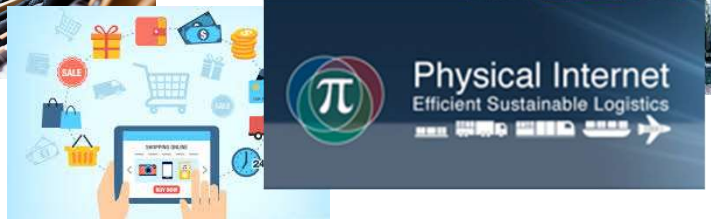

MORPHEUS
AN OPEN DATA SHARING INFRASTRUCTURE FOR SUPPLY AND LOGISTICS WITH BLOCKCHAIN TECHNOLOGY
TNO
TNO innovation for life

BUSINESS CASES FOR DATA SHARING

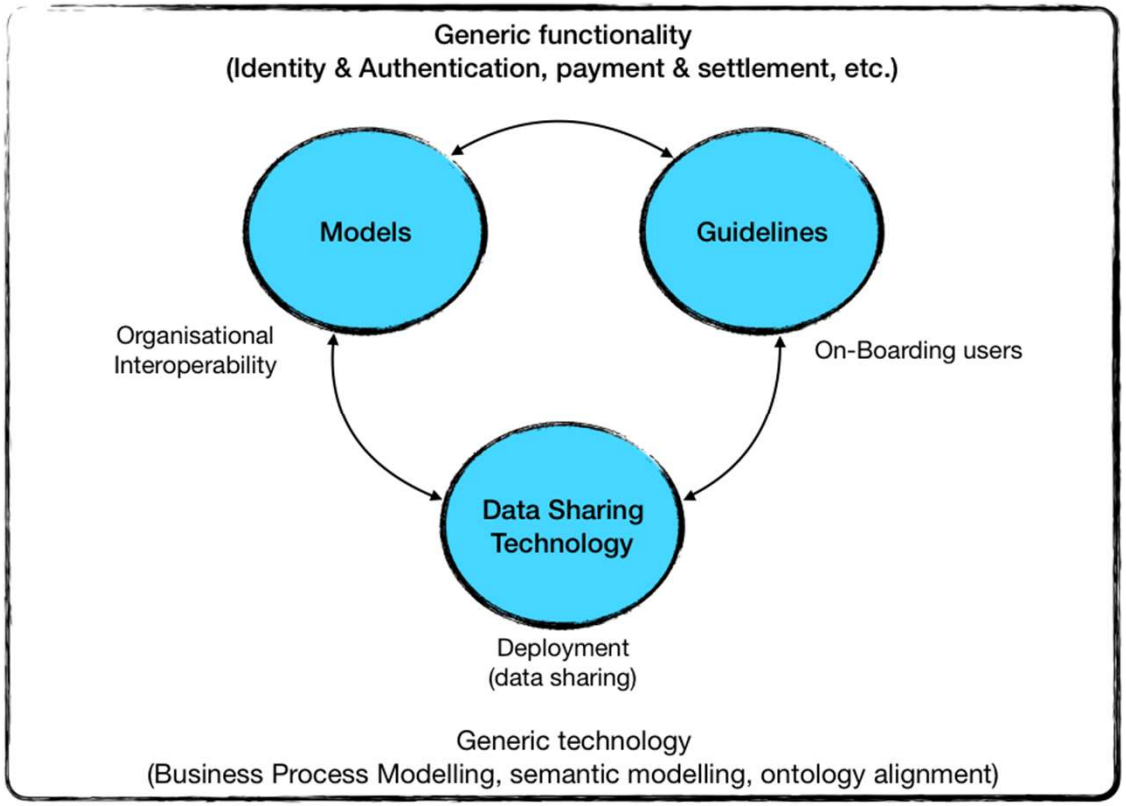
Performance	Performance indicator	Papers
Cost	Distribution cost	Bartlett et al. (2007), Gustin et al. (1995)
	Inventory cost	Barratt and Oke (2007), Beamon (1999), Chen et al. (2000), Ding et al. (2011), Gavirneni (2002), Lee et al. (2000), Ryu et al. (2009), Sahin and Robinson (2005), Yu et al. (2001), Wu and Cheng (2008), Zhang et al. (2011)
	Stock out cost	Clark and Hammond (1997), Kulp et al. (2004)
	Shortage cost	Lee et al. (1997a, 1997b, 2000, 2004), Yu et al. (2001), Disney and Towill (2003a, 2003b)
	Back order penalty cost	Cachon and Fisher (2000)
	Total cost	Lee et al. (2000), Zhao et al. (2002), Wu and Cheng (2008)
Quality	Supplier quality level	Bartlett et al. (2007)
	Internal quality level	Bartlett et al. (2007)
	External quality level	Tse and Tan (2012)
Service level	On time delivery	Beamon (1999), Prajogo and Olhager (2012), Zhou and Benton (2007)
	Customer response time	Beamon (1999), Zhou and Benton (2007)
	Product availability	Barratt and Oke (2007), Ryu et al. (2009)
Flexibility	Volume flexibility	Beamon (1999), Prajogo and Olhager (2012)
	Mix flexibility	Beamon (1999)
	New product flexibility	Beamon (1999)
Time	Manufacturing lead-time	Handfield and Bechtel (2002), Jayaram et al. (1999)
	New product development time	Handfield and Bechtel (2002), Jayaram et al. (1999)
	Cycle time	Kulp et al. (2004)
	Responsiveness	Barratt and Oke (2007)

