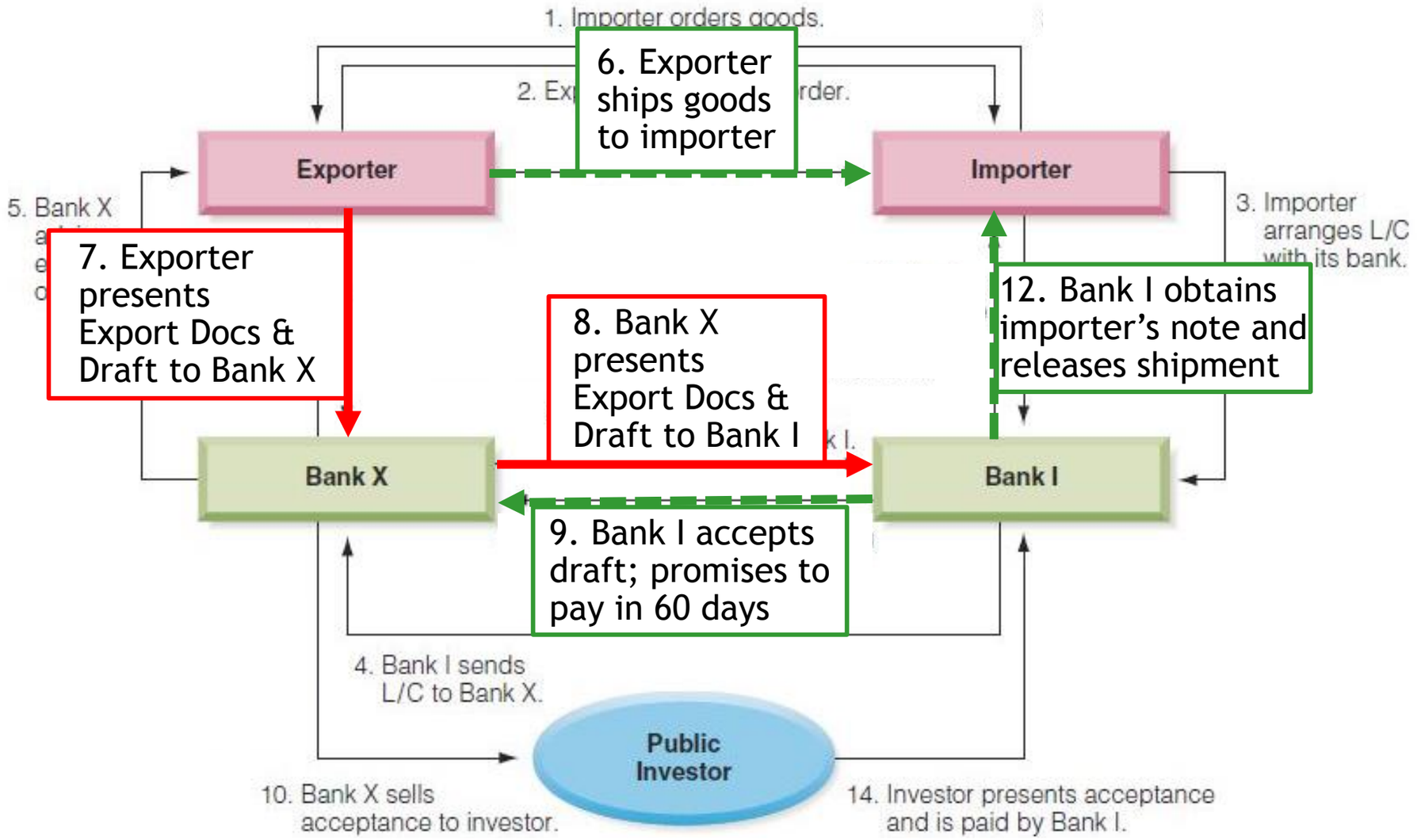

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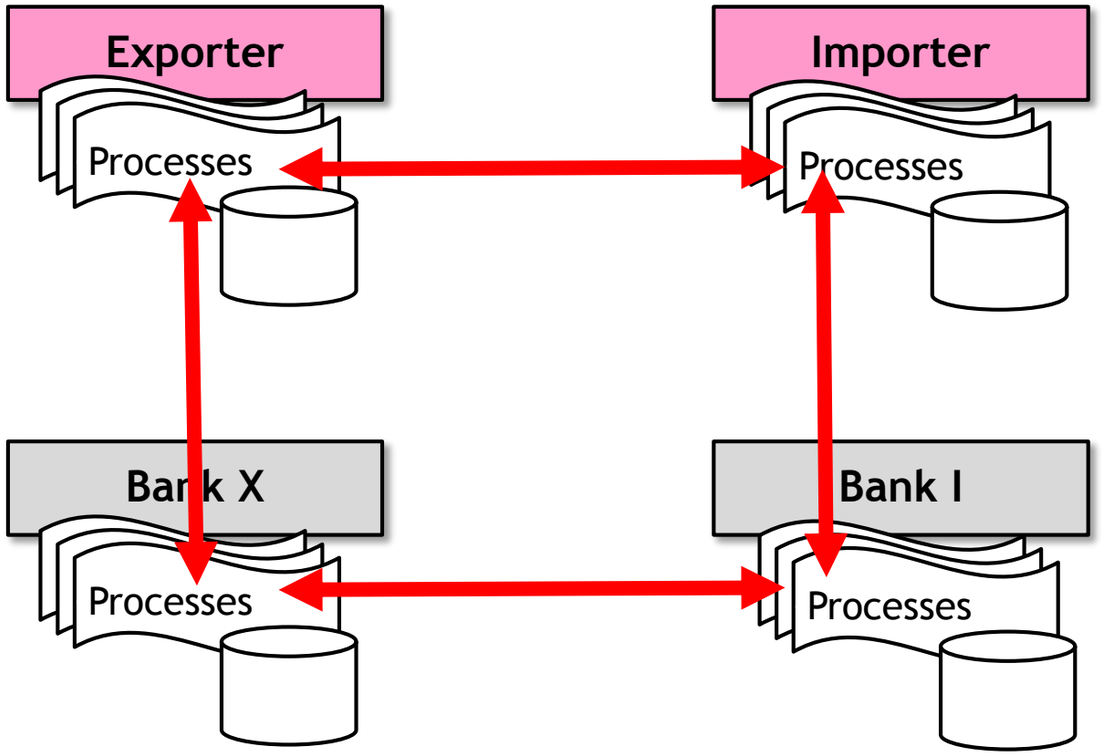
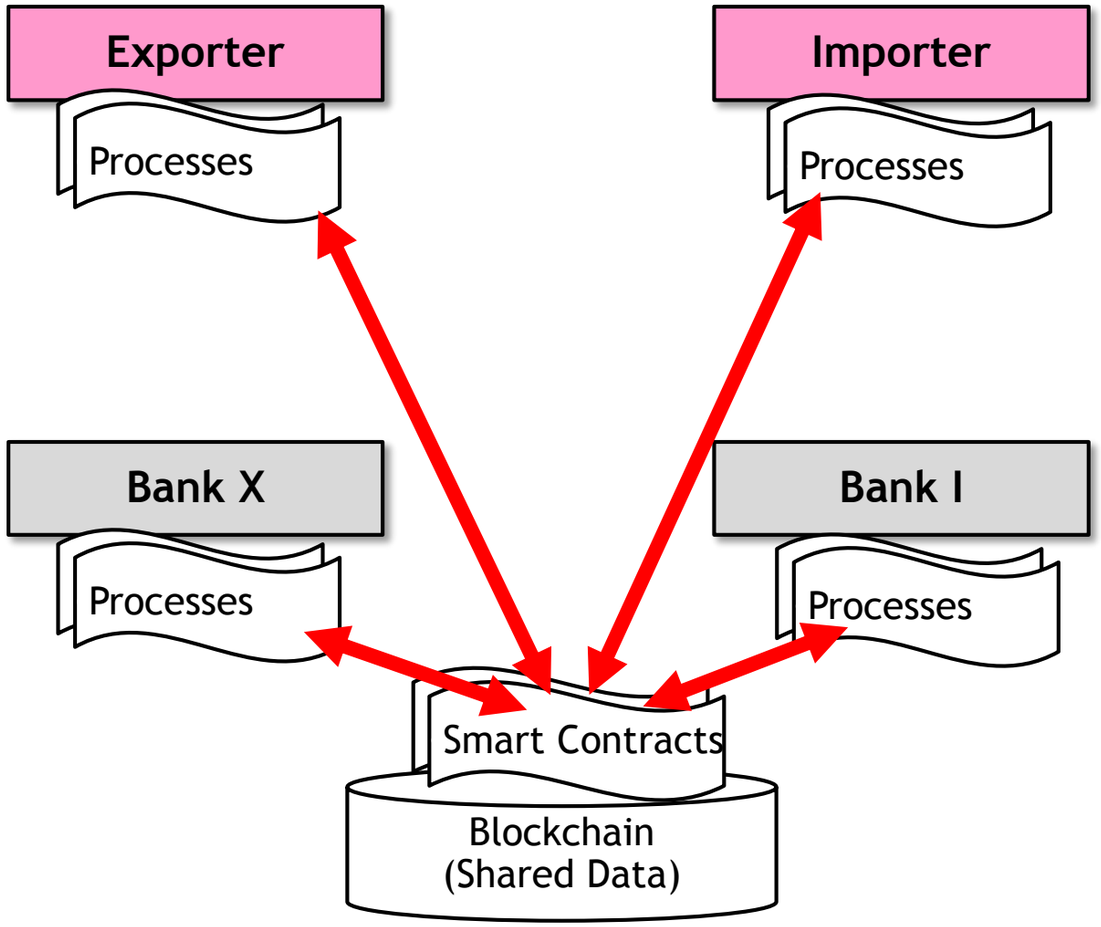
Before Blockchain



- Private copies of collaboration data
  → Disputes can take month+ to resolve
- Private copies of collaboration processing logic
  → Trust is based on binary relationships

With Blockchain



- Single shared copy of collaboration data
  → Disputes can be resolved in a day
- Single shared copy of collaboration processing logic
  → Trust becomes based on broadly visible shared data

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Many application areas

- Trade Finance
  - Trust between numerous parties, dispute resolution
- Supply chain/logistics
  - Non-disputable order tracking, dispute resolution
  - Important to both advanced and developing countries
- Mortgage processing
  - Capture machine readable data once; From redundant paper copies to single source of truth
- Certified Emissions Reduction (CER)
  - Enabling manufacturers to certify that they are producing product with low carbon footprint
- Food supply
  - Provenance from farm to fork
- Healthcare
  - More solid, robust basis for electronic health records
- Education (especially in developing countries)
  - Accurate, non-disputable student & teacher records
- …

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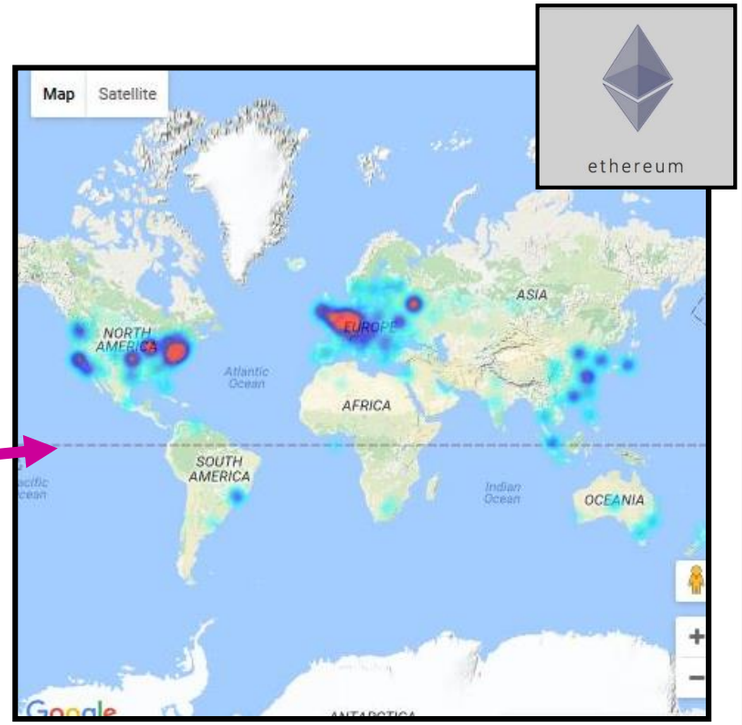
A highly selective & brief history of Blockchain

- Bitcoin
  - Introduces Blockchain paradigm as basis for a crypto currency
  - Sole focus is on possession/transfer of Bitcoins
  - Privacy guaranteed for currency holders
  - Exchanges to trade Bitcoins for state-provided currencies ($, €, ¥, …)
- Etherium – a Swiss nonprofit, launched in 2014
  - General purpose, custom built Blockchain: ~7000 nodes
  - Crypto currency is called “Ether”
  - Framework includes notion of “fuel” or “gas money” – pay for transactions along the way
- “The DAO” hack
  - A Distributed Autonomous Organization (DAO) can be set up on Etherium
    - Participants can contribute funding, and collectively vote on investments
  - “The DAO” launched on April 30, 2016, by German company Slock.it
    - By May 27 the DAO at raised $150M
  - An attacker drained 3.6M ether, worth about $70M, by June 18
  - Value of ether dropped from $20 to $13
- HyperLedger
  - Launched by the Linux Foundation – Dec 2015
  - 30 founding members, including: Accenture, Cisco, Digital Asset Holdings, Fujitsu, IBM, Intel, J.P. Morgan, R3, SWIFT, Wells Fargo, …



http://ethernodes.org/network/1

- Etherium Blockchain itself did not show vulnerability nor hacking
- The smart Contract of “The DAO” was hacked

HYPERLEDGER

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Blockchain 101 (with bias towards Hyperledger) (1 of 3)

- A blockchain provides
  1. High reliability
  2. Shared single source of truth
  3. Trusted
  4. Selective privacy
  5. Non-repudiable data updates

- A blockchain consists in a network of servers
  - They may not trust each other at level of individuals
- Blockchain network supports ACID transactions
  - Consensus algorithm, such as Practical Byzantine Fault Tolerance (PBFT)
- Blockchain network supports selective privacy
  - Deep usage of encryption technologies
  - Selective access to data and service calls
  - (Often, the “smart contracts” are broadly visible)

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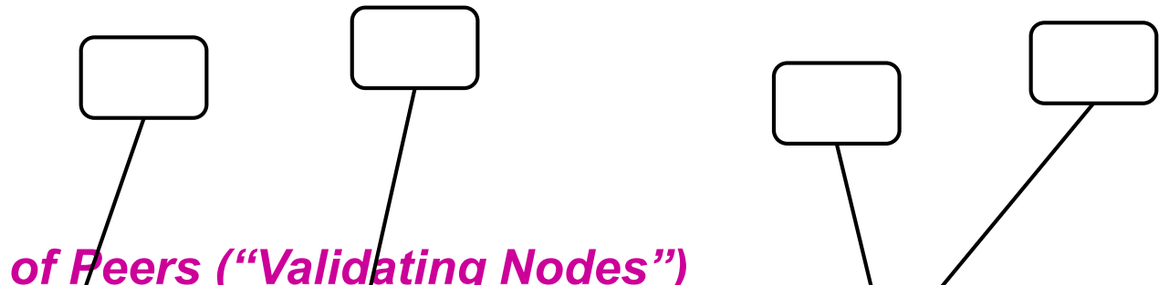
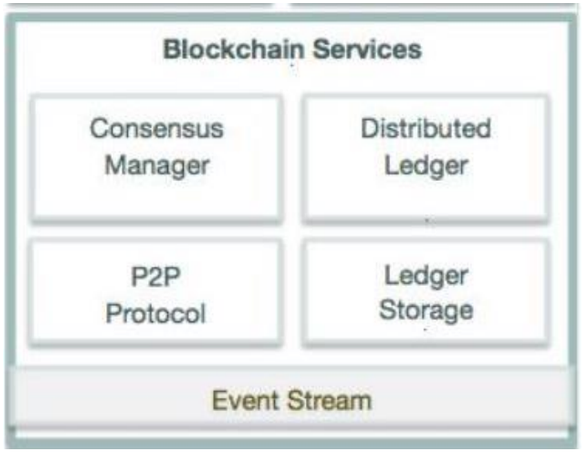
Blockchain 101 (with bias towards Hyperledger) (2 of 2)