COMPLEXITY

INDIVIDUAL CASES VERSUS HOLISTIC APPROACH
TRADITIONAL (MESSAGE) STANDARDIZATION IS INSUFFICIENT

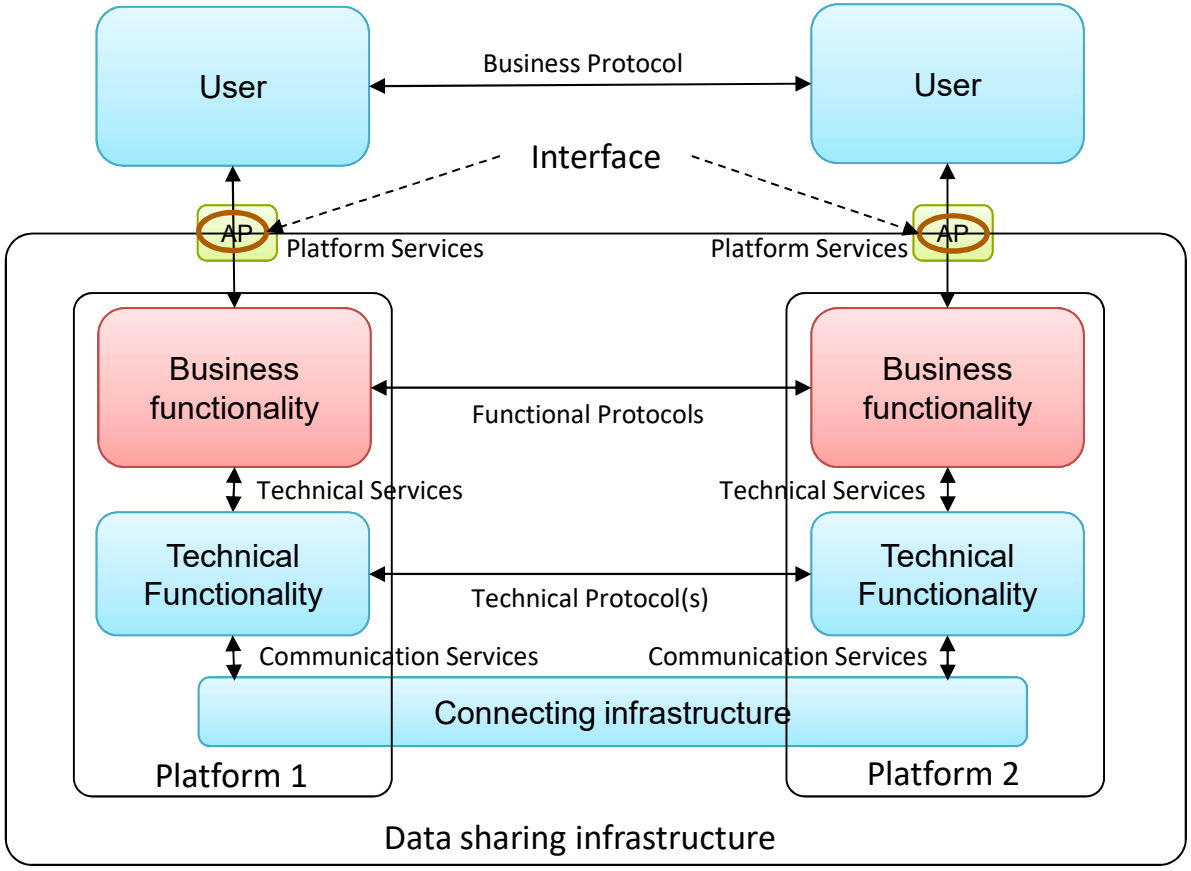


COMPONENTS OF OUR SOLUTION

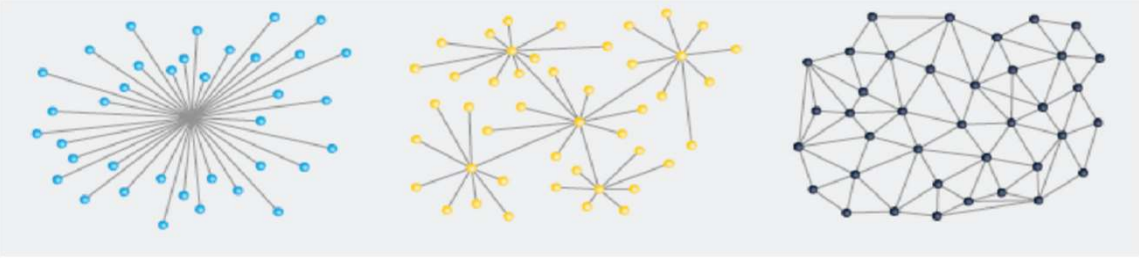


TECHNICAL LAYERS OF FUNCTIONALITY

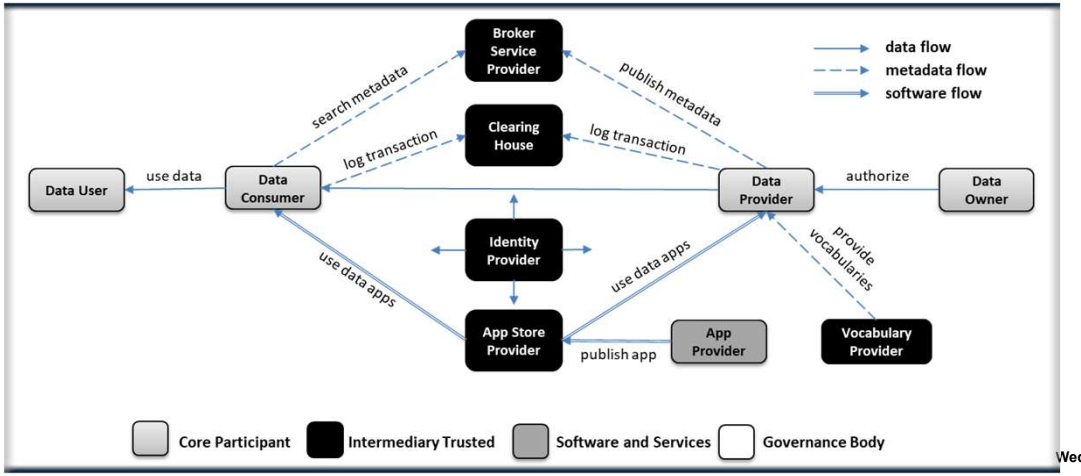
Blockchain
IDS
Platform(s)



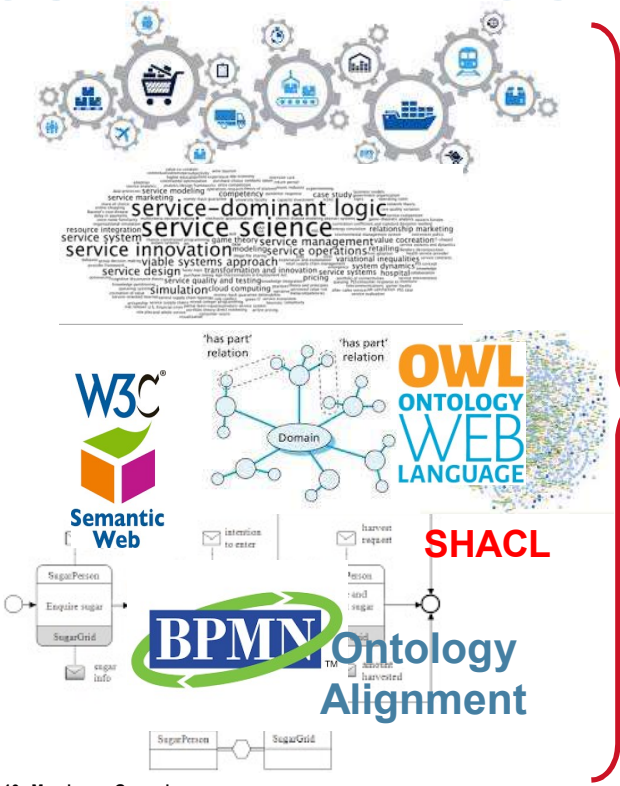
TYPES OF NETWORKS



Centralized Decentralized Distributed

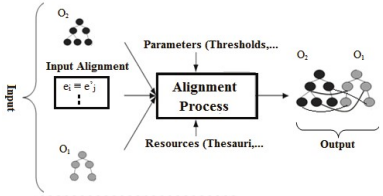


RAPID DEVELOPMENT AND DEPLOYMENT OF DLT IN SUPPLY AND LOGISTICS



Functionality

Technology



{JSON}

python™

DIF

BIGCHAIN DB

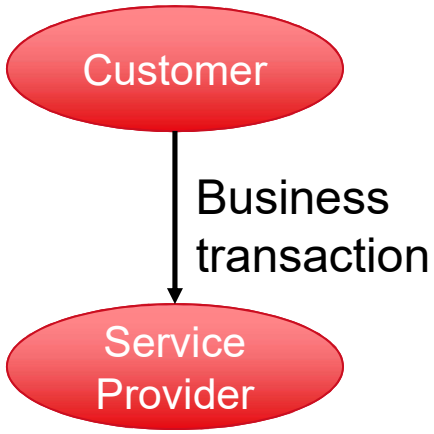
BLOCKCHAIN FOUNDRY

sovrin identity for all

IoT Internet of Things

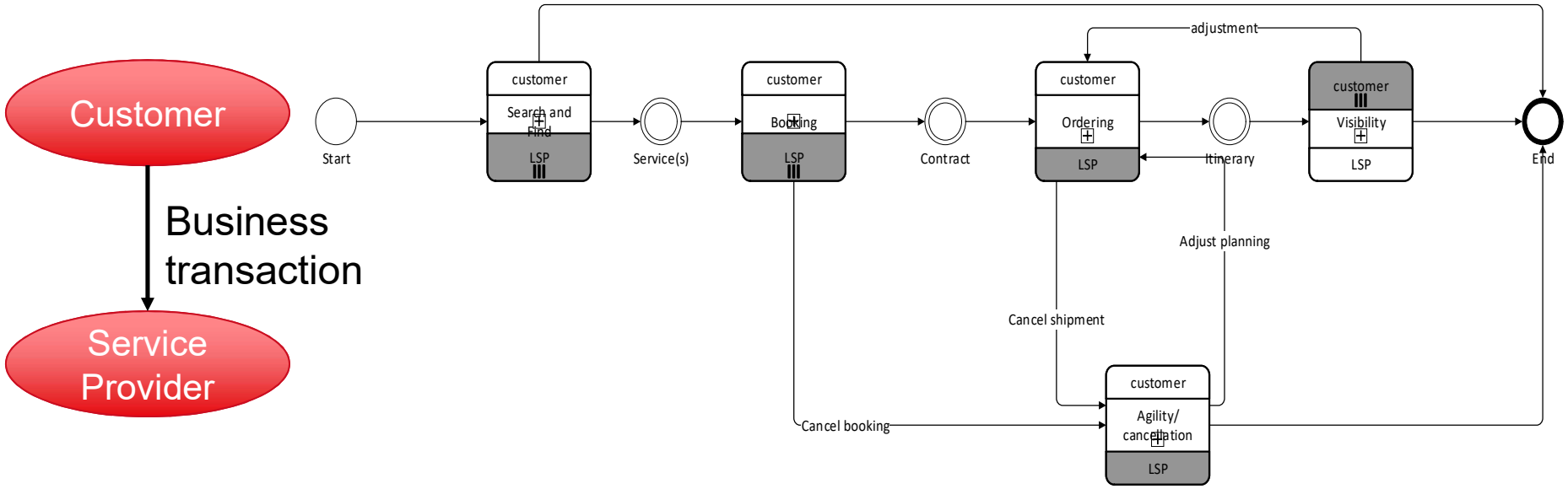
iSHARE

BUSINESS SERVICES AND - TRANSACTIONS



- A service provider offers a business service to customers
- Business services relate to objects and their properties
- Examples
  - Container Transport
  - Bulk Transhipment
  - Liquid (oil) bulk Storage
  - Quality surveillance
  - Customs formalities (import, export, ..)
  - …
- Transport services can be represented by for instance time tables, voyage schemes, flight schedules, ..
- Publication of business services – input to market place services (search and find)

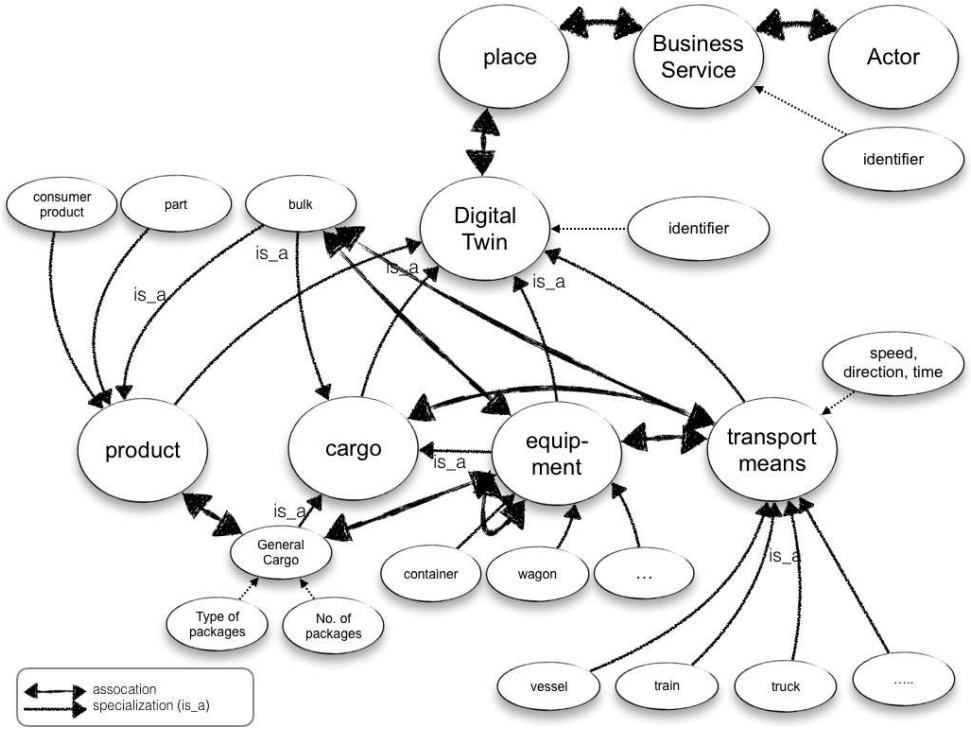
CHOREOGRAPHIES – MODELLING PERSPECTIVE (BPMN)



Business transaction choreography and thus the operations on DLTs can be standardized (DEMO; Digital Transport and Logistics Forum)

Different DLTs can be developed for each step in the choreography

ONTOLOGIES: COMPLEX STATEMENTS AND STATE OBJECTS



The ontology and thus Morpheus can be further specialized to fit various supply and logistics chains