Participants (executing on behalf of businesses)

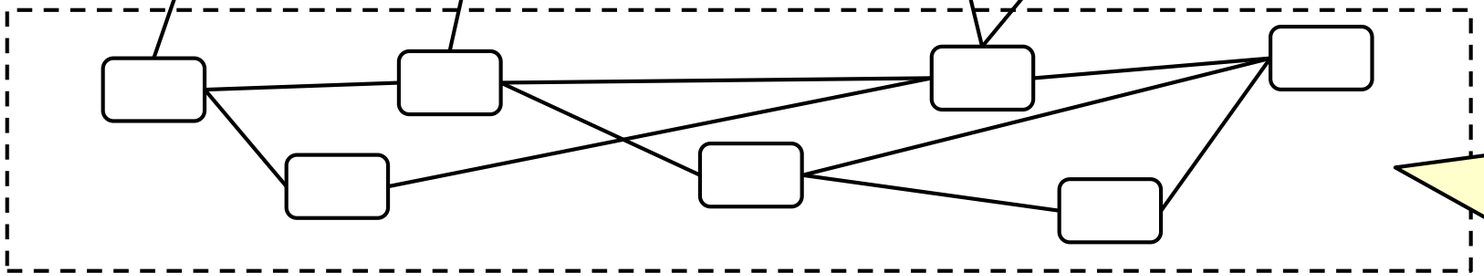


A participant can connect to a single peer, and will always see the single shared version of the ledger



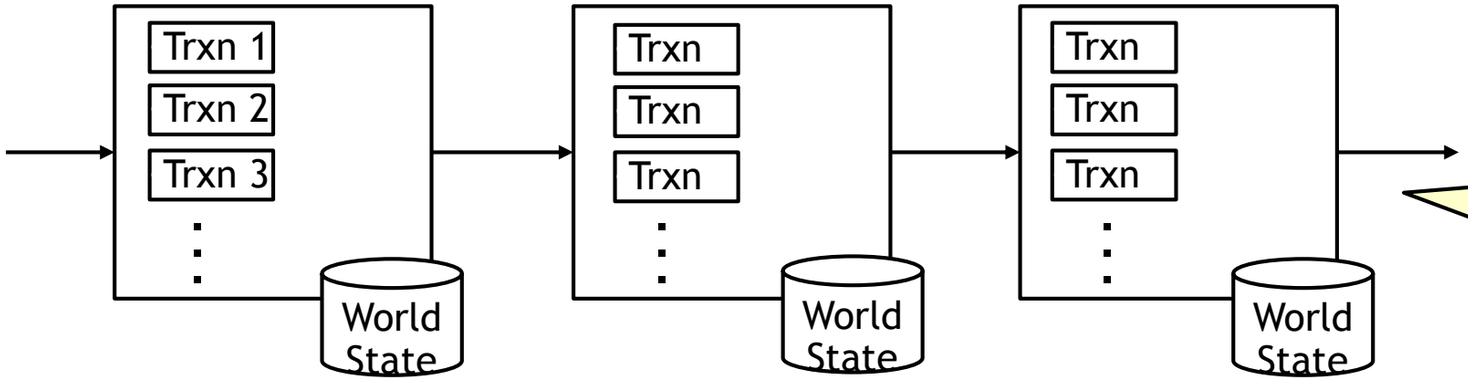
http://www.the-blockchain.com/docs/Hyperledger%20Whitepaper.pdf

Network of Peers ("Validating Nodes")



After each round of consensus, each peer holds a replica of the ledger

Shared Ledger View



- A "chain" of "blocks"
- The sequence of blocks is the shared "ledger"

Two types of txns
- Code Deploying
- Code Invoking

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Blockchain 101 (with bias towards Hyperledger) (3 of 3)

- What makes Hyperledger different?
  - No built-in crypto currency
  - Cost of processing & data storage is not of major concern
    - Smaller number of peers
  - Anticipation of many Blockchain networks – spectrum including
    - Some more public
    - Some more private
  - All of the nodes are white-listed within a Blockchain network
    - Transactors are granted an identity by an issuing authority
  - Modular consensus
    - Consensus algorithms are pluggable

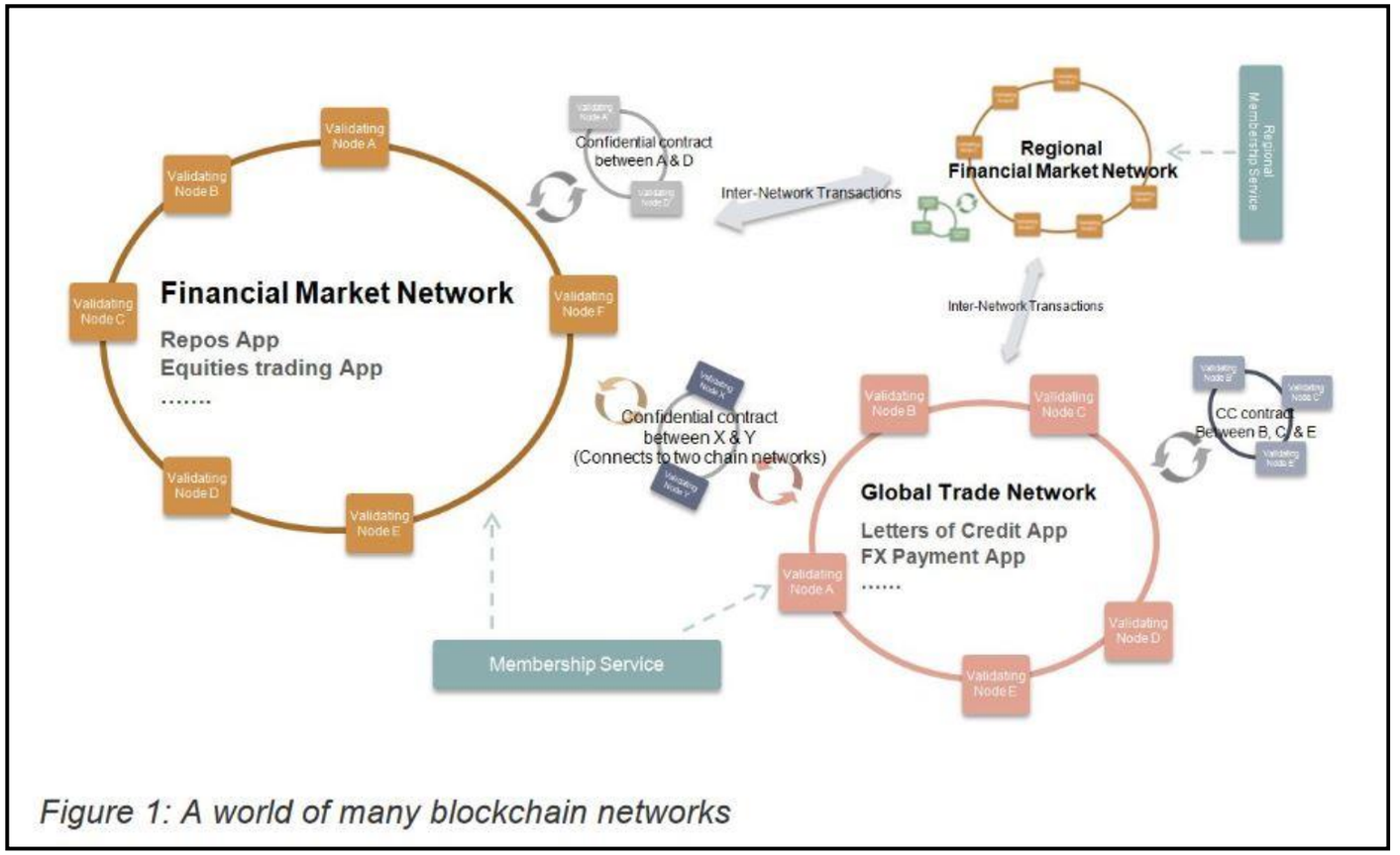

Figure 1: A world of many blockchain networks

http://www.the-blockchain.com/docs/Hyperledger%20Whitepaper.pdf

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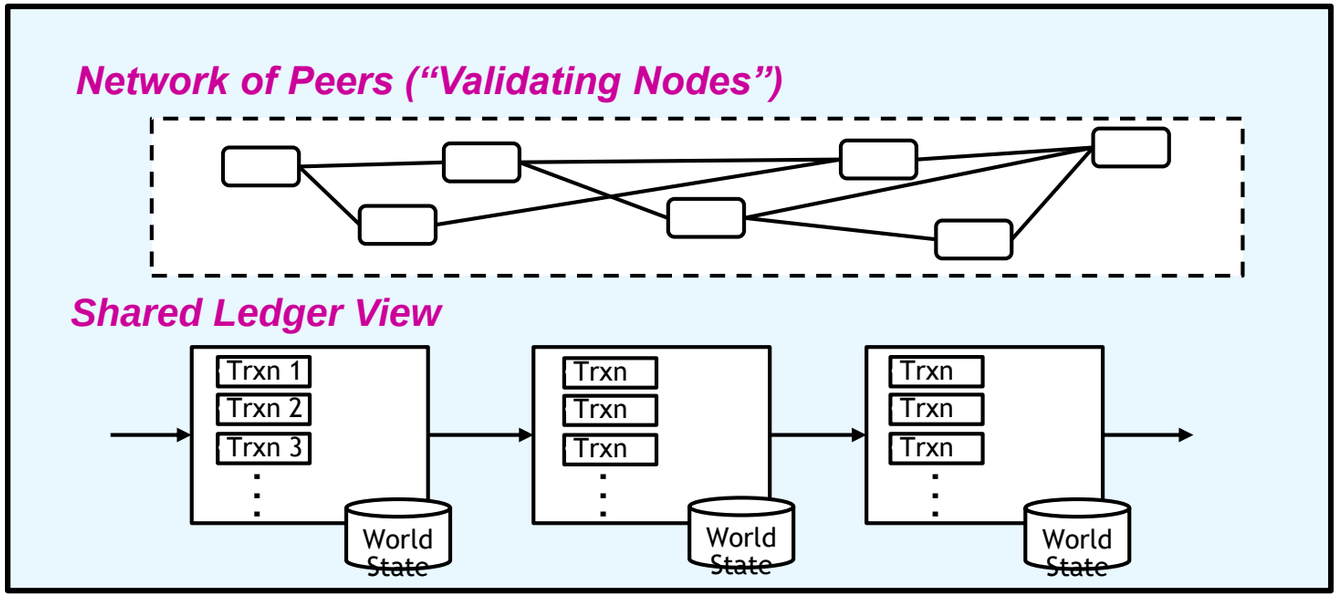
Business Collaboration Language logically above Shared Ledger

Business-Level
Smart Contract
Language & Framework

Logical Abstraction Separation



- Reminiscent of "Physical Data Independence" in databases
- Proof point:
  [Weber et. al., BPM 2016]
  - Maps BPMN onto Ethereum blockchian

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- Logical separation between Blockchain mechanics and Biz-level programming
- Artifact-centric paradigm as starting point for Business Collaboration Language
  - Business Artifacts and related models
  - ACSI – Artifact-Centric Service Interoperation
- Selected research challenge areas
- Conclusions

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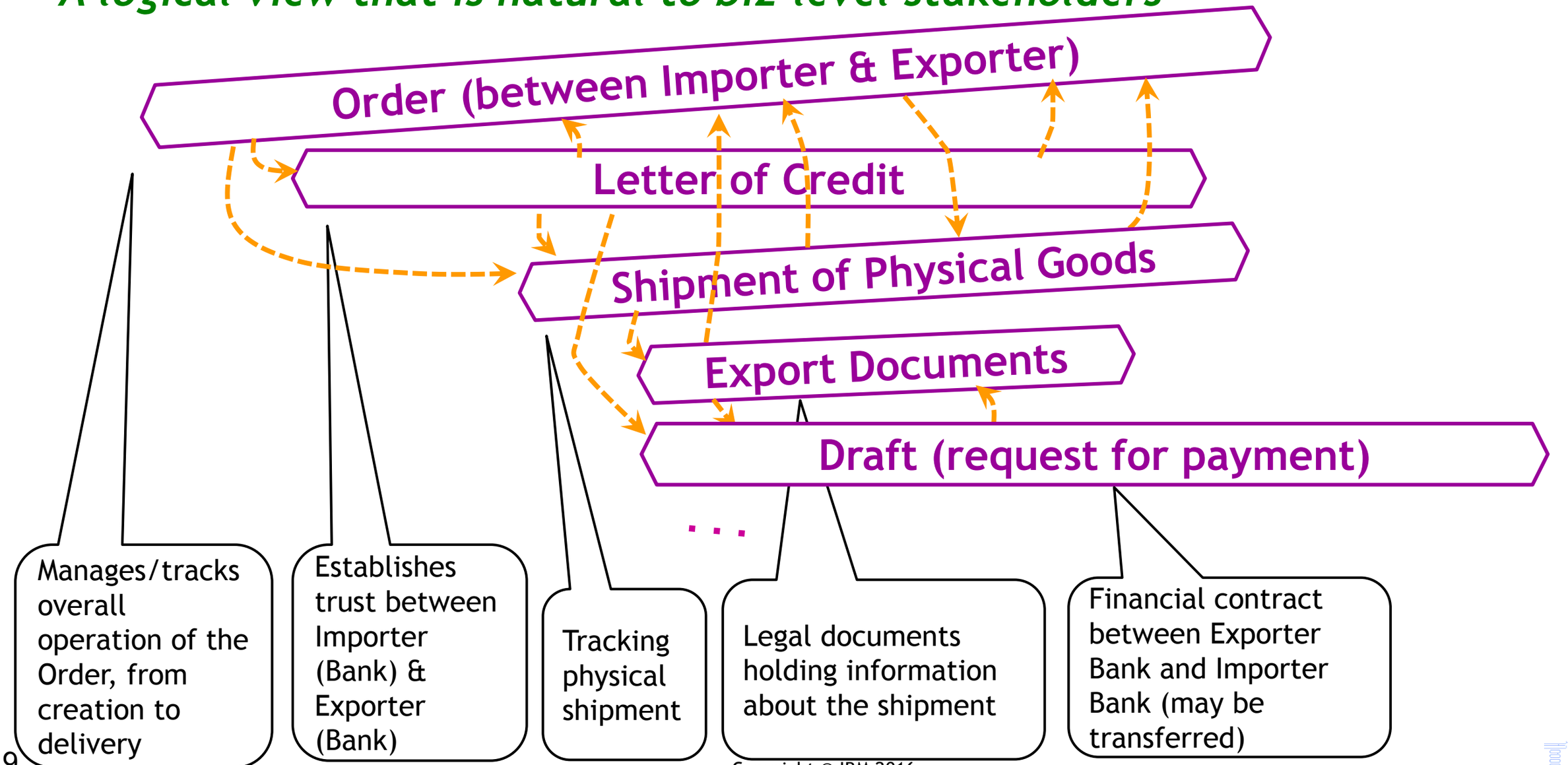
Business Artifacts with Lifecycles: A way to factor Business Processes and their data that gives unifying, end-to-end view

A logical view that is natural to biz-level stakeholders



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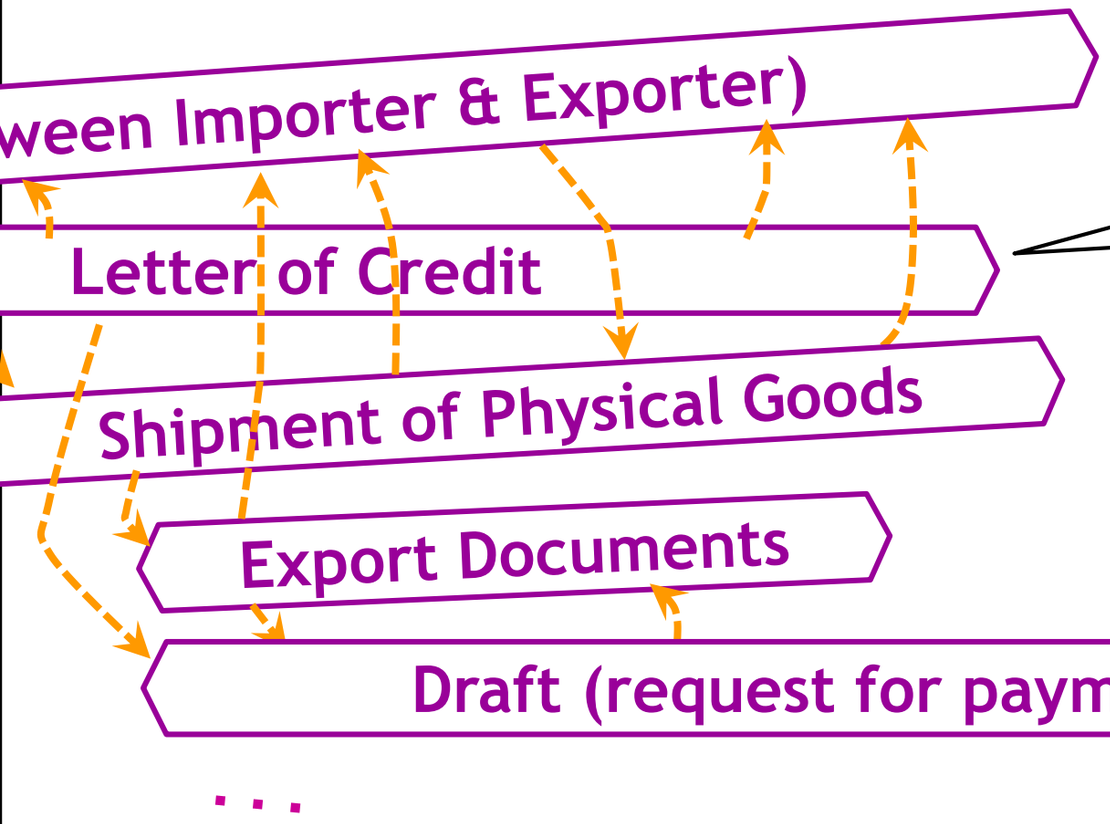
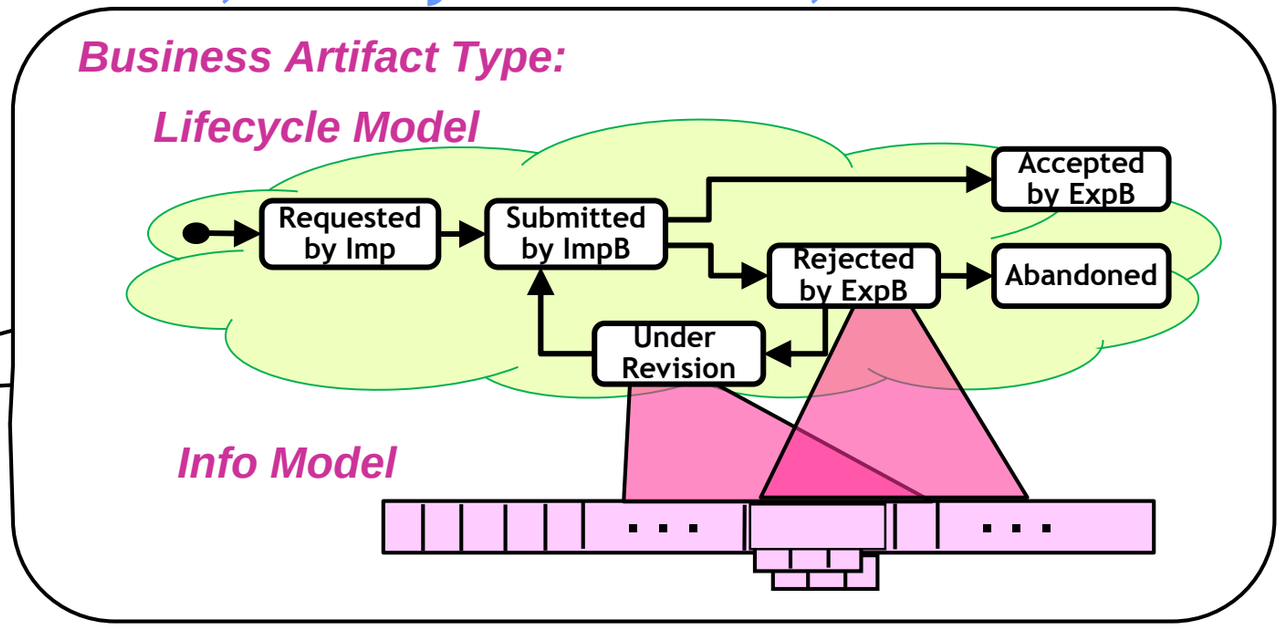
Each Artifact type includes info model, lifecycle model, and roles





- Info model brings together all biz-relevant data about a given artifact type
  - These cut across parties, organizational silos, etc.
  - Provide a common vocabulary across parties, silos
- Lifecycle model shows possible progressions of artifact instance through the business operations
  - Status of Lifecycle is stored in the info model
- Roles have access rights to data & operations
- Biz-level stakeholders can easily query, monitor, use dashboards, and specify rules/policies

There is extensive research on “Data-aware” Business Process

- The use of entities with FSM-based lifecycles appears as early as [K. Robinson 1979] and [C. Rosenquist 1982]
  - Focus is on Information Systems and System Dynamics rather than modeling modern business operations.
- Business Artifacts (a.k.a., Business Entities with Lifecycles) [Nigam+Caswell 2003, Kumaran et al 2003]
  - Use cases – Pharmaceutical, supply chain, manufacturing, finance, je.g., [Bhattacharya et al 2007], …
  - Systems – e.g., BizArtifact open source system [Boaz, Limonad, Gupta 2013]
  - Standards – impact of GSM approach on CMMN standard [Marin, _, Vaculin 2012]
  - Foundations – e.g., [Bhattacharya et al 2007] [Deutsch et al 2009] [_ et al 2010] [Calvenese et al 2013] …
  - Collaboration – Artifact-Centric Service Interoperation (ACSI) [_, Narendra, Nigam ICSOC 2009]
- Business Objects
  - Very similar to Business Artifacts with FSM lifecycles
  - FlowConnect Object Behavior Model [Redding et al 2007, 2010]
  - PHIharmonicflows [Kunzle, Reichert 2011] …
- Active XML Artifacts model
  - Information Model based on (Active) XML [Abiteboul, Segufin, Vianu 2009]
  - Collaboration [Abiteboul et al 2010]
- Case Management
  - Pallas Athena FLOWer [van der Aalst, Weske, Grünbauer 2007]
  - Adaptive Case Management [Swenson 2010]
  - OMG Case Management and Modeling Notation (CMMN) [2014]

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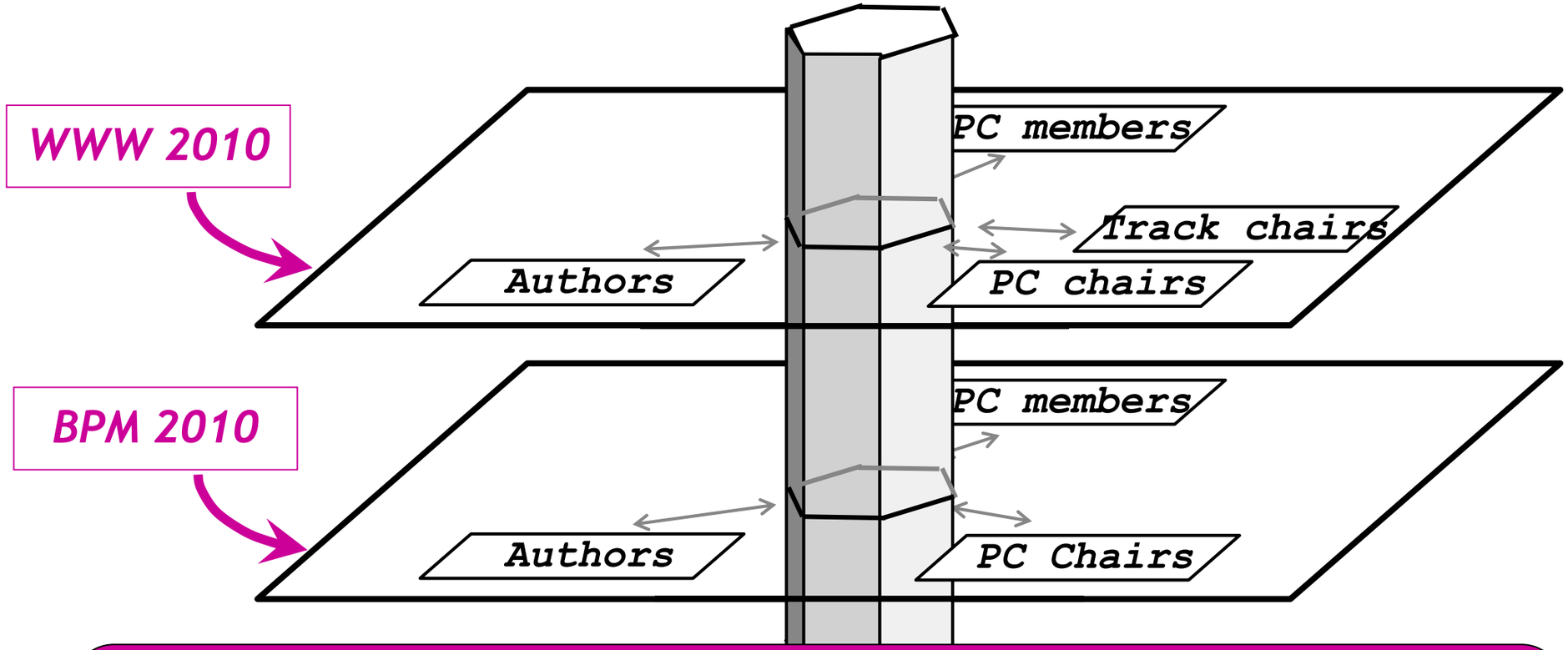
Artifact-Centric Service Interoperation (ACSI) [_, Narendra, Nigam, ICSOC 2009]

- Our Inspiration: EasyChair
- A “hub” that supports numerous conferences



- **How to replicate this in arbitrary application areas?**
- **How do we make it easy for services to “understand” what a hub is doing, how it is working?**
- **How do we provide systematic access controls?**

Artifact-centric Service Interoperation hubs in a nutshell

- Like orchestration, puts a “hub” in the middle of collaborating services
- Unlike orchestration, an ACSI hub:
  - ***Establishes a “pseudo-standard”*** as the center of a collaboration environment
    - Different service collaborations will need to comply to this standard
    - Enables scalability because of distribution of adaptation
  - ***Primarily re-active***; essentially a structured whiteboard
    - Assumes that the services are “self-motivated” and pro-active
    - Permits service-to-service communication
  - Based on ***Business Artifacts***
    - Demonstrated to simplify understanding of business operations
    - A structured approach to ***data + process + roles***
    - ***Data***: Info Model provides skeleton that provides full status snapshot
    - ***Process***: Lifecycle Model provides top-down structure for processes, events
    - ***Roles***: Info Model + Lifecycle Model provides structure for intricate, conditional access control

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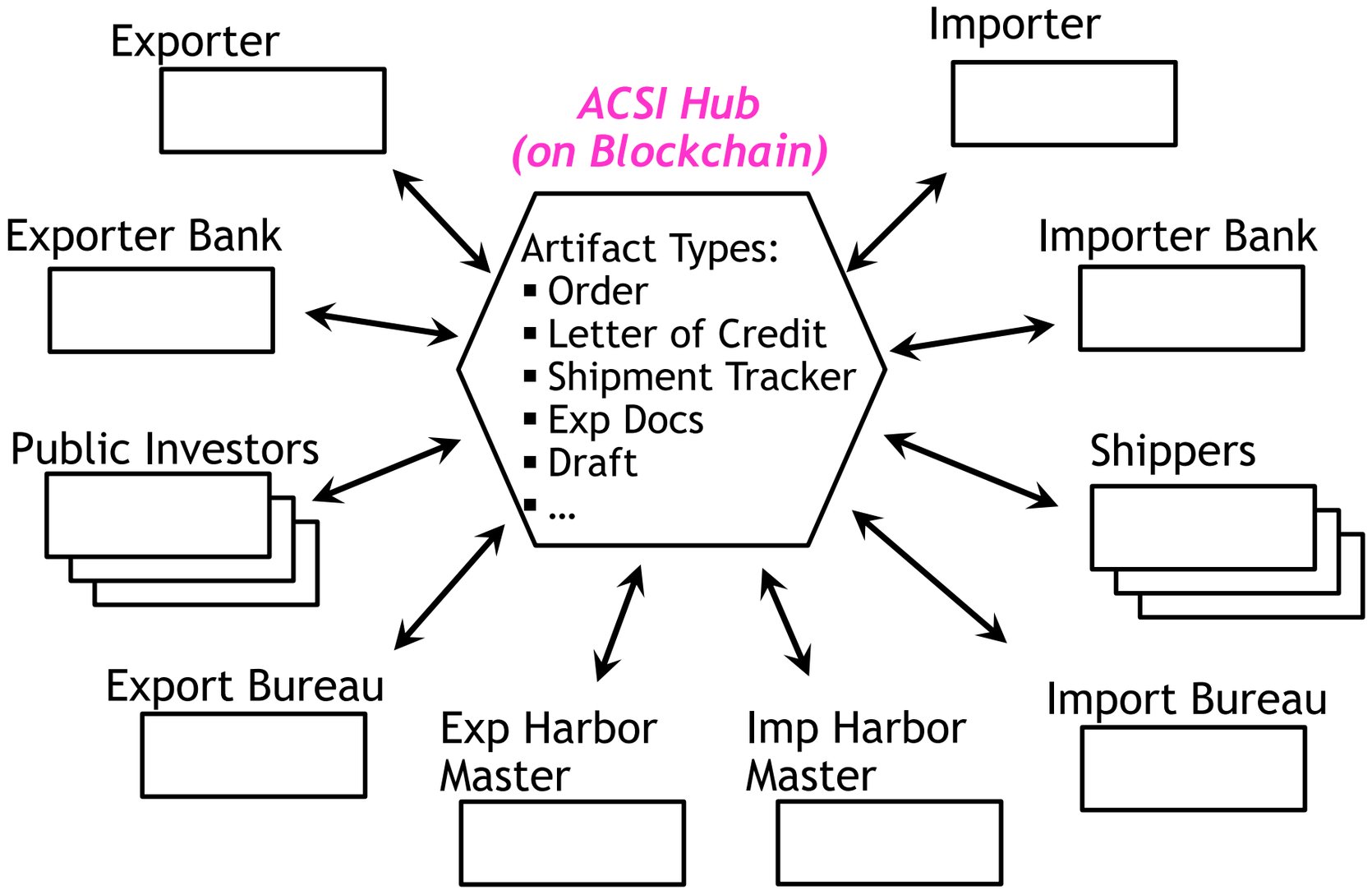
Example ACSI Hub for Trade Finance