- Modelling semantics – ontology
- Guiding principles
  - Digital twins – representation of physical reality (IoT)
  - Business transactions and choreography – ontologies by creating views or rules
- Examples of complex statements
  - Bookings, quotations
  - Orders, shipping instructions
- Representation of complex statements
  - Views (ontology) – import of a core ontology → message structures, JSON-LD
  - Rules – minimal data requirements
  - Example: a transport booking must contain data on cargo, locations, and times

BUSINESS SERVICE SEMANTICS

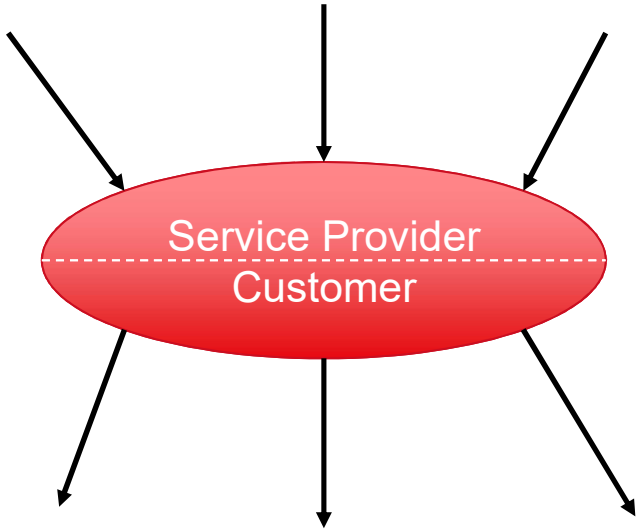
- Types of business services
  - Transport, transship. Storage, …
  - Administrative (formal) procedures, documentation
  - ..
- Infrastructure business services
  - Paths, corridors, traffic management
  - Exceptions: maintenance, incidents

- Business service semantics – (SHACL) rules
- For instance, a transport service should at least contain cargo with their nature, two locations (or one or more geographical areas), a duration (between the locations, within the area or between the areas), and prices and conditions
- Technically: a transport service should contain
  - One of the subtypes of cargo (bulk, pallets, boxes, equipment (containers))
  - Physical characteristics: min/max weight and/or volume
  - Transport conditions: reefer, dangerous
  - A minimal, average, maximal duration
  - Geographical areas: cities, region(s), country(-ies),..
- Alternative – transport services expressed by timetables, voyage schemes, etc.

- Data shared during a business transaction gradually provides more detail, which specify the (SHACL) rules for minimal data sets of interactions. For instance:
  - Booking – cargo subtype, totals (weight, volume, no. of packages/containers/pallets/..), two locations, two (indicative) time windows
  - Order – actual cargo with totals per cargo item/container/..
  - Event – actual location and action of a physical object at a time

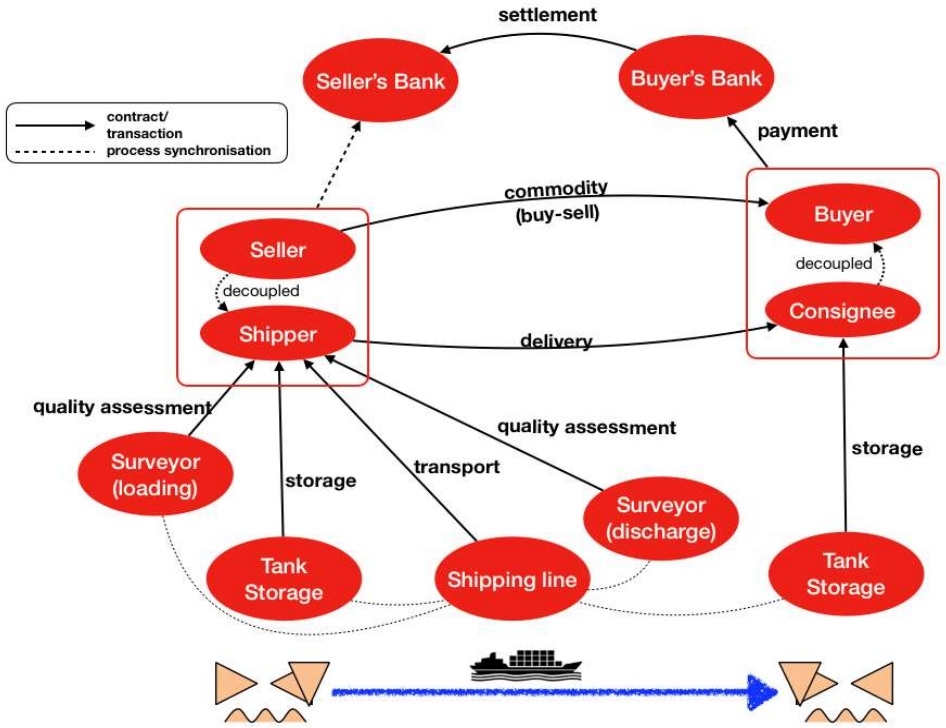
BUSINESS TRANSACTION MANAGEMENT

- CONSTRUCTING SUPPLY AND LOGISTICS CHAINS
- CONTROL TOWER AND 'SMART CONTRACTS'



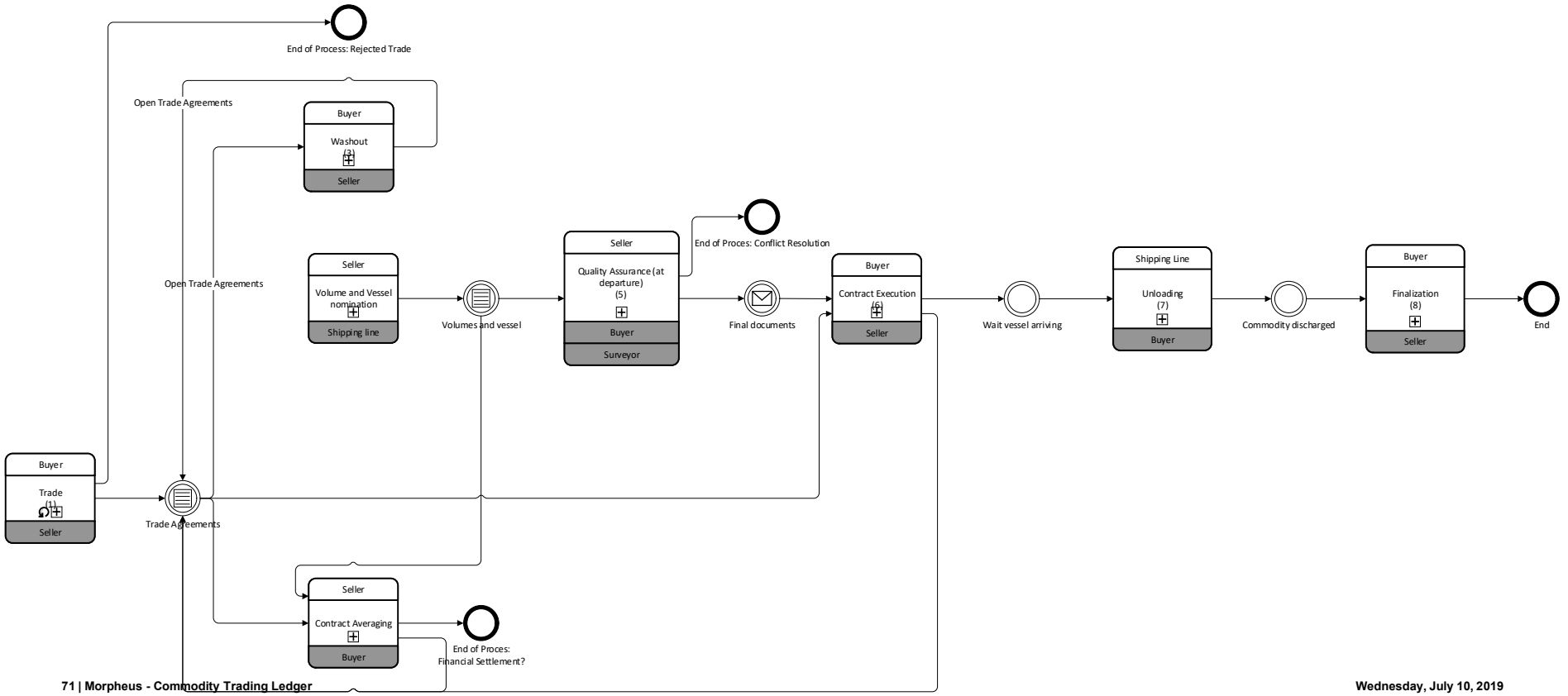
- Outsourcing strategies – involving business stakeholders
- (Dynamic) chain planning – composing supply chains
- Horizontal – and vertical bundling – combining/splitting orders and capacity
- Synchromodality – (last minute) multimodal planning
- Smart contracts?
  - Standardization of such strategies
  - Triggering other transactions (e.g. payments)
  - Automatically propagate service provider data to customers
  - Others?