- The participating services do not have to be artifact-centric

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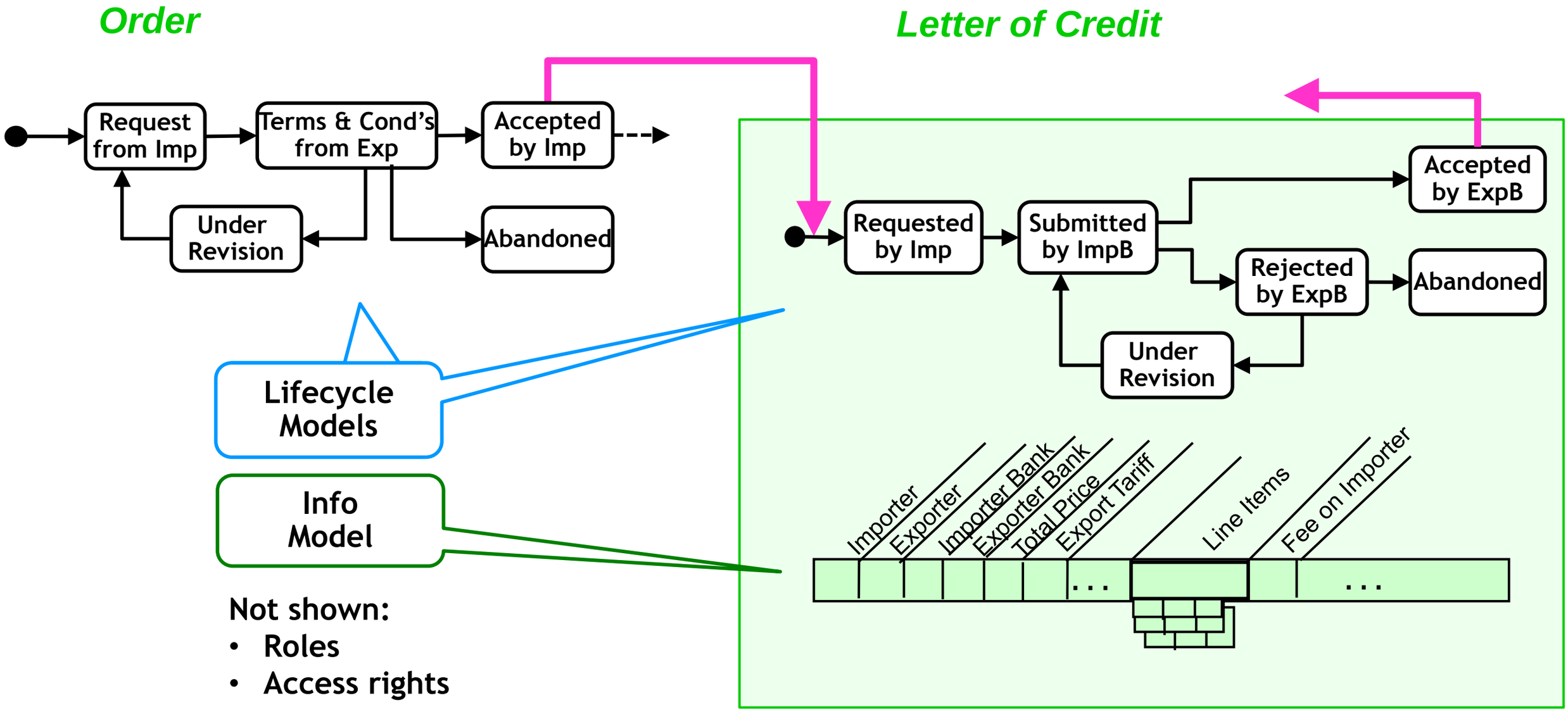
Illustration of Lifecycle & Info Models



Not shown:

- Roles
- Access rights

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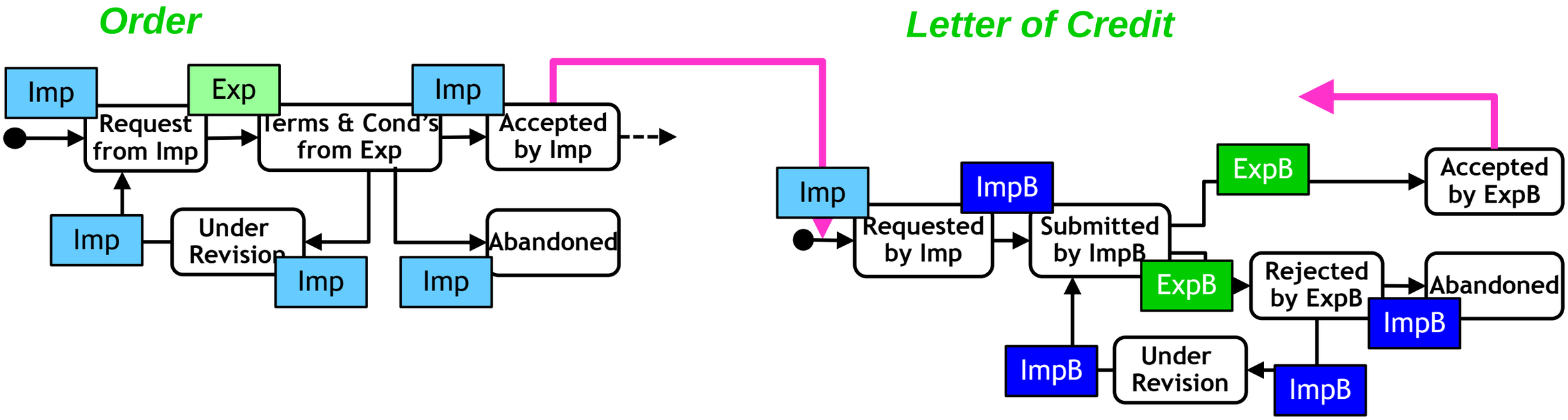
Separated lifecycle models are natural backbone for access to services



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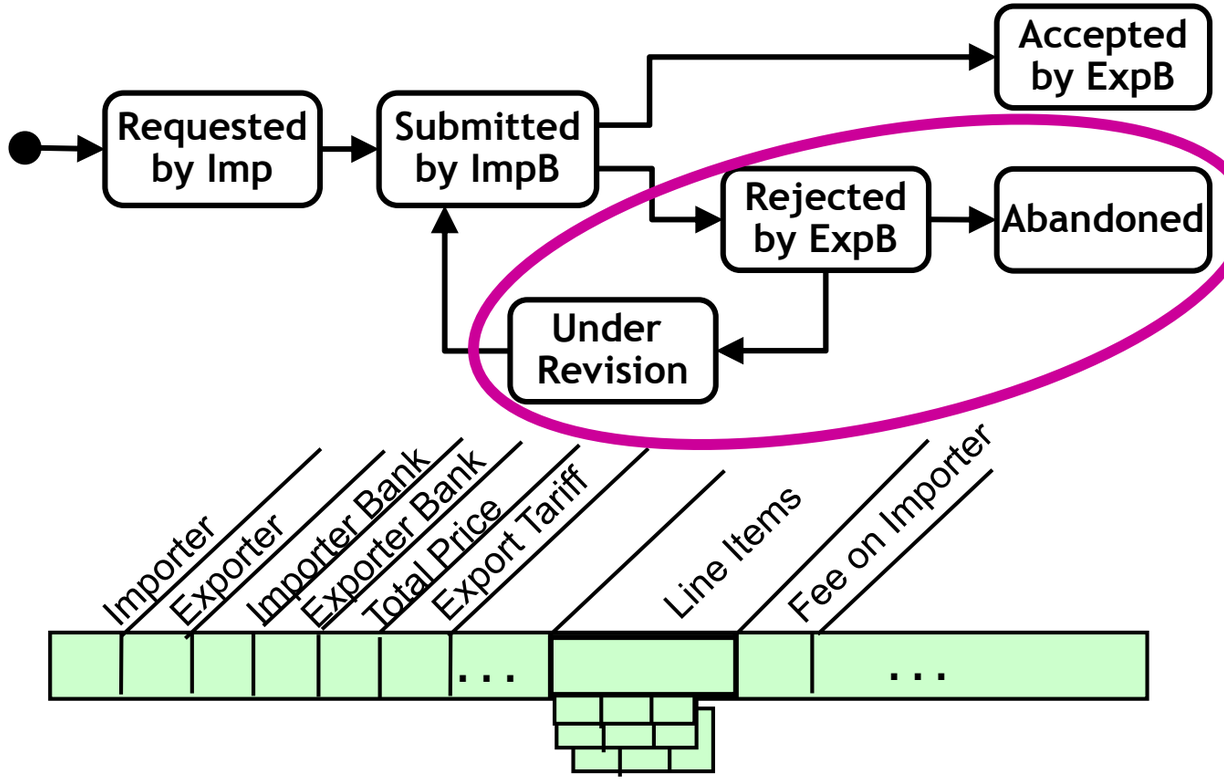
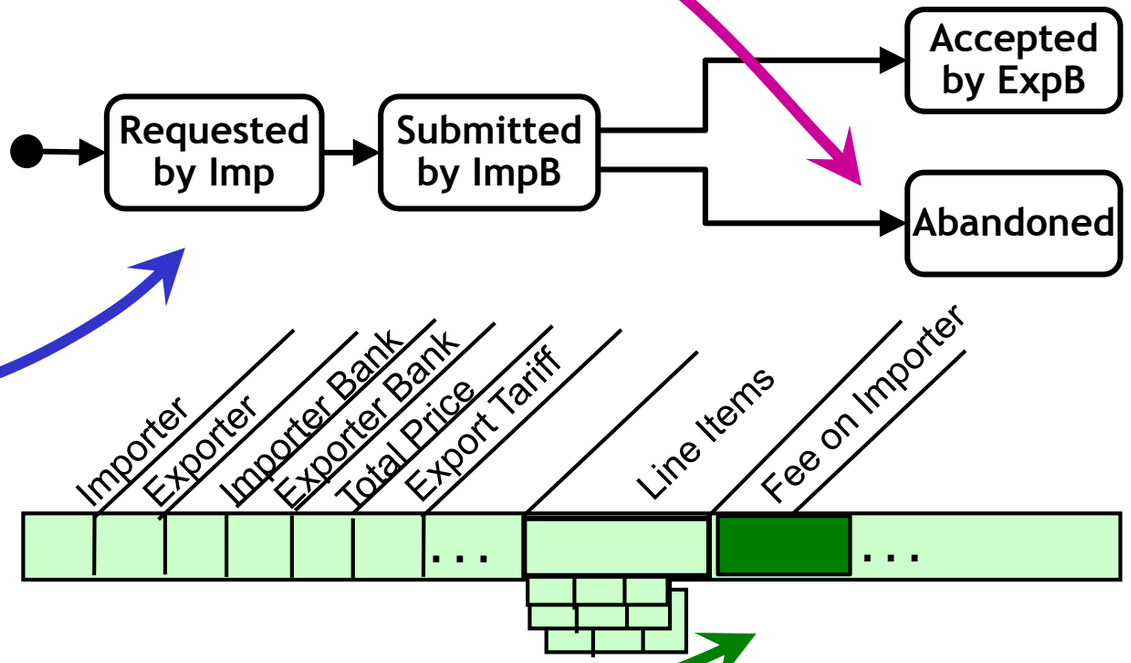
ACSI Views: Limiting what can be seen



View for Exporter:
Hiding negotiation between
Importer Bank & Exporter Bank



State Condensation:
Exporter sees one state that
is a “collapse” of 3 states

Attribute Projection:
Certain attributes are
hidden from Exporter’s view

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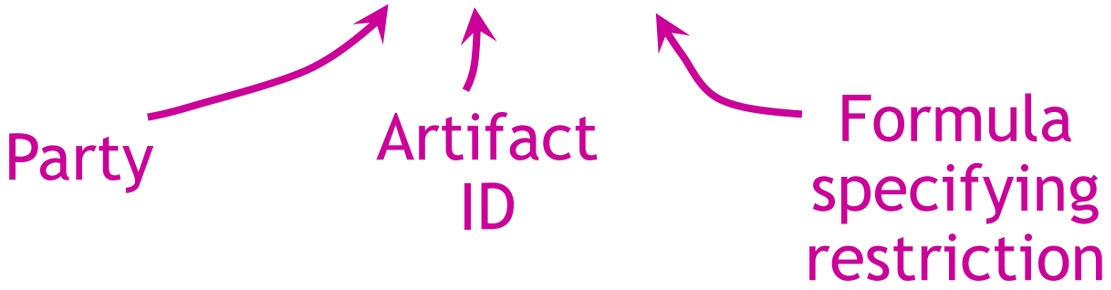
ACSI Windows: Limiting which artifact instances can be seen

Window query: $\{ (p, a) \mid \varphi(p, a) \}$



Examples:

1. Importer sees all of it's Orders
2. Importer Bank sees all Letters-of-Credit, Export Docs, and Drafts for which it is providing or receiving credit
3. Harbor Master sees all Shipments coming in or out of harbor

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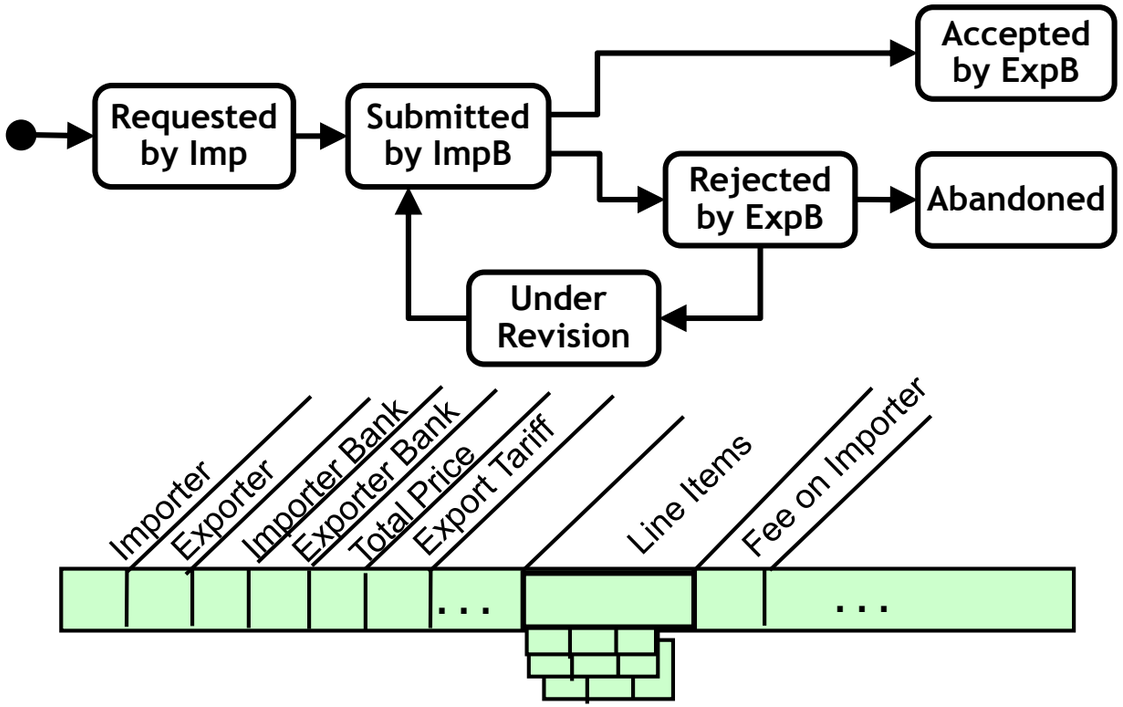
ACSI service controls: Limiting what participants can do

- E.g., for Importer Bank, we can specify in detail which attributes can be created, read, updated, …
- Permissions change based on state you are in

Create
Read
Update
Delete
Append
Execute



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Artifacts and ACSI: Providing a robust starting point for a Business-Level Collaboration Framework for Blockchain

- There is also substantial research on the ACSI paradigm
  - Cf. EU-supported ACSI project (2010 to 2013)
- Systems – Biz Artifact (open source)
- Foundations

But … We cannot apply them “out of the box”

- Conceptual models: Blockchain restrictions – e.g., synchronous service calls
  - Operational perspective
  - Contractual perspective, including legal and natural language
- Systems: Mapping onto Hyperledger, Ethereum, etc.
- Collaboration/Choreography: Very relevant
- Verification: Different questions

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Requirements on Business-level Smart Contracts Framework

Solution Language

- ***Intuitive*** for Business-level users to create and understand smart contracts
  - Example users: Business Analysts, Trade Specialists, Financial Analysts, Supply Chain Specialists, …
  - Holistic way of representing key business objects, including data, lifecycles, rules, roles
- Linkage between ***Legal Contractual perspective*** and Operational perspective
- Linkage to ***existing standards, e.g., UBL, SWIFT, …***
- Intuitive support for adding variations into existing smart contract specifications
  - Including modifications to business object data, lifecycles, rules
- ***Modularity & Composability***
  - Intuitively natural ways to do "plug and play", and to substitute portions of a smart contract
  - Note: in the future, smart contracts will be created by different organizations and mashed together
- Access Control & Privacy features – specified at business level
  - For data
  - For invocable operations

- Ricardian contracts appear relevant
- Emerging CLACK language [Clack et al 2016] aimed at this challenge

- Artifact types can serve as natural composable modules
- Data & lifecycles provide further modularity

Solution Development & Administration

- Visual editor
- Enable ***rapid development & modification of production-level solutions***
  - Use a fully interpreted paradigm for execution of smart contracts
- Design, develop, deploy, test, refine
- Version management

The BizArtifact system [Boaz et al 2013] for artifacts included
- Visual editor
- Fully interpreted implementation of artifacts
- Administration framework

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Working hypothesis for a Business Collaboration Language (BCL)

- Leverage Business Artifact / Business Object paradigm
- Information model
  - Nested relations (e.g., represented as JSON)
  - Query/conditions by subset of SQL++ [Ong, Papakanstatinou, Vernoux
- Lifecycle model – multiple possibilities
  - Acyclic DAGs with rollback (cf. [van der Aalst, Weske, Grünbauer 200
  - Finite State Machines
  - Guard-Stage-Milestone/CMMN (see [Marin,H.,Vaculin 2011])
  - Active XML
  - Proclets [van der Aalst et al 200?] / BPMN
  - More declarative, e.g., DecSerFlow [van der Aalst et al 2009], DCR Graphs [Hildebrant et al 2011]
  - Other ???
- Access constraints
  - Data: should be conditioned on Lifecycle status and data values
  - Lifecycle:
    - Restricted access has not been emphasized in Blockchain literature
    - Techniques from ACSI might be adapted

FSM's as reasonable starting point because

- Adoption: "Everyone" is familiar
- US Office of Financial Research suggests FSMs for financial contracts [Flood, Goodenough 2015]
- Natural mapping from Functional Programming formalization of legal contracts (see below)

Use extended Event-Condition-Action (ECA) rules

- Captures the reactive nature of Blockchain smart contract
- While permitting declarative style

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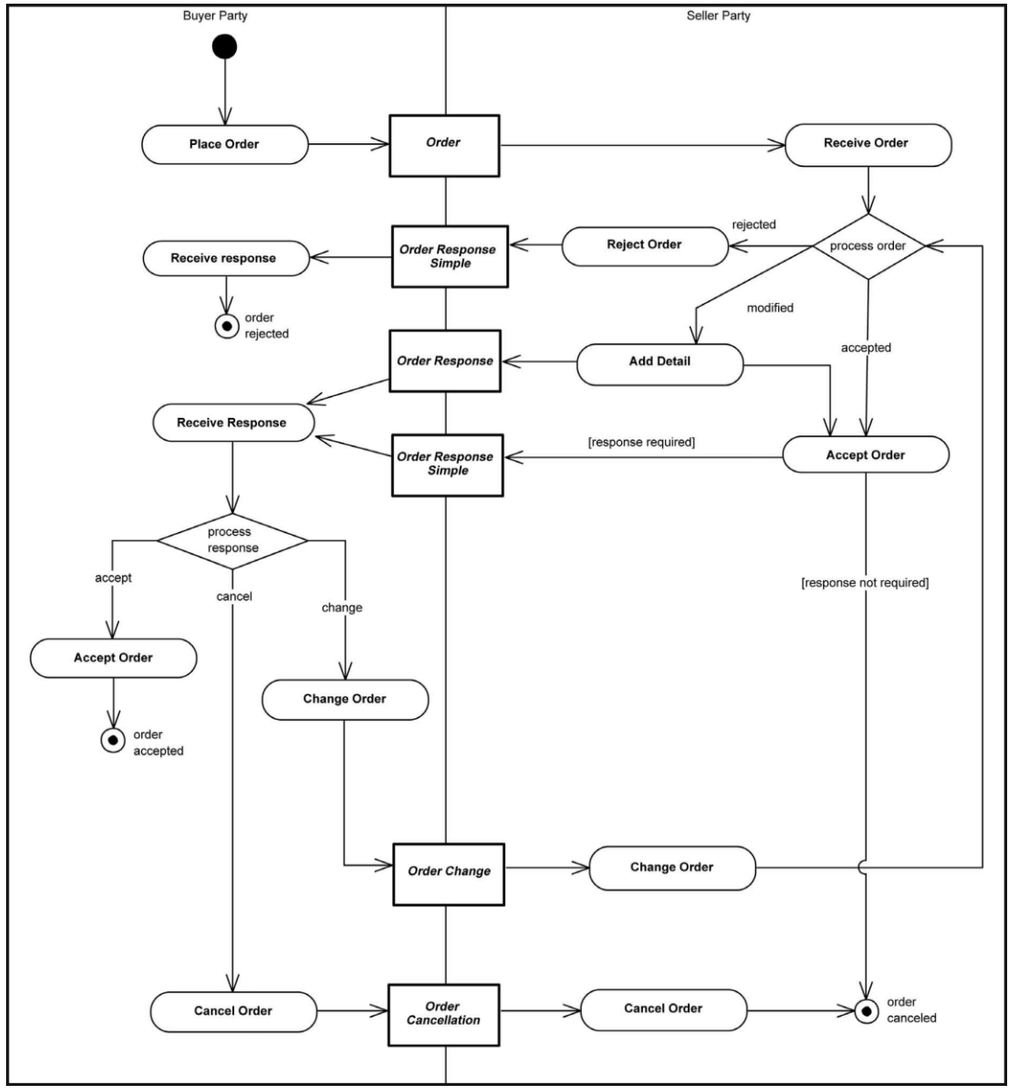
Representative standard – UBL 2.1

- OASIS standard focused on Supply Chain use cases
  - Approved by OASIS in 2013 and as ISO Standard in 2015
  - Adopted by/extended by: EU Public Sector; various procurement frameworks (Norway, Sweeden, EU DIGIT, UK Natl. Health Service, OpenPEPPOL (several Euro countries), Port of Hong Kong, Port of Singapore, …
  - Supports approx. 45 business process flows and 65 document types
  - For document types: validators, authoring software, parsers, generators
- Focus is mainly on binary relationships/processes, and includes
  - Workflows for order, invoice, shipment, consignment, …
  - For each workflow, document types for exchanging information
    - The workflows provide the business context within which documents are exchanged
- E.g., "Ordering is the collaboration that creates a contractual obligation between the
  - Seller Supplier Party and the
  - Buyer Customer Party."

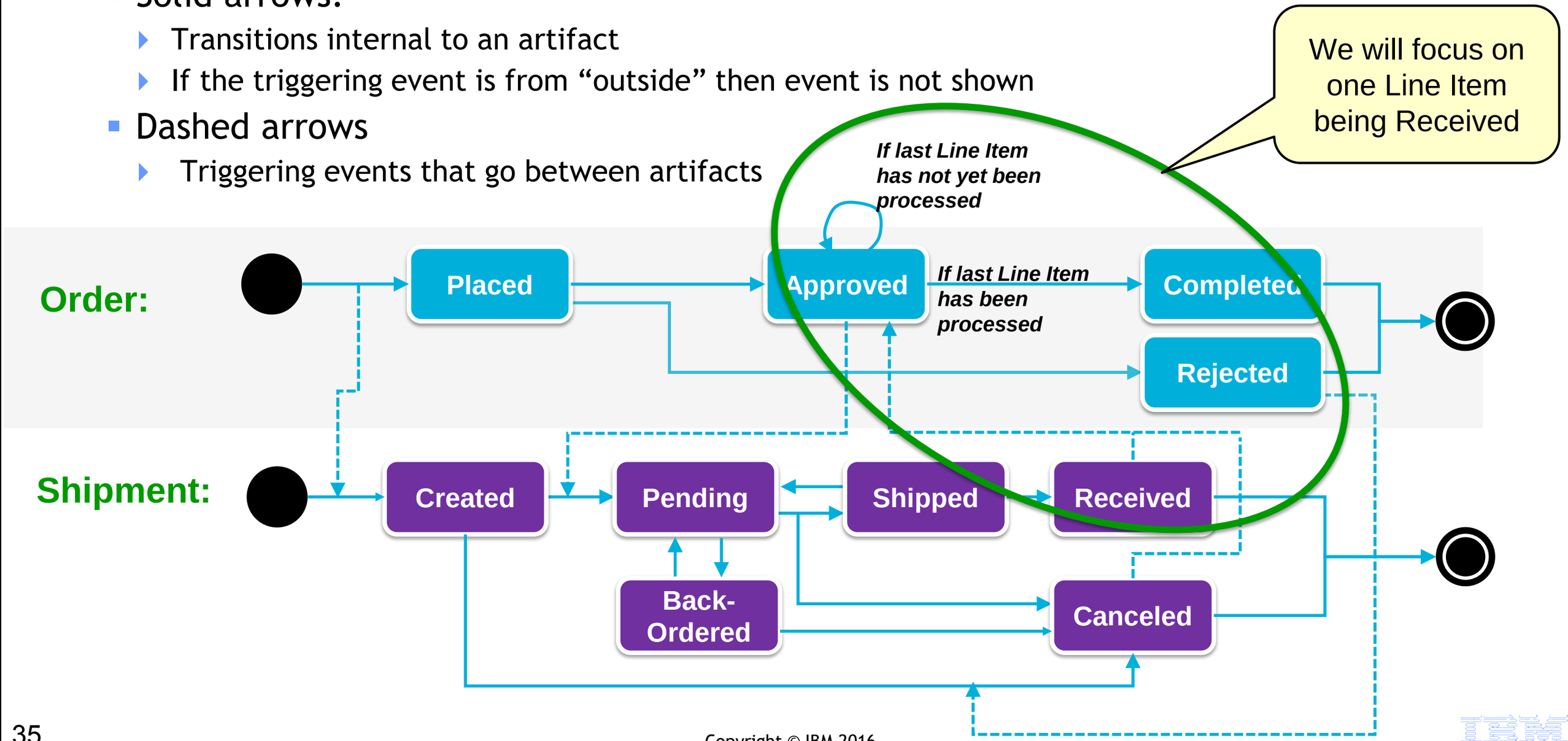


UBL 2.1: Figure 21, section 2.6, p. 39

Blockchain allows the documents to be shared . . .
. . . enables the documents to support change through time

Example based on Order with multiple Line Items, each shipped separately

- Solid arrows:
  - Transitions internal to an artifact
  - If the triggering event is from “outside” then event is not shown
- Dashed arrows
  - Triggering events that go between artifacts



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Targeted example: Info Models and Lifecycle Models