COMMODITY USE CASE - TRANSACTION TREE



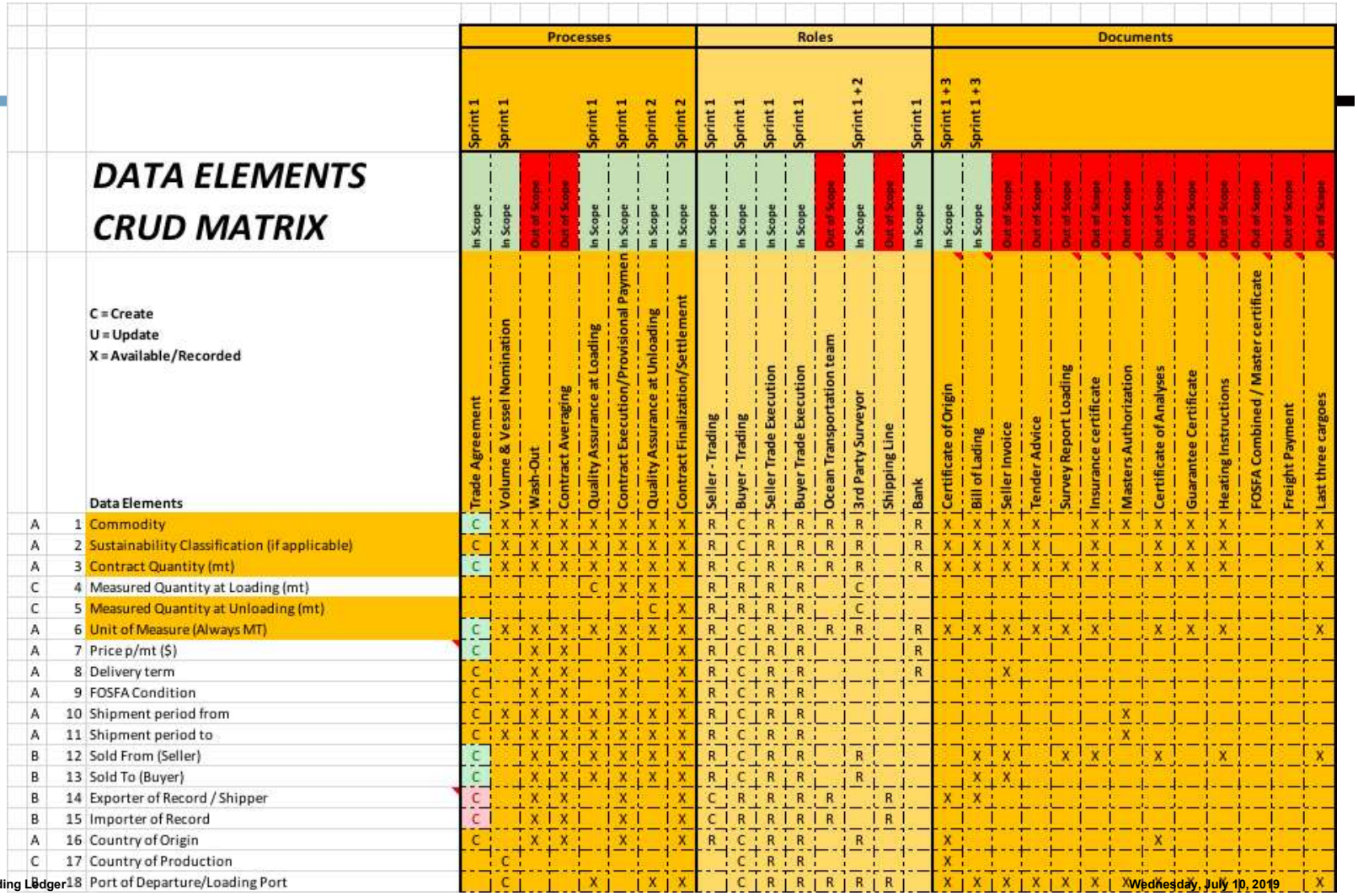
Buy/sell (products)
Visibility of transport and quality assessment (and partly transport ordering)
Payment triggering

MODELLING – CHOREOGRAPHIES (FROM ACTIVITY DIAGRAMS)



CRU(D) MATRIX

(PART – TOTAL 57 DATA ELEMENTS)



DATA ELEMENTS CRUD MATRIX

C = Create
U = Update
X = Available/Recorded

		Data Elements	Processes								Roles								Documents											
			Sprint 1	Sprint 1			Sprint 1	Sprint 1	Sprint 2	Sprint 2	Sprint 1	Sprint 1	Sprint 1	Sprint 1		Sprint 1 + 2		Sprint 1	Sprint 1 + 3	Sprint 1 + 3											
			In Scope	In Scope	Out of Scope	Out of Scope	In Scope	In Scope	In Scope	In Scope	In Scope	In Scope	In Scope	In Scope	Out of Scope	In Scope	Out of Scope	In Scope	In Scope	In Scope	Out of Scope	Out of Scope	Out of Scope	Out of Scope	Out of Scope	Out of Scope	Out of Scope	Out of Scope	Out of Scope	Out of Scope
			Trade Agreement	Volume & Vessel Nomination	Wash-Out	Contract Averaging	Quality Assurance at Loading	Contract Execution/Provisional Paymen	Quality Assurance at Unloading	Contract Finalization/Settlement	Seller - Trading	Buyer - Trading	Seller Trade Execution	Buyer Trade Execution	Ocean Transportation team	3rd Party Surveyor	Shipping Line	Bank	Certificate of Origin	Bill of Lading	Seller Invoice	Tender Advice	Survey Report Loading	Insurance certificate	Masters Authorization	Certificate of Analyses	Guarantee Certificate	Heating Instructions	FOSFA Combined / Master certificate	Freight Payment	Last three cargoes
A	1	Commodity	C	X	X	X	X	X	X	X	R	C	R	R	R	R		R	X	X	X	X		X	X	X	X	X			X
A	2	Sustainability Classification (if applicable)	C	X	X	X	X	X	X	X	R	C	R	R	R	R		R	X	X	X	X		X	X	X	X	X			X
A	3	Contract Quantity (mt)	C	X	X	X	X	X	X	X	R	C	R	R	R	R		R	X	X	X	X	X	X	X	X	X	X			X
C	4	Measured Quantity at Loading (mt)					C	X	X		R	R	R	R		C															
C	5	Measured Quantity at Unloading (mt)							C	X	R	R	R	R		C															
A	6	Unit of Measure (Always MT)	C	X	X	X	X	X	X	X	R	C	R	R	R	R		R	X	X	X	X	X	X		X	X	X			X
A	7	Price p/mt ($)	C		X	X		X		X	R	C	R	R				R													
A	8	Delivery term	C		X	X		X		X	R	C	R	R				R			X										
A	9	FOSFA Condition	C		X	X		X		X	R	C	R	R																	
A	10	Shipment period from	C	X	X	X	X	X	X	X	R	C	R	R											X						
A	11	Shipment period to	C	X	X	X	X	X	X	X	R	C	R	R											X						
B	12	Sold From (Seller)	C		X	X	X	X	X	X	R	C	R	R		R				X	X		X	X		X		X			X
B	13	Sold To (Buyer)	C		X	X	X	X	X	X	R	C	R	R		R				X	X										
B	14	Exporter of Record / Shipper	C		X	X		X		X	C	R	R	R	R		R		X	X											
B	15	Importer of Record	C		X	X		X		X	C	R	R	R	R		R														
A	16	Country of Origin	C		X	X		X		X	R	C	R	R		R			X							X					
C	17	Country of Production		C								C	R	R					X												
B	18	Port of Departure/Loading Port		C			X		X	X		C	R	R	R	R	R		X	X	X	X	X	X	X	X	X	X			X

GUIDELINES - SCOPING A PROJECT

Supply chain collaboration project (two or more stakeholders)

Include Formalities – (inter)national trade compliance

Multi-stakeholder business case

As-is → To-be ; based on models

On-boarding

- Marketplace
- Booking and ordering
- Supply chain visibility

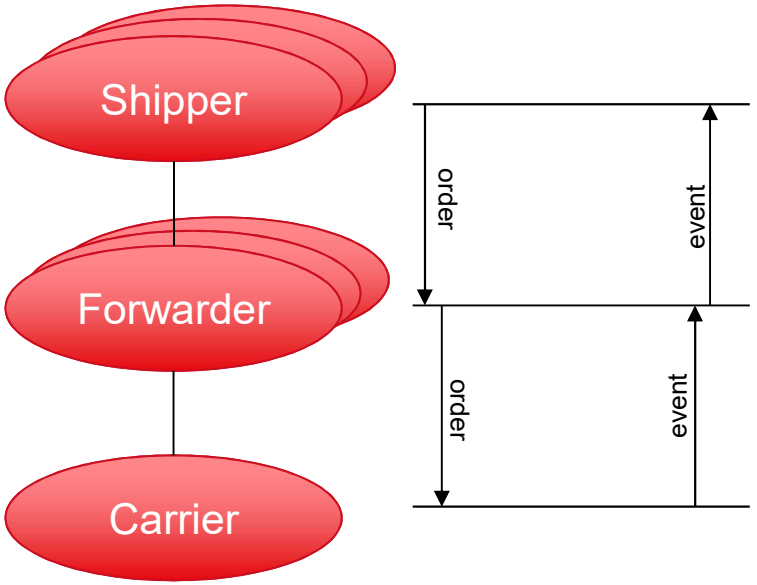
Business case, As-is -> To-be

Functionality requirements

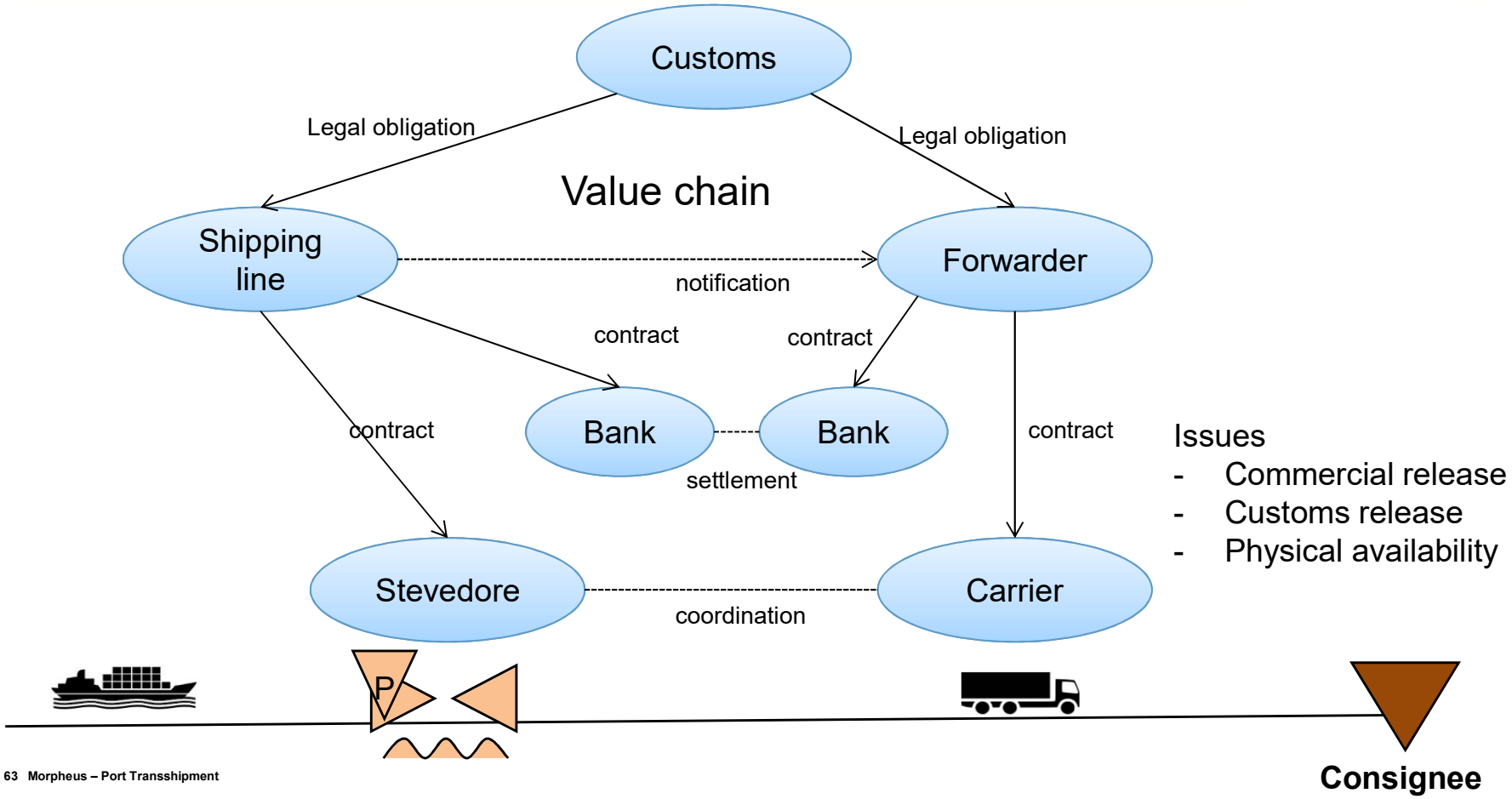
- Data and data semantics
- Choreography subset, operations (of roles), and interaction labels
- Legal requirements (data that needs to be shared, triggers in processes, etc.)