Order

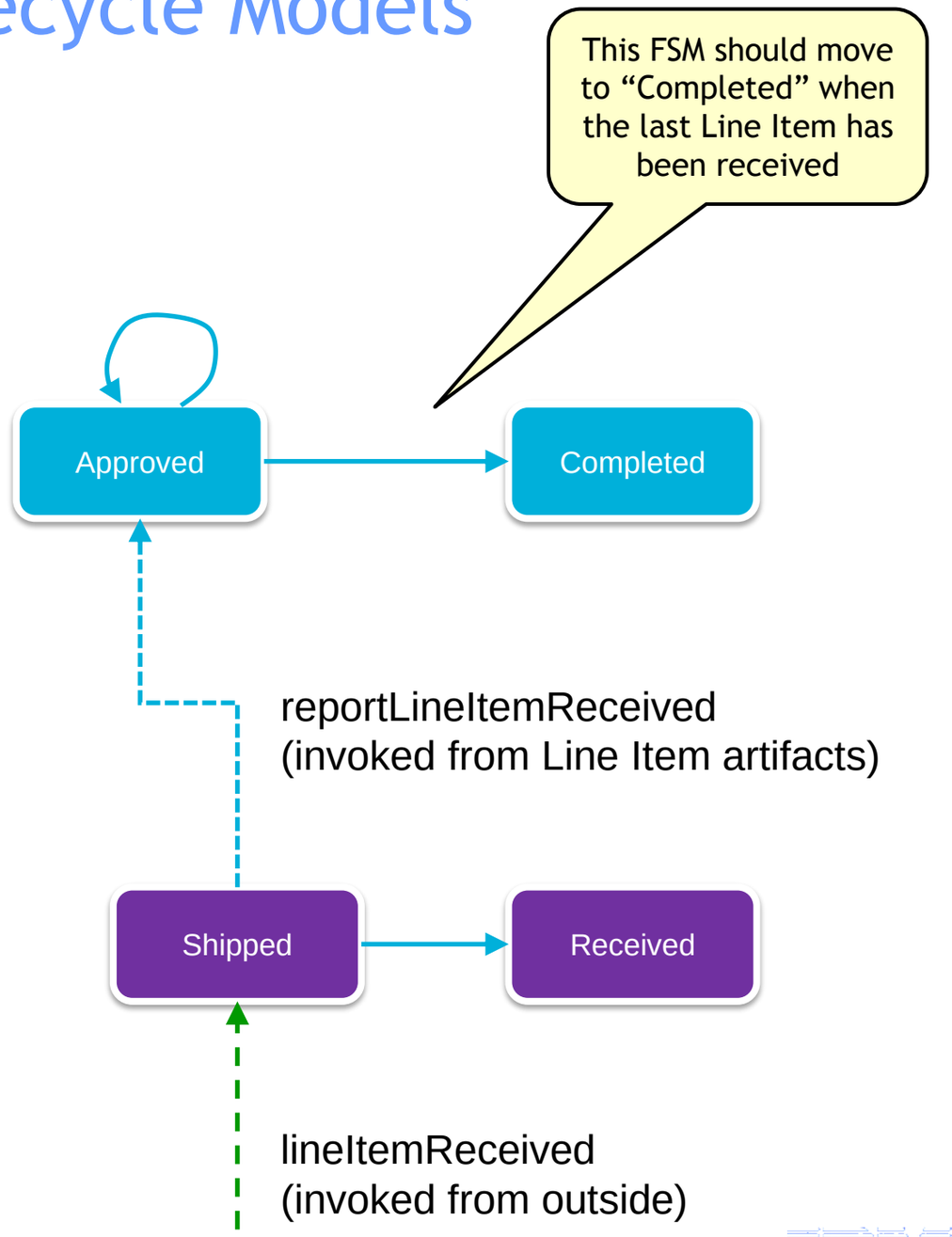
- PurchaseOrderId: string
- LineItemList: [{ LineItemId: string, Price : int, Weight: float }]
- LineItemsReceivedSoFar : [{ LineItemId : string }]
- Status: string

This unary relation is used to hold list of all Line Items that have been received by the Buyer so far

Line Item

- LineItemId: string
- ParentPurchaseOrderId: string
- Price: int
- Weight: float
- Status: string

"Status" is used to hold current FSM state



Note: each artifact has an implicit attribute "WaitingFor : { name: string, id: string } ", which is used to record invokes that have gone out but not returned yet. A transaction is not completed unless all the attributes WaitingFor have null value

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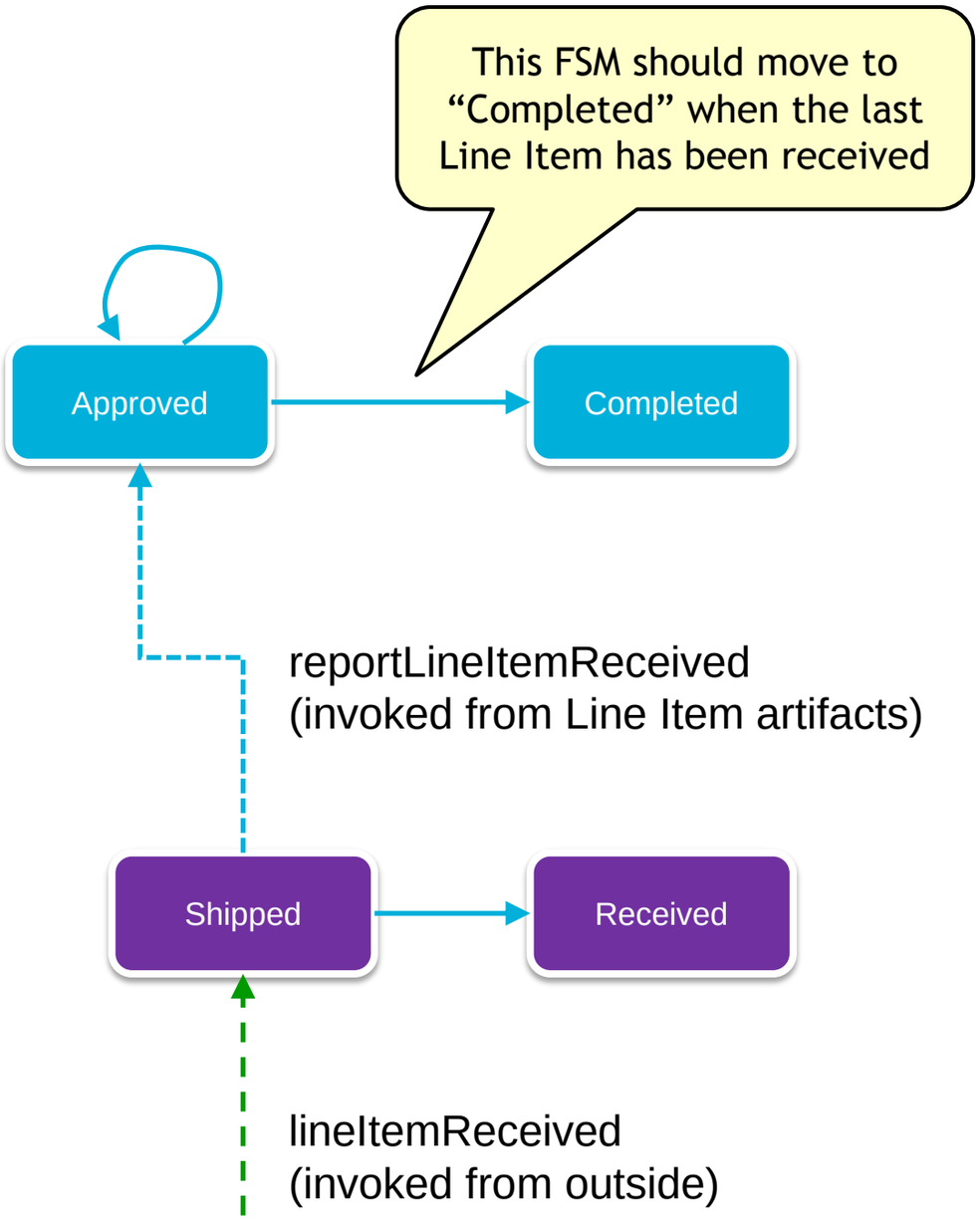
Illustration: Three ECA rules that string together



Switch from Line Items to Shipments

Line Item

```
Who: Buyer
On: receive lineItemReceived ( LineItemId: string, date:
Let:
If: self.state == "Shipped"
Then:
    self.state := "Shipped" ;
    invoke reportLineItemReceived ( target: self.ParentPurchaseOrderId,
                                    RecievedLineItemId: input.LineItemId,
                                    ReceivedDate: input.date)
```

Purchase Order

```
Who: Buyer
On: receive reportLineItemRecieved ( target: string,
                                     ReceivedLineItemId: string,
                                     ReceivedDate: dateTime)
Let: allLineItems := self.LineItemList.{LineItemId}
     allReceived := union ( self.ReceivedLineItems,
                            { { LineItemId: input.RecievedLineItemId } } )
If:  (self.state == "Approved") and
     (allLineItems == allReceived)
Then:
    self.ReceivedLineItems := allReceived;
    self.state = "Completed";
    invoke Callback ( target: input.ReceivedLineItemId )
```

Test of whether all Shipments have been processed

Line Item

```
Who: Buyer
On: receive callBack reportLineItemRecieved ( target: string )
Let:
If:  self.state = "Shipped"
Then:
    self.state = "Received";
    invoke Callback ( LineItemsStatus: "Finished" )
```

A design method for Artifact-centric Smart Contracts

(adapted from [Nandi et al 2008])

- Identify, name, and describe the key shared evolving Entities in the scope of the project
- These will sometimes correspond to document types in existing standards
- ***Provide clear, un-ambiguous description of the business intent of each Entity***

- Identify the key milestones of each Entity in the scope of the engagement
- ***Sketch the data needed to enter into each milestone***
- For each Entity, sketch a picture of valid transitions between its milestones
- For each edge, determine which Roles can invoke that transition

- Finalize the Data Groups for each Entity milestone
- Expand each Data Group into fields
- Identify any ***rules and constraints to ensure quality and consistency of the data***

- For each Entity, identify the rules for each transition between the key milestones
- ***Also identify the rules that move between Entity types***
- For each rule, include the roles that can invoke it, conditions under which it should be fired, and what data updates it performs

- Perform testing based on variety of examples and corner cases
- ***Examine how legacy services will need to be modified in order to use the Blockchain solution.*** (If there will be large expense, consider modifying the solution.)

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Agenda

- Blockchain enables a new level of trust & communication
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- Logical separation between Blockchain mechanics and Biz-level programming
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- Selected research challenge areas
  - Language design
  - Reasoning about artifacts
  - Relationship to natural language contracts
- Conclusions

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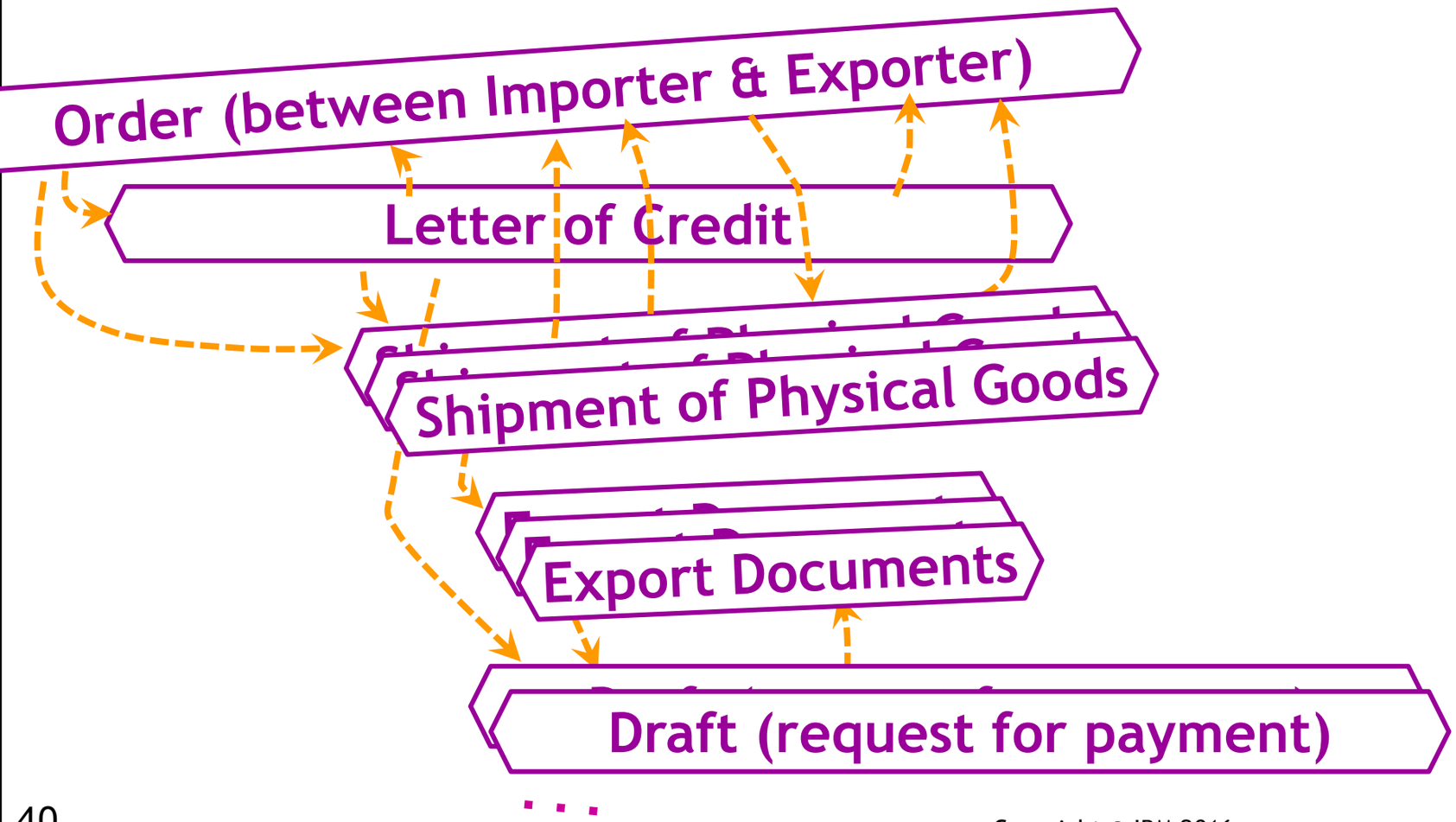
A world that we anticipate:

A single collaboration will involve numerous artifact instances, with multiple 1-to-many relationships



Different artifact types designed & maintained by different organizations

Why?

- Making artifact types similar to existing standards, e.g., UBL, SWIFT, …
- Different kinds of concerns for logistics vs. finance

Impact:

- Interaction between artifact types must be understood

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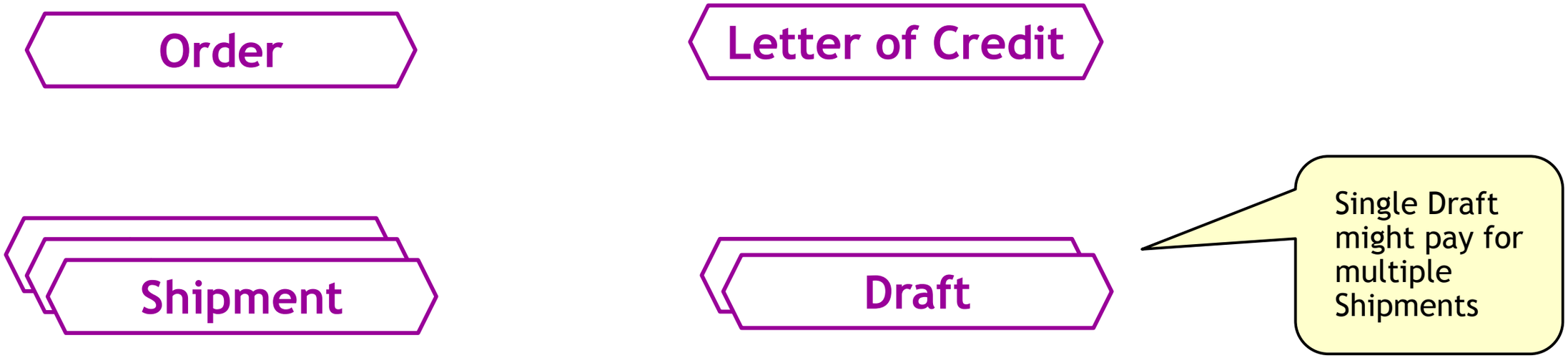
Reasoning about "Choreographies" of Artifacts
(adapting from [Sun,Xu,Su ICSOC 2012], [Su, Sun 2013])

- Suppose that each artifact type is a separate Smart Contract
- In a HyperLedger fabric, communication will be by synchronous service calls



- How to develop a framework for specifying desired properties?
  - Design "correctness", auto realization, mechanisms for monitoring, …
  - Key Issue: Need explicit way to model & reason about correlations