SUPPLY CHAIN VISIBILITY LEDGER - OBJECTIVE

- Automatically propagate events generated by physical assets (trucks, cranes, scanners, etc.) in a controlled way based relationships between stakeholders
- Orders specify the relationships between stakeholders

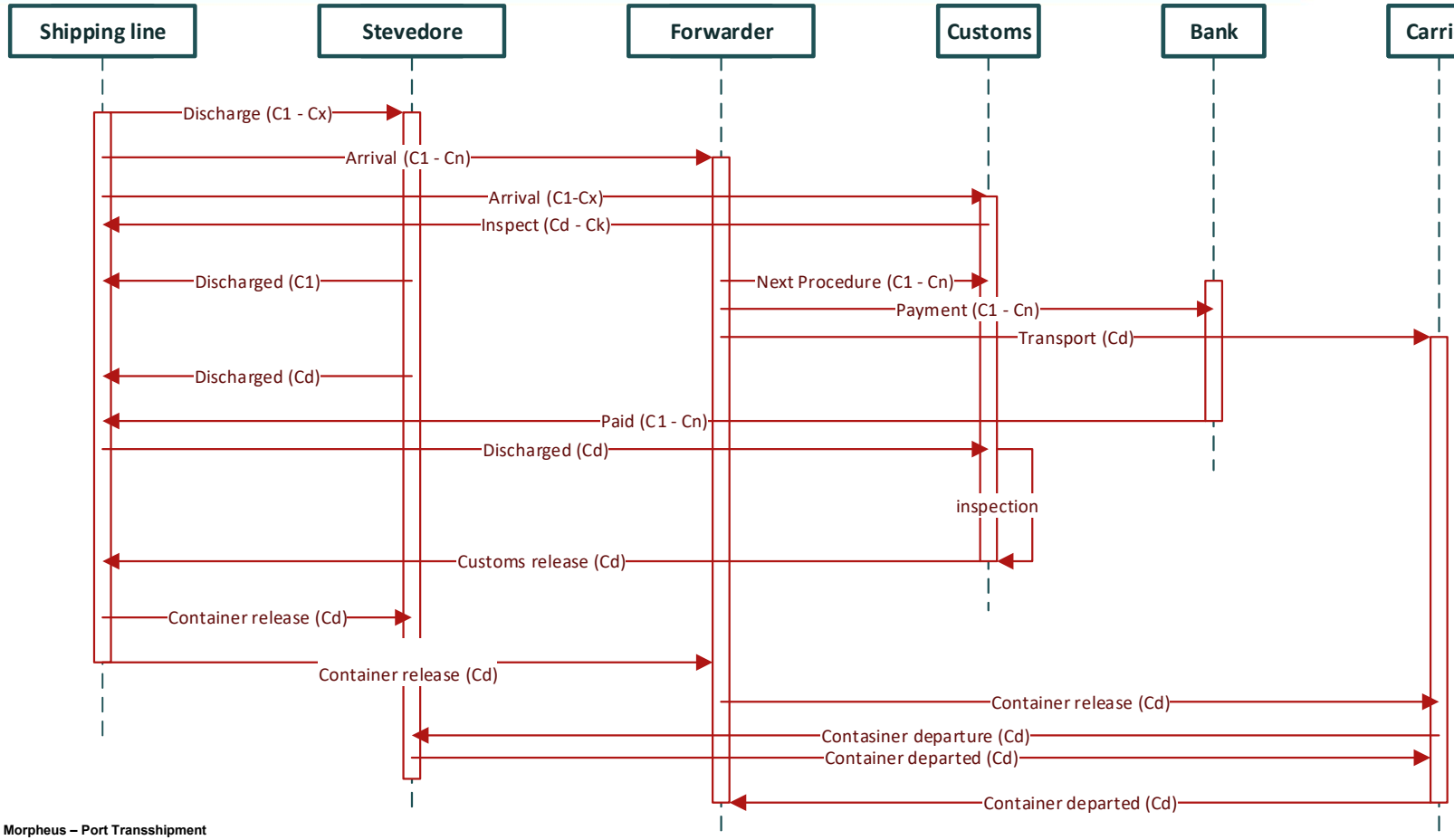


AN EXAMPLE – CONTAINER TRANS-SHIPMENT IN A PORT



Issues
- Commercial release
- Customs release
- Physical availability

CURRENT SITUATION

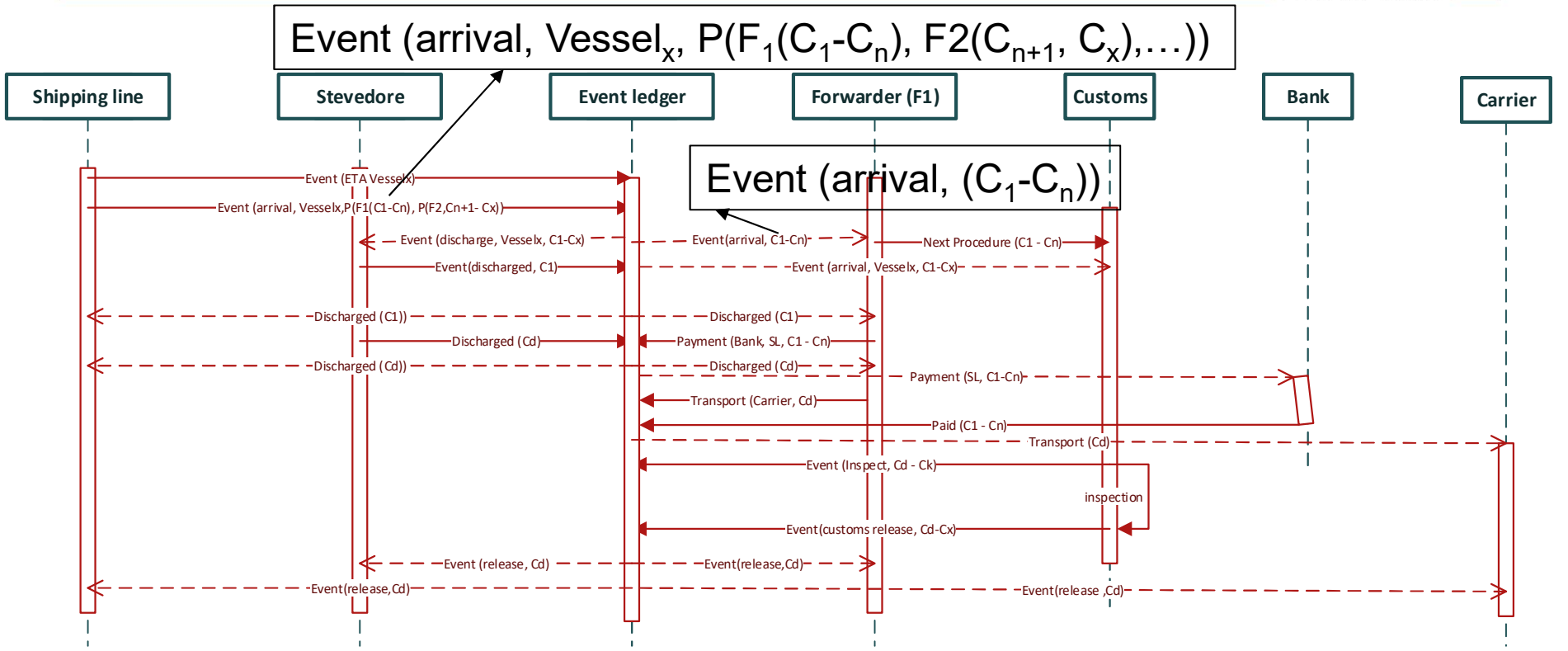


FEATURES

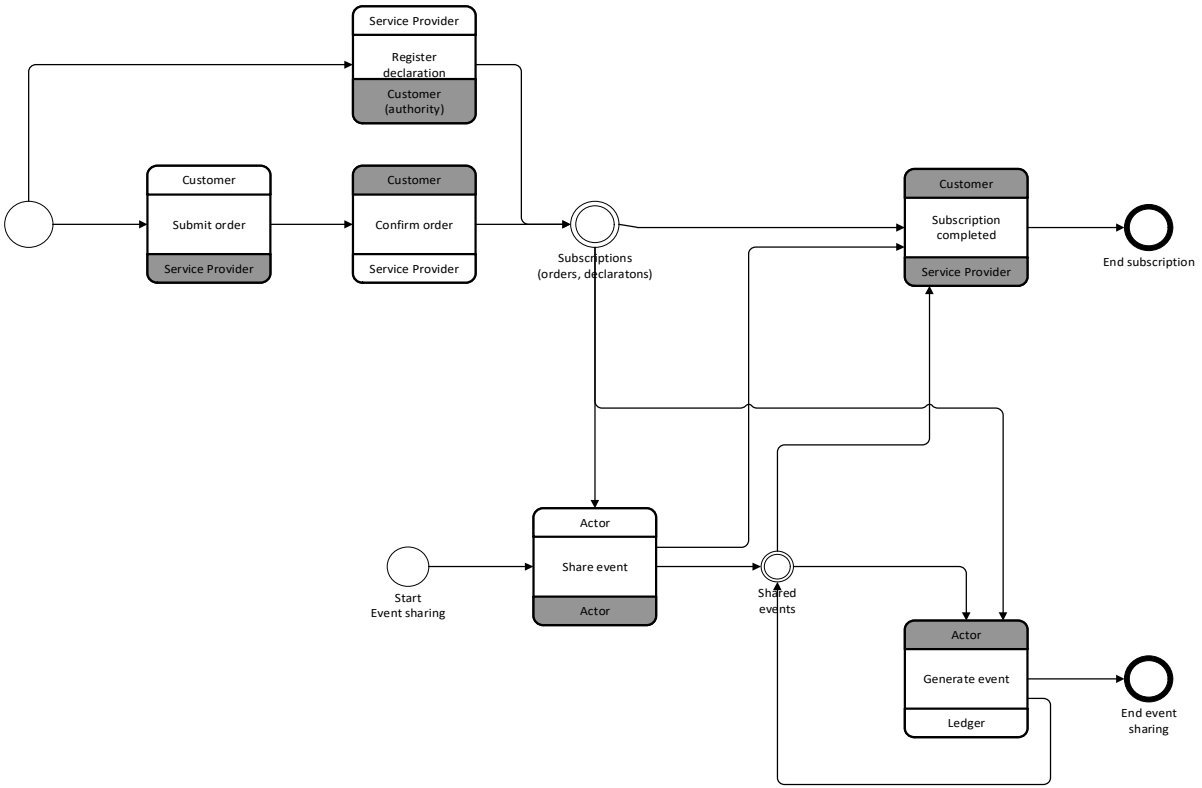
- A community (or commercial) system can be used to distribute data and address various challenges like
  - Many stakeholders – one point of entry
  - Many stakeholders need to share the same data – data distribution, data re-use
  - Different implementation guides of open standards of various stakeholders – data transformations

- Data quality
  - Duplication of data to many stakeholders – errors due to process changes and (no) propagation
  - Status changes are shared too late (e.g. discharge data available after vessel departure) – delays in the process, increased lead times

REAL TIME STATUS SHARING WITH BLOCKCHAIN



SUPPLY CHAIN VISIBILITY CHOREOGRAPHY



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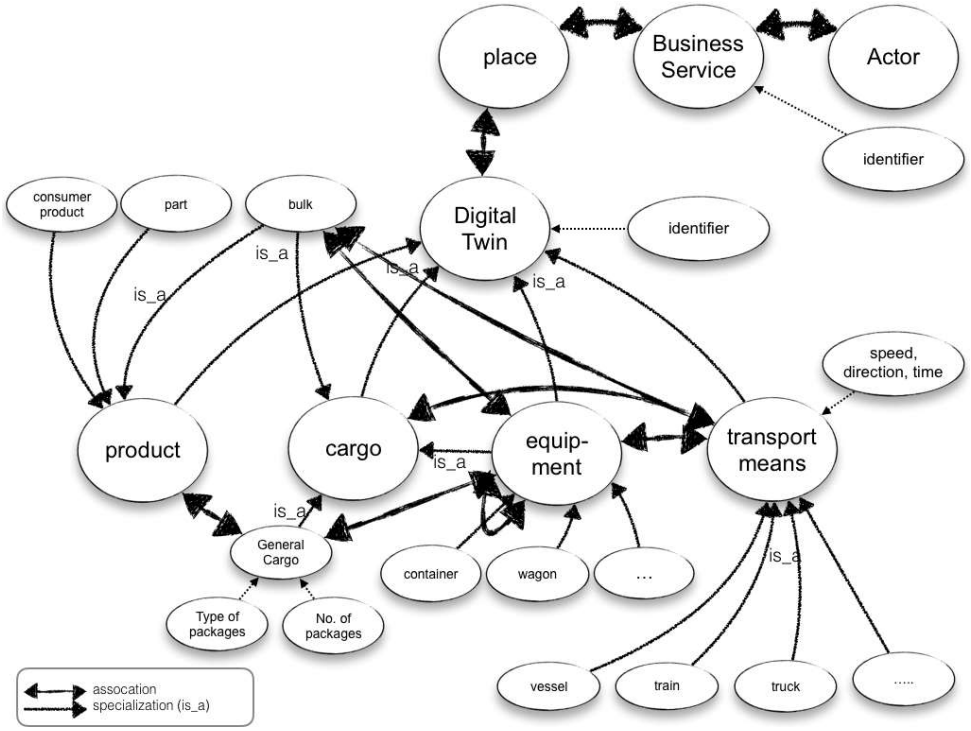

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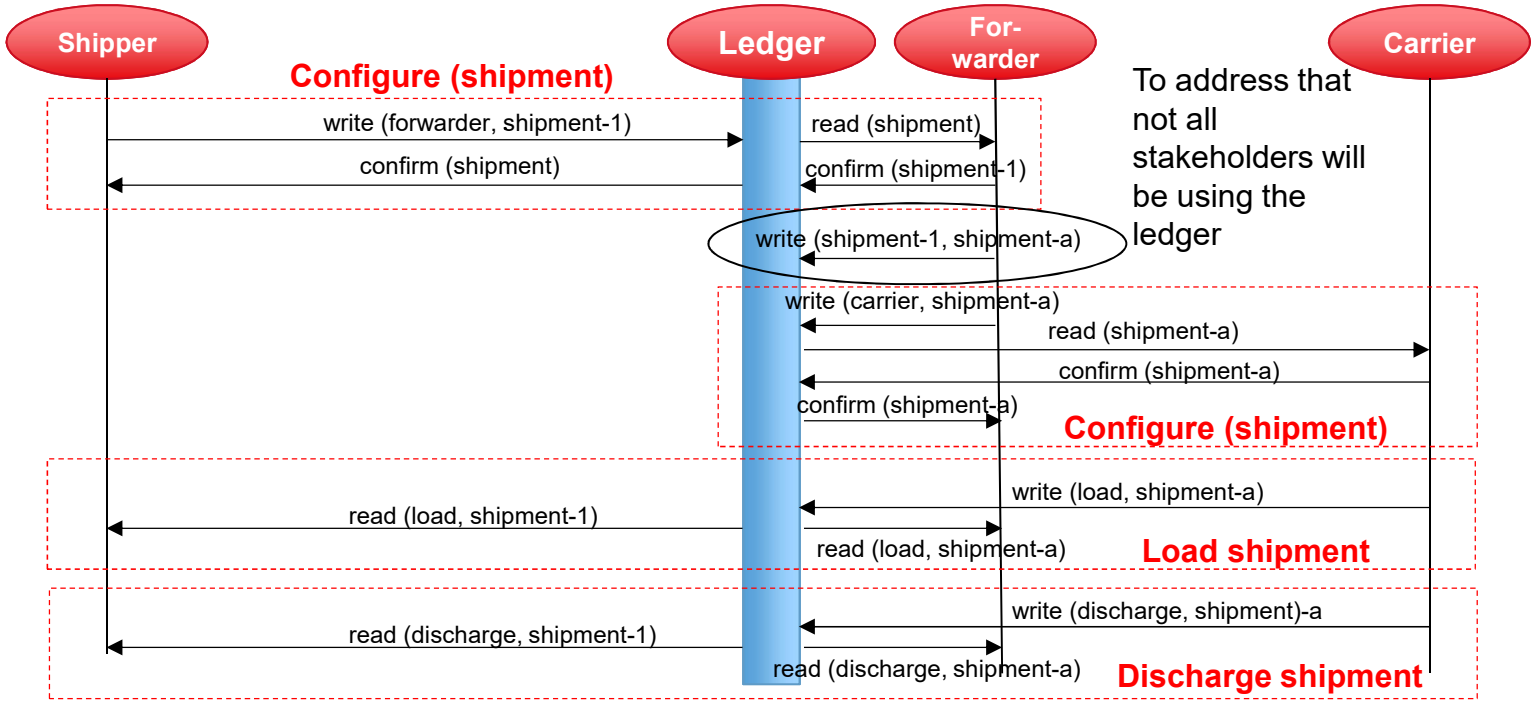
SUPPLY CHAIN VISIBILITY – DATA STRUCTURE

Conceptual structure		
Data properties	Order	Event
Actor		
customer	x	x
service provider	x	x
identifier	x	x
Digital Twin		
Identifier	x	x
Subtype	x	x
Digital Twin - place of acceptance		
alternative role	x	x
planned time	x	
estimated time		x
actual time		x
Digital Twin - place of delivery		
alternative role	x	x
planned time	x	
estimated time		x
actual time		x
Digital Twin - intermediate place		
alternative role	x	x
planned time	x	
estimated time		x
actual time		x
Place - name	x	x
General cargo - equipment	o	o
number of packages		x
planned stuffing time	x	
actual stuffing time		x
planned stripping time	x	
actual stripping time		x
Cargo - transport means	o	o
planned loading time	x	
actual loading time		x
planned discharge time	x	
actual discharge time		x

Implementation structure		
Implementation structure	Order	Event
Actor		
customer	x	x
service provider	x	x
identifier	x	x
milestone		x
timestamp		x
encrypted hash		o
provider of the hash		o
Digital Twin	x	x
Identifier	x	x
Subtype	x	x
No. of units		x
place of acceptance	x	
time of acceptance	x	
place of delivery	x	
time of delivery	x	
intermediate place	o	
time at intermediate place	o	
place		x
time		x
Speed (transport means)		o
Direction (transport means)		o
Relation to data		o
URL to data		x
Type of data		x
Data representation standard		x
Digital Twin associaton	o	o
Identifier		x
Subtype		x
time	o	x