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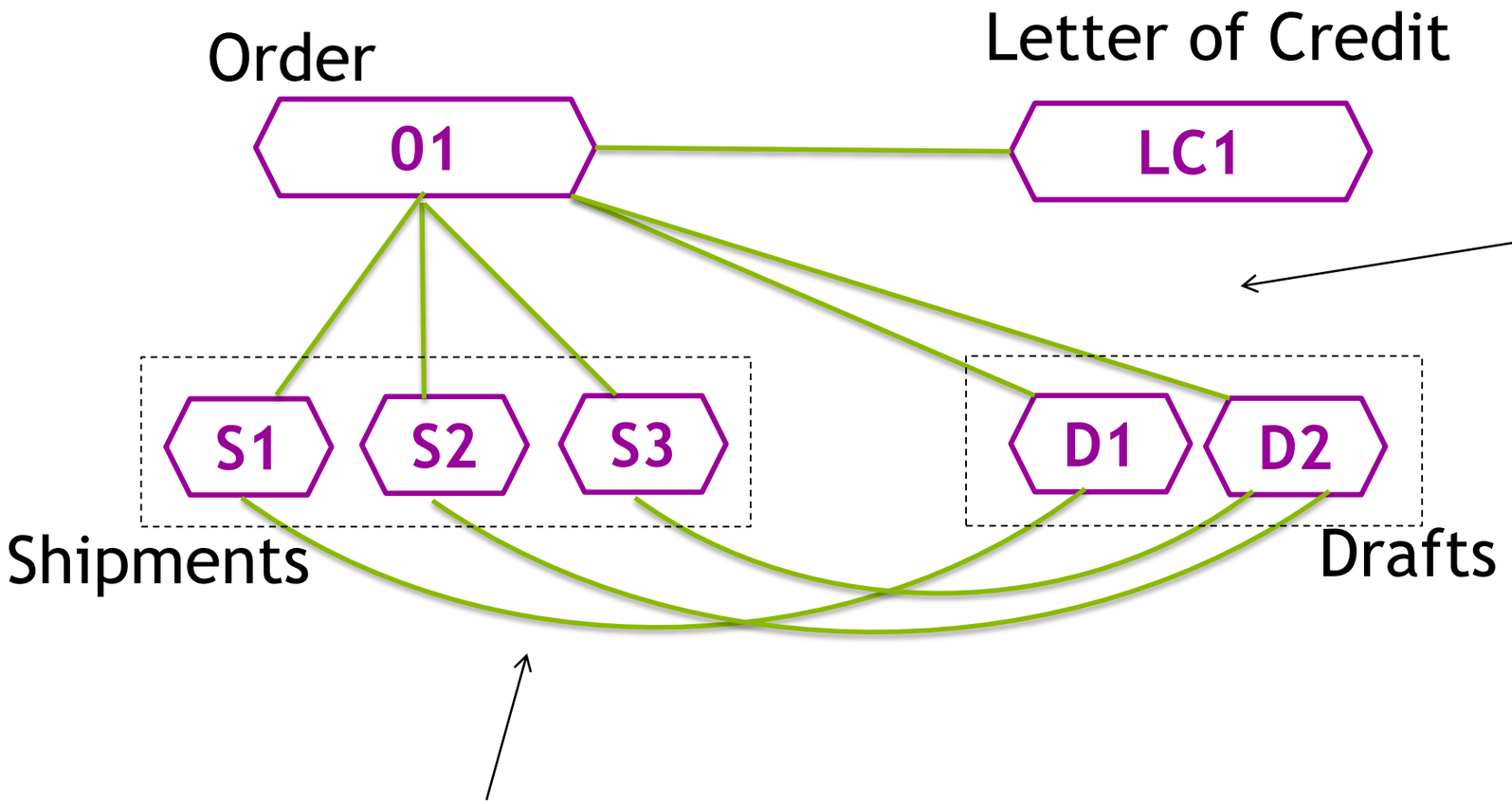
Two Key Aspects of Choreography Languages



Conditions involving Data:

For each shipment, if Export Docs obtained by Exporter, then a Draft including that Shipment is generated by Importer Bank

If the amount is less $1000 and additional Shipments pending, then delay Draft

Instance-level correlation:

Which artifact instances are correlated during the runtime?

Who sends messages to whom?

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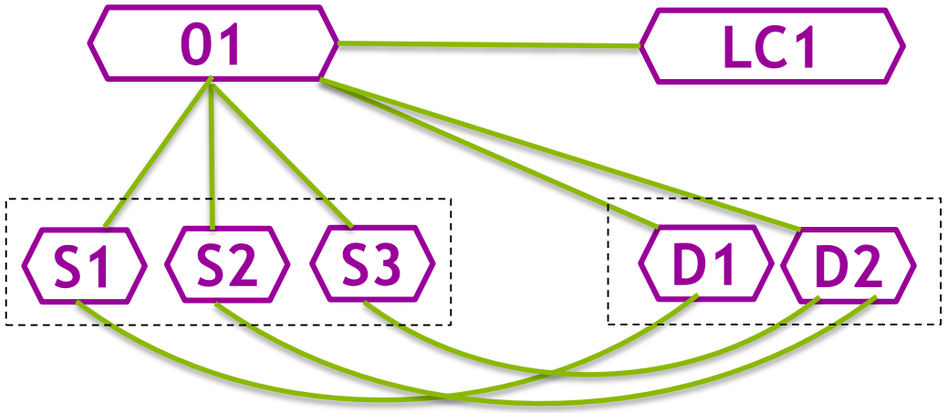
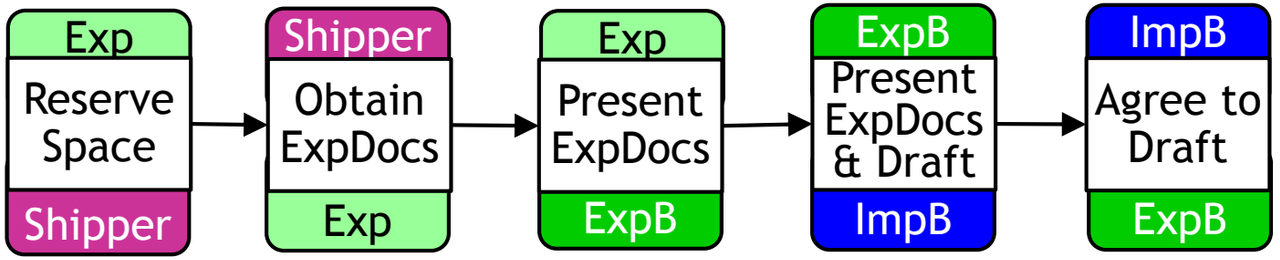
Tangent: How might BPMN “Collaboration” model this?



- This is collaboration diagram for a single Shipment mapping to Draft



- In general
  - Grouping of Shipments into Drafts will be random
  - Timing of different Shipments completing, and different Drafts completing will be random

- So, well-formed multi-instance construct cannot be used

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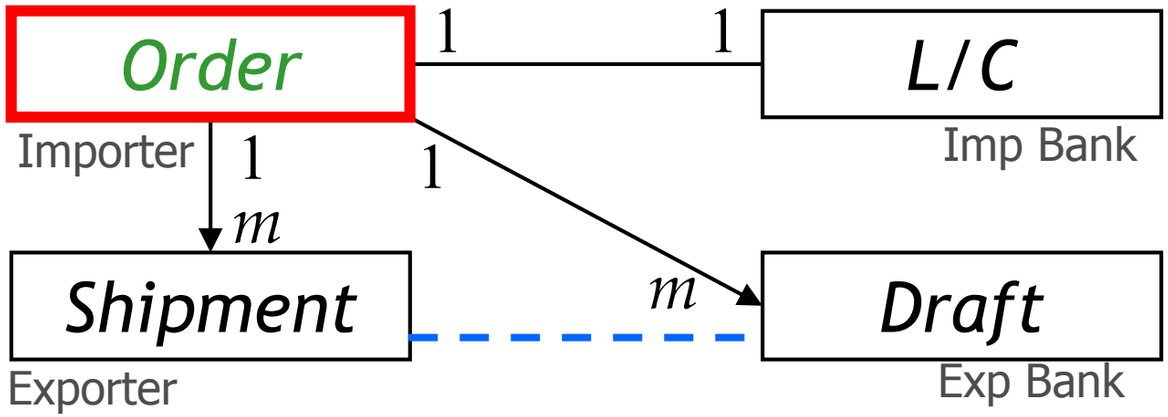
Framework for Interacting Artifact Types: Correlation Diagrams

- Two artifact instances are correlated if they are involved in a common collaborative BP instance
  - *Messaging only between correlated instances*
- Correlations for a collaboration are defined in a diagram, with one artifact as the root or primary process



  - Directed edge indicates creation of Artifact instance(s)
  - Cardinality constraints are also defined
  - Some syntactic restrictions (acyclic, "1" on root, …)
- Correlations can also be derived

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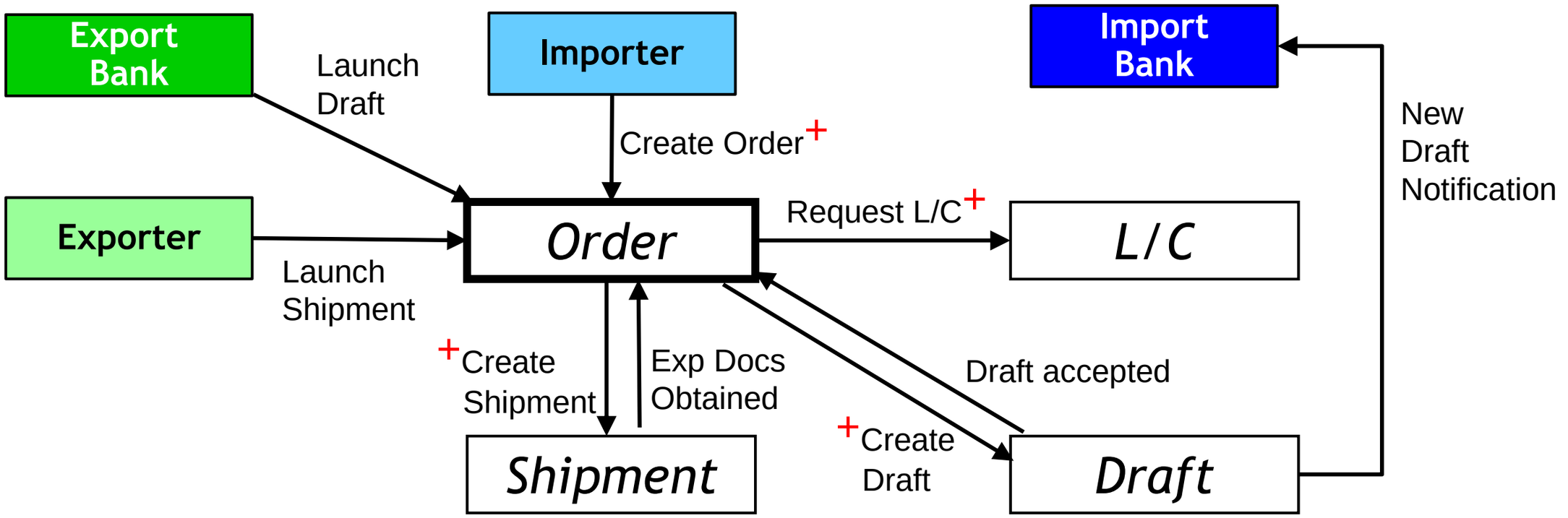
Messages Diagrams



- A message diagram defines message types and sender/receiver of each type
  - Includes messages from/to the external parties
  - "+" means creation of new BP instance
- Message may have data attributes
  - Path expressions are used to access data contents

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Choreography Constraint Example

Expressed in LTL-FO
(with some syntactic sugar)

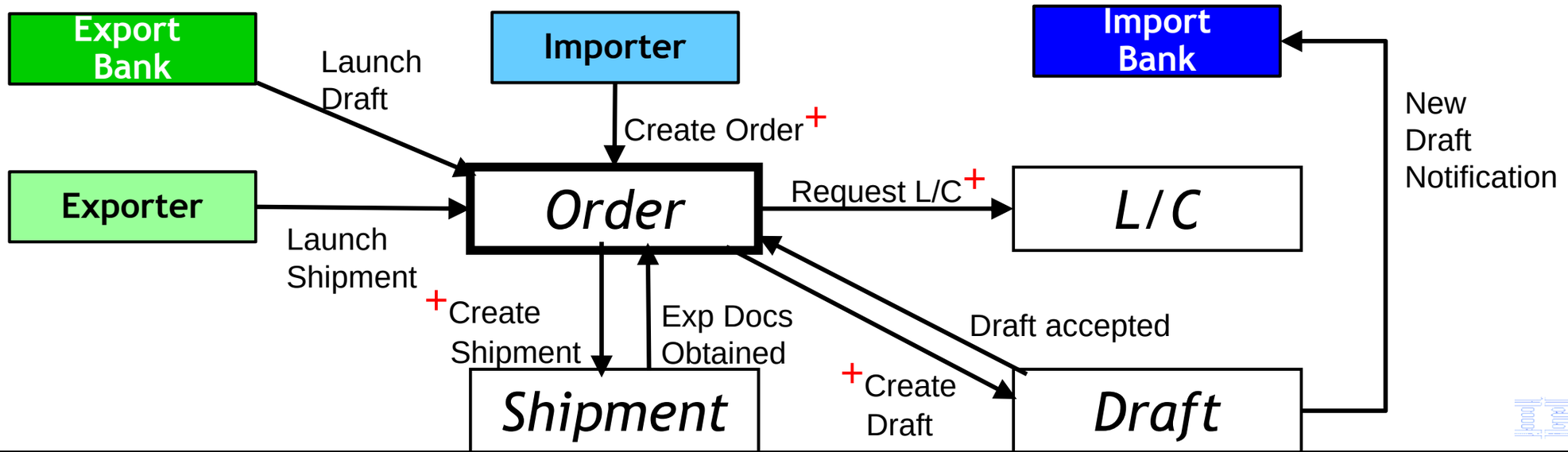
always ***eventually***

For each Shipment s, G (p → F q)

Exist Expdocs D
(D.shipment.ID = s.ID and
D.status = “Received by Exp”)

Exist message μ(Draft, ImpB)
(Type(μ) = “New Draft Notif.” and
s in μ.payload.shipments)

“For each shipment, if ExpDocs received by Exporter, then eventually a Draft Notification including that shipment is sent to Import Bank”



Reasoning with Choreography Constraints on Artifacts

- This field is still in its infancy
- [Su,Sun 2013] study “Realizability”

Given an artifact message diagram and family C of Choreography Constraints …

… is there a family of services that “realizes” exactly the runs that satisfy C ?

  - Preliminary result: “Yes”, if there are no 1-to-many relationships between artifacts
  - Question remains open in the general setting

- What about Verification ?

Given full artifact system S and family C of Constraints …

… does every run of S satisfy C ?