HOW DOES THIS WORK – SCENARIO FOR ONE SHIPMENT (SHIPPER, FORWARDER, CARRIER)



EACH STAKEHOLDER CAN ACT IN TWO ROLES

Customer

- Write (order, service provider, object-id)
- Read (confirm object-id)
- Read (event, milestone, object-id)
- Object ϵ {**shipment**, container, wagon, …}

Service Provider

- Read (order, customer, object-id)
- Write (confirm object-id)
- Write (event, milestone, object-id)
- Object ϵ {**shipment**, container, wagon, …}

Customer – Service Provider link

- Write (association, object-id-1, object-id-2)

USER INTERFACE FUNCTIONALITY – FIRST DEMO

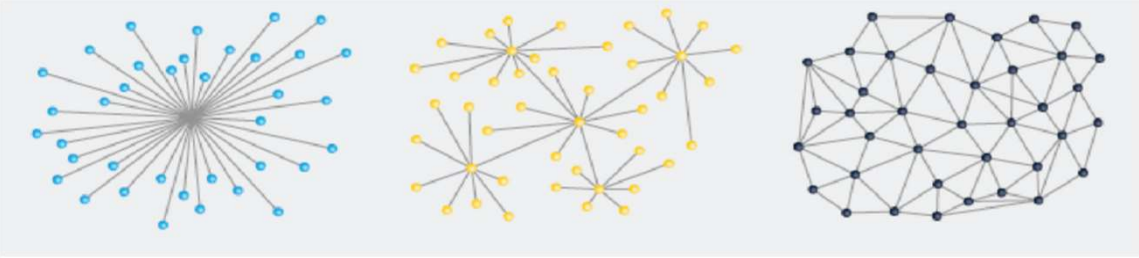
- Overview of orders with service providers and their status
  - Status ϵ {open, confirmed, milestone}
  - Milestone ϵ {loaded, discharged}
- Functions of a service provider on customer orders:
  - Create an order out of a customer order and select a service provider for that order
  - Change status of a customer order: open → confirmed
  - Add milestone to a customer order that has no related outstanding orders:
    - First milestone: loaded
    - Second milestone: discharged
- Automatic function shows the propagation of updates
  - **If** new milestone for an outstanding order
  - **Then select** all associated customer orders for that outstanding order
    - **and for all** associated orders write(event, customer order, 'milestone'), where 'milestone' gets the milestone value of the customer order

SUPPLY CHAIN VISIBILITY LEDGER - CONCLUDING

- DLT with ‘smart contracts’ based on business relations (‘orders’) optimal supports supply chain visibility

- Standardization on process milestones (date/time, place) for digital twins (cargo, equipment, transport means) subject to logistics services (transport, transship):
  - ‘start’
  - ‘estimated completion’ (ETA, ETD)
  - ‘actual completion’ (arrival, depature, loaded, discharged)

TYPES OF NETWORKS



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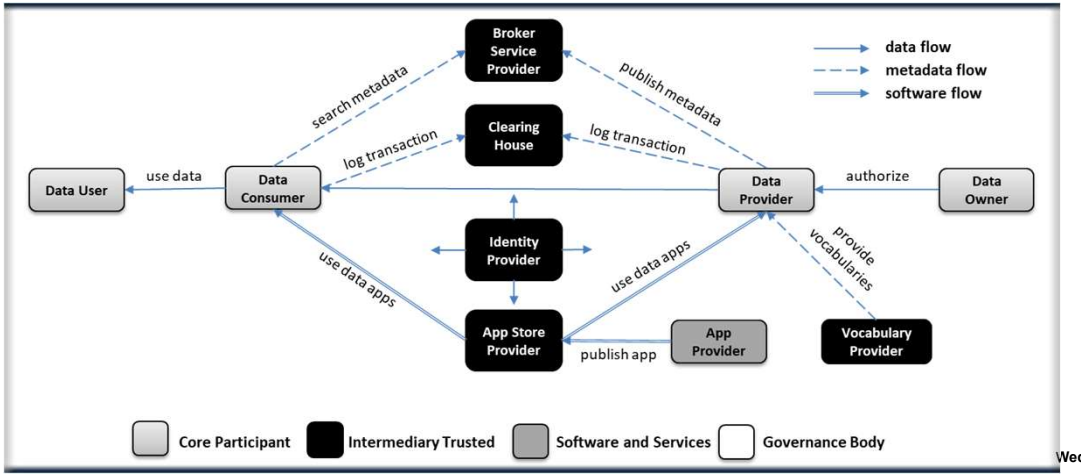
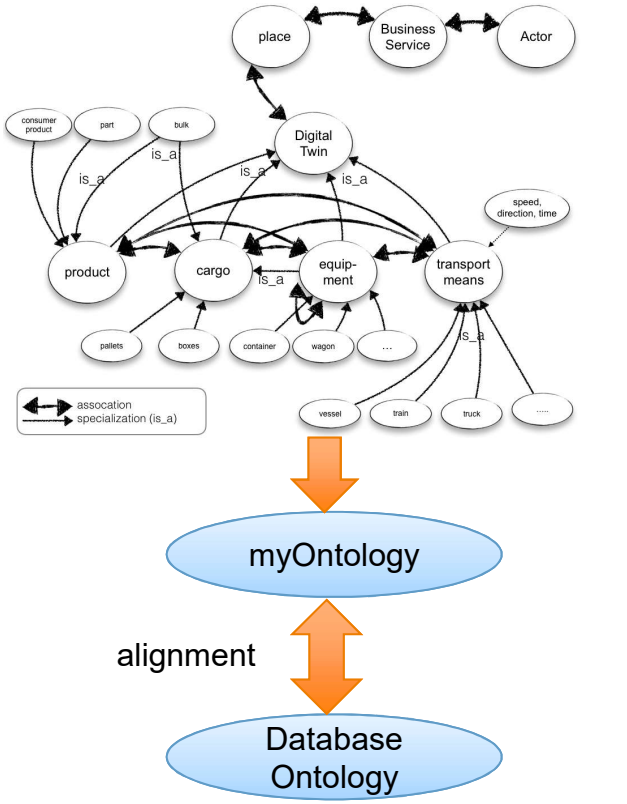


PLUG AND PLAY – GENERAL APPROACH

- Business services specify data requirements
  - For instance: transport services require some type of Digital Twin
  - Business service data requirements → myOntology
- Database structure (or data interfaces) represented as ontology
- Ontology alignment
  - (Semi-)automatic create mappings between database ontology and myOntology
  - Use of for instance Wordnet and Conceptnet for ontology alignment
  - Annotate the common ontology with mappings to improve ontology alignment
- Orchestration of Morpheus APIs and back-offices



ONTOLOGY ALIGNMENT - OBJECTIVE

- To cater with the many (bilateral) data transformations
  - Reduce costs
  - Reduce manual effort and maintenance
- By (semi-)automatically generate transformations between internal data and (implementation guides of open) standards
  - SANOM – Simulated Annealing

DYNAMIC 'ENERGY' FUNCTION

THE PROPOSED ENERGY FUNCTIONS TO BE MINIMIZED BY SIMULATED ANNEALING IS

$$E(e) = -\left(\sum S_s(e) + \sum S_l(e) + \sum S_{st}(e)\right)$$

The string similarity measure. The Levenstein is utilized in SANOM

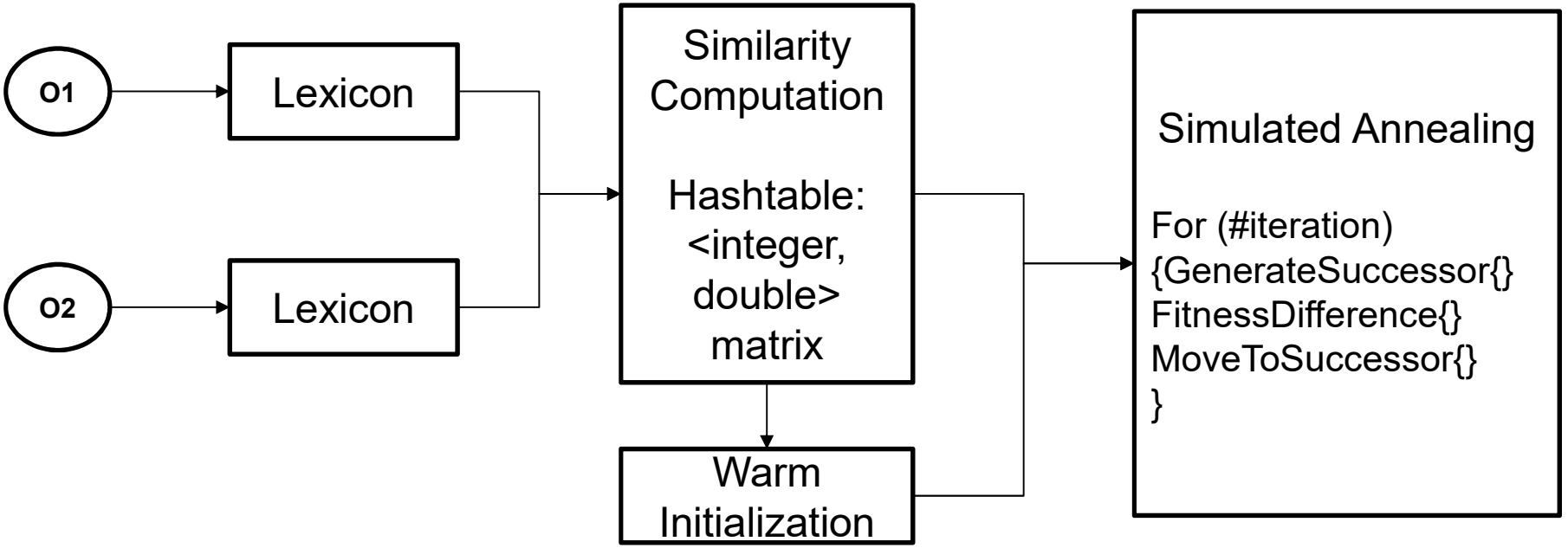
The linguistic similarity measure. The synonym, antonym are set to 1 and 0, respectively. For hypernym and and hyponyms, 0.5 is considered.