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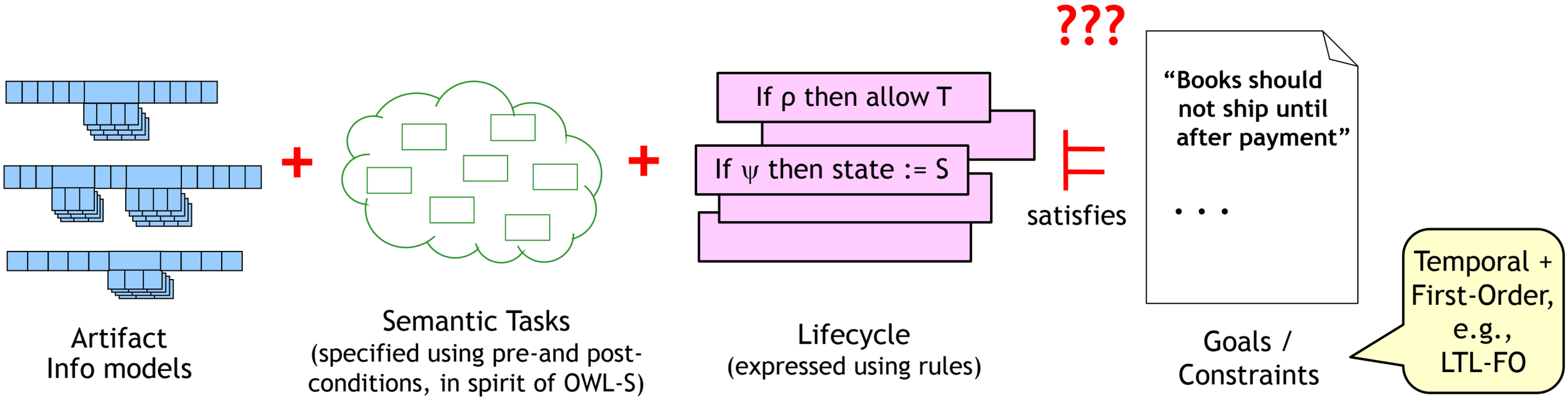
Verification for artifact-centric models: a representative framework

- Given an artifact-based model M and a property P, do all executions of M satisfy P ?



- The presence of data leads to an infinite state space
  - Verification in general is undecidable
  - Several different approaches to restrict expressive power have been developed

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Several approaches to verification for data-centric process
(see surveys [Calvanese, De Giacomo, Montali 2013], Deutsch, H., Patrizi, Vianu 2014])

- Early results: Focus on “flat” artifacts
  - [Bhattacharya, Gerede, _, Liu, Su 2007] multi-artifact system; PSPACE-complete verification
  - [Zhao, Su, Yan, Qiu 2009] verification of propositional LTL
- Flat artifacts with fixed re-only database
  - [Deutsch, H., Marcus, Patrizi, Sui, Vianu, Zhou, starting in 2009]
  - Strong restrictions, e.g., no dependencies, no arithmetic, focus on ∃FO conditions; LTL+∃FO constraints
  - Obtain PSPACE verification by reduction to finite-state model checking
- Recent extension
  - Hierarchical lifecycle models and artifacts with relation-valued attributes
  - [Deutsch, Li, Vianu 2016] Obtain PSPACE verification with reduction to Vector Addition System with States
- Data-Centric Dynamic Systems (DCDS)
  - [Bagheri Hariri, Calvanese, De Giacomo, De Masellis, Felli 2011] and others ...
  - Artifacts range over relations, powerful temporal logics
  - Acyclicity conditions guarantee bounded domain
  - [Belardinelli, Lomuscio, Patrizi 2013] Verification of DCDS in context of multi-agent system

Blockchain context brings a different focus –
limited data, access rights, choreography constraints, 1-to-many relationships, …

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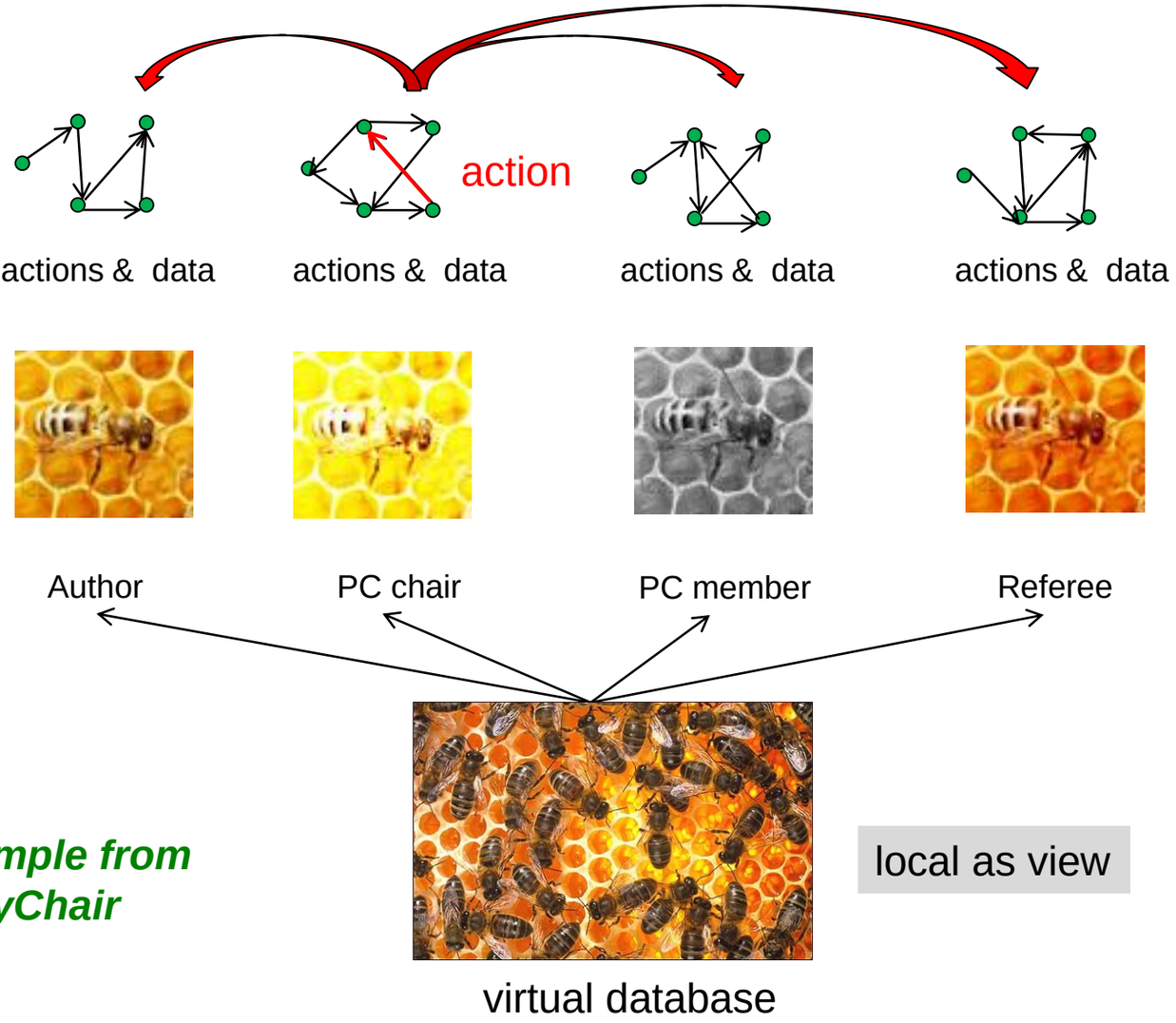
Reasoning about views [Abiteboul, Vianu 2015]



Example from EasyChair

- Each participant working on a view
  - Their actions are propagated to the others, according to semantics of the (virtual) global state
- Studying what a participant can infer about the global state, e.g.,
  - As an author, has my paper been accepted?
  - As a PC member, can I tell if a decision was made about my own submission?
- Model
  - Global database is set of relations with keys
  - Each view sees projections, with entire key present
  - Using PLTL-FO – "P" for "previous"
- For fixed workflow schema, reasoning in PSPACE

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From www.legalese.com home page

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Legal contracts: what makes them different?

- Binary relationship
  - "Holder"
  - "Counterparty"
- Contract based along time dimension
  - As they move through time …
  - … people make choices
  - … result is essentially a new contract
- Contracts are exchanged, combined, traded, …
- Contract may depend on external "random" variables
  - E.g., exchange rates, stock prices
- A focus of financial industry is

  What is the current value of this contract ?

  - Must incorporate uncertainties of future
  - Various statistical techniques available

On 15 July 2000 you may choose between:

D_1 Both of:

D_{11} Receive £100 on 29 Jan 2001.

D_{12} Pay £105 on 1 Feb 2002.

D_2 An option exercisable on 15 Dec 2000 to choose one of:

D_{21} Both of:

D_{211} Receive £100 on 29 Jan 2001.

D_{212} Pay £106 on 1 Feb 2002.

D_{22} Both of:

D_{221} Receive £100 on 29 Jan 2001.

D_{222} Pay £112 on 1 Feb 2003.

From "How to write a financial contract",
S.L. Peyton Jones and J-M. Eber,
Proc. Intl. Conf. on Functional Programming, 2000

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Functional programming can provide formal abstraction for finance-based contracts

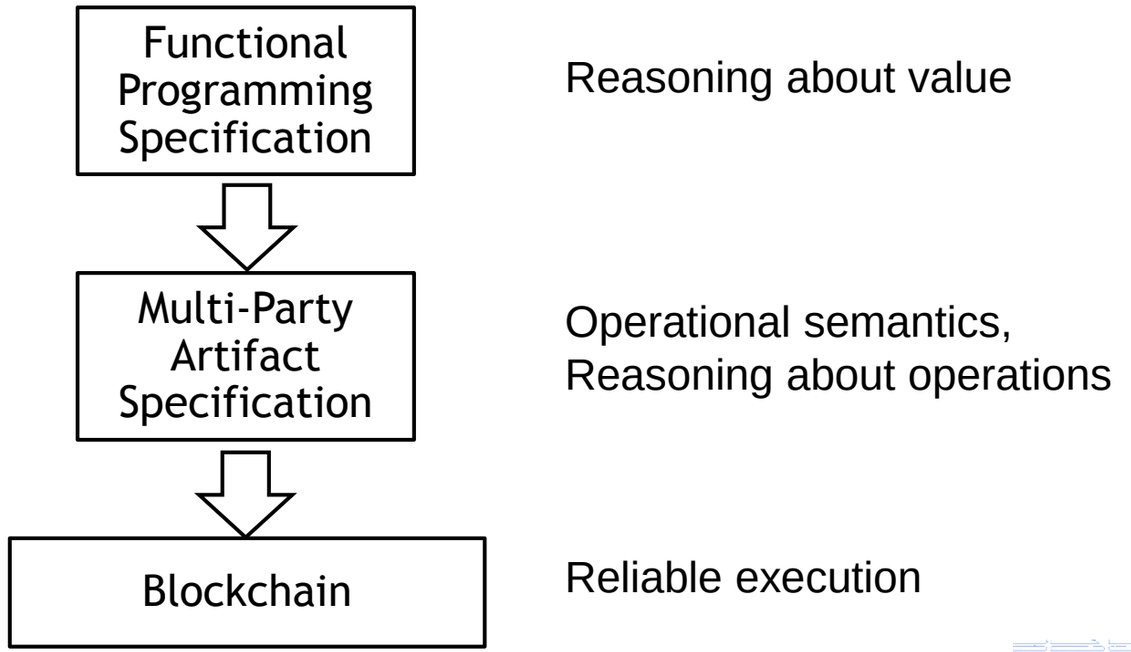
[Peyton Jones, Eber 2000] provides a family of 10 primitive combinators that can be used to formally define contracts

- "and": if you acquire "c1 and c2", then you immediately have both
- "or": if you acquire "c1 or c2", then you must immediately choose to retain one or the other
- "when": if you acquire "when <obs> c", where <obs> is a Boolean-valued observable, then c becomes available to you if/when <obs> becomes true
- "until": "until <obs> c" acts like c until <obs> becomes true. From that moment the contract becomes worthless
- …

This functional programming view enables

- Composability
- Formal reasoning about semantic equivalence

Conjecture: a family of inter-related binary contracts can operationalized using an artifact-based Blockchain implementation



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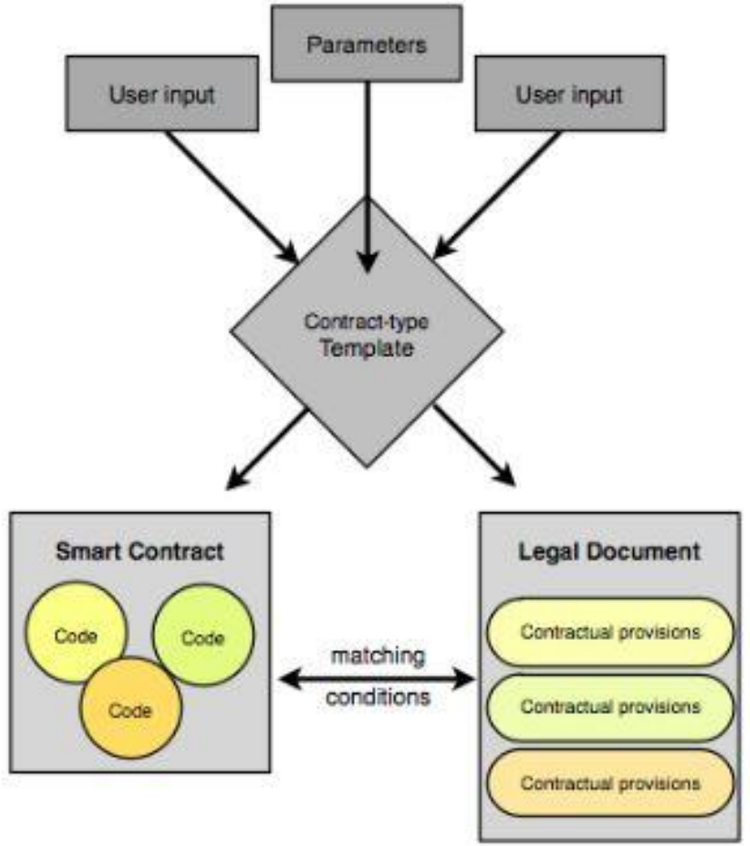
Another perspective on mixing “legal” and “smart” contracts

- Distinction made in CoinDesk by Stark [2016]
  - Smart Contract Code: code that embodies how agents want to collaborate, running on a Blockchain
  - Smart Legal Contract: combination of legal wording and executable code that correspond to each other

- Ricardian contracts: an example of Smart Legal Contract
  - Invented by Ian Grigg [2004]
  - “A digital contract that defines the terms and conditions of an interaction between two or more peers, that is cryptographically signed and verified”
  - It is both **human and machine readable**
  - Has a unique and secure identifier



http://www.webfunds.org/guide/ricardian_implementations.html

Groups like CommonAccord are attempting to create a body of “universal contracts” that can handle essentially all useful kinds of collaborations

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Blockchain: A new technology with growing adoption for Business Collaboration

This raises many of the classical questions from Services Research community . . .

. . . But with a twist:

A persistent shared trusted data store is at the very center of things

- Allows, and forces, a re-thinking of basic services paradigms, such as
  - Orchestration/choreography: is ACSI hub the right abstraction, or something else?
  - Service composition: It's not just about message/conversation compatibility anymore
    - Will Business Artifacts be the unit of composition, or something else?
  - Service design patterns: How to use presence of data to best advantage?

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Blockchain: Operational vis-a-vis Legal/Financial perspectives

Two critical observations:

- The courts will always be the remedy of last resort → legal perspective is always present
- Almost every operational task has a financial aspect → financial perspective is always present

- Brings a new style of challenge to the services community
  - Service composition: Legal and Financial contracts are interlocking, interdependent
    - Do our current paradigms adequately model this?
  - Formal reasoning/verification: We need to address Legal/Financial patterns (among others)
  - Design/Coding style: How will marriage of legal+code be structured, at macro- and micro- levels

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