The structural similarity measures. The simple subclass-superclass relation is considered.

SIMULATED ANNEALING – PSEUDO CODE

- Let $s = s_0$
- For $k = 0$ through k_{max} (exclusive):
  - $T \leftarrow$ temperature(k)
  - Pick a random neighbour, $s_{new} \leftarrow$ neighbour(s)
  - If $E(s) < E(s_{new})$ then $s \leftarrow s_{new}$
  - Else if $P(E(s), E(s_{new}), T) \geq$ random(0, 1), then $s \leftarrow s_{new}$
- Output: the final state s

SANOM – ONTOLOGY ALIGNMENT ALGORITHM



SANOM – second best in Ontology Alignment Initiative

SANOM FEATURES

- Lexicon – preprocessing to an internal data structure
- Similarity Computation - string and linguistic similarity
  - Textual analysis algorithm
  - Most ‘doubles’ are zero, they don’t get indexed
- Structural similarity
  - Warm Initialization – near estimate of probable similarities
  - Simulated Annealing - fitness
    - Structure matching (parent)
    - Property (domain) matching

ONTOLOGY ALIGNMENT IS AT STRUCTURE LEVEL

- Database scheme alignment (considered too complex)
- Functional view alignment (e.g. order view – many bilateral alignments required; sort of implementation guides)
- Open standard alignment (full functionality of a standardized functional view – limited value to organizations)
- Implementation guide alignment
- Canonical Information Model
  - Functional view
  - Open standard
  - Implementation guide

ONTOLOGY ALIGNMENT EXPERIMENTS

- Experiment 1
  - O1 - simplified ontology of UN/CEFACT eCMR XSDs (core concepts)
  - O2 - simplified ontology of a Shipping Instruction data structure
- Experiment 2
  - O1 – Common Information Model
    - LogiCo (EU FP7 SEC Cassandra and EU FP7 INFSO iCargo) – www.ontology.tno.nl
  - 2a - O2 – simplified ontology of UN/CEFACT eCMR XSDs (core concepts)
  - 2b - O2 – simplified ontology of a Shipping Instruction (SI) data structure

THIS COULD BE EXPECTED USING SANOM…

10	shipper	Shipper office name.	object-actor-shipper
11	shipper_address	Shipper office street address (this field in many cases will have the full address).	(shipper) object-address-..
12	shipper_city	Shipper office city (may be null and embedded in street address instead).	(shipper) object-address-..
13	shipper_state	Shipper office state (may be null and embedded in street address instead).	(shipper) object-address-..
14	shipper_postal_code	Shipper office postal code (may be null and embedded in street address instead).	(shipper) object-address-..
15	shipper_country	Shipper office country (may be null and embedded in street address instead).	(shipper) object-address-..
16	forwarder	Forwarder office name.	object-actor-forwarder
17	forwarder_address	Forwarder office street address (this field in many cases will have the full address).	(forwarder) object-address-..
18	forwarder_city	Forwarder office city (may be null and embedded in street address instead).	(forwarder) object-address-..
19	forwarder_state	Forwarder office state (may be null and embedded in street address instead).	(forwarder) object-address-..
20	forwarder_postal_code	Forwarder office postal code (may be null and embedded in street address instead).	(forwarder) object-address-..
21	forwarder_country	Forwarder office country (may be null and embedded in street address instead).	(forwarder) object-address-..
22	consignee	Consignee office name.	object-actor-consignee
23	consignee_address	Consignee office street address (this field in many cases will have the full address).	(consignee) object-address-..
24	consignee_city	Consignee office city (may be null and embedded in street address instead).	(consignee) object-address-..
25	consignee_state	Consignee office state (may be null and embedded in street address instead).	(consignee) object-address-..
26	consignee_postal_code	Consignee office postal code (may be null and embedded in street address instead).	(consignee) object-address-..
27	consignee_country	Consignee office country (may be null and embedded in street address instead).	(consignee) object-address-..
28	first_notify_party	First Notify Party office name.	-
29	first_notify_party_address	First Notify Party office street address (this field in many cases will have the full address).	-
30	first_notify_party_city	First Notify Party office city (may be null and embedded in street address instead).	-

FIRST ONTOLOGY ALIGNMENT TEST RESULTS

- BAD! Only roles e.g. shipper, forwarder, consignee) can be matched, both in experiment 1 and 2.

- Reasons
  - No common data dictionaire
    - UN/CEFACT eCMR introduces complete new terminology
    - CIM (LogiCo) has complex structures and more abstract concepts
  - CIM is incomplete – not all concepts of SI can be matched
  - Business perspective
    - single – versus composite business service
    - Representation of cargo

HOW TO MAKE ONTOLOGY ALIGNMENT EFFECTIVE

- Next experiment – add synonyms, etc. to CIM.
- Recommendation
  - Use a common dictionaire (UN Trade Data Elements Directory) and common terminology
  - Guidelines for modelling of CIM (and future open standards).

GUIDELINES - SCOPING A PROJECT

Supply chain collaboration project (two or more stakeholders)

Include Formalities – (inter)national trade compliance

Multi-stakeholder business case

As-is → To-be ; based on models

On-boarding

- Marketplace
- Booking and ordering
- Supply chain visibility

Business case, As-is -> To-be

Functionality requirements

- Data and data semantics
- Choreography subset, operations (of roles), and interaction labels
- Legal requirements (data that needs to be shared, triggers in processes, etc.)

GOVERNANCE - STAKEHOLDERS

- Users
  - Supply and logistics enterprises
  - Authorities - (inter)national (EU) regulations for global trade
  - Infrastructure managers (public and private)
- Data service providers – providing innovative applications based on a Distributed Ledger
- Ledger operators
- Software developers
- Research and academia

BUSINESS MODELS

- **Ledger operators** can run multiple nodes
  - Cloud Service Providers
  - Users (community)

- **Rules of engagement**
  - Each user connects to one operator
  - In case of failure of an operator, another operator will be selected

- **Business model** (initial thoughts)
  - Cloud Service Providers: yearly subscription fee, combined with transaction/data volume fees (up to each cloud service provider)
  - Users/community: cost sharing based on transaction/volume rates of individual users (e.g. authorities)
  - Amongst different operators, agreement is required:
    - Clearing and settlement between operators based on transactions/volumes shared amongst two users or among one user and a data service provider, operating on different operators
    - Note – all other operators will also store the same data, depending on the data management plan
    - Requires monitoring services
  - Research and academia – free of costs for research

DISTRIBUTED ONTOLOGY DEVELOPMENT AND MAINTENANCE

- Core ontology for logistics (upper ontology)
  - Digital shadows – data representation of physical objects
  - Business services and interactions
  - Additionally
    - Terms and conditions (e.g. INCOTERMS)
    - Tarif and rates, prices and payment conditions
- Specific Models
  - Specialization of products (e.g. palm oil → edible oil → liquid bulk → bulk)
  - Document views, e.g. eCMR
  - Personnel qualifications
  - Transport safety requirements
  - Container cleansing requirements
  - Etc.
  - Mode and/or cargo (subtype) specific views
- Specific authority data requirements
- Enterprise templates (e.g. role specific)

INTEROPERABILITY BETWEEN VARIOUS LEDGERS

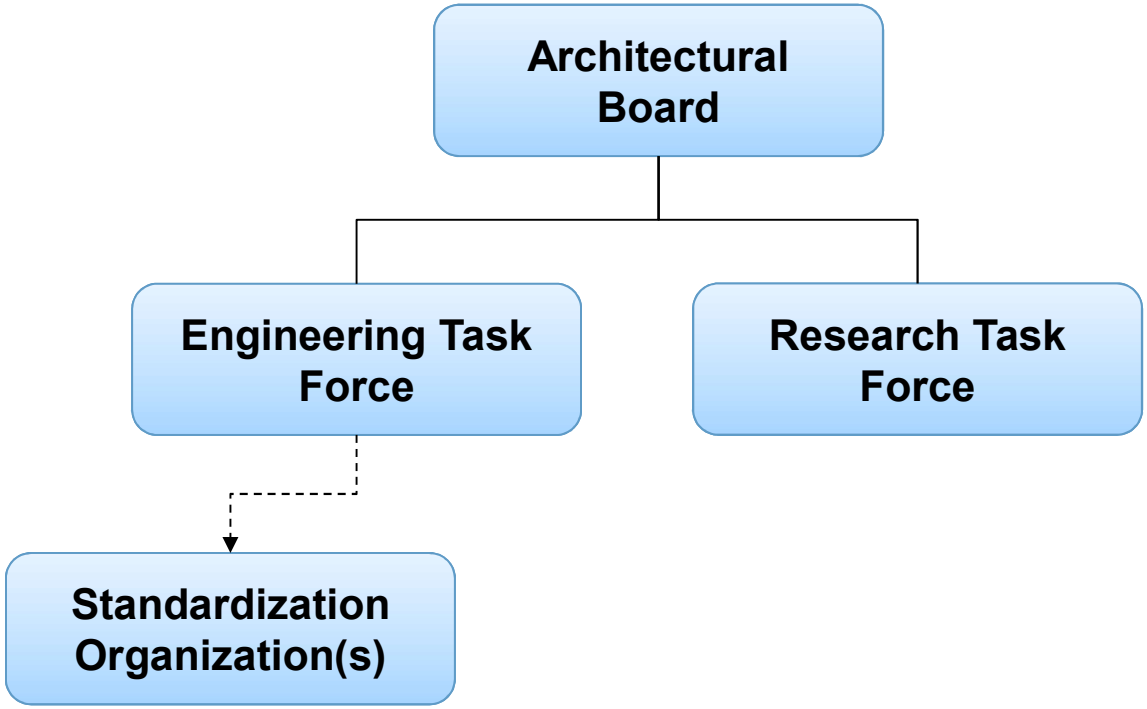
- Horizontal interoperability
  - Any two ledgers with similar/identical functionality (e.g. two supply chain visibility ledgers)
  - Technical interoperability – technical data sharing between the two ledgers
  - Functional interoperability
    - Specification of a protocol to provide interoperability between the end-user services of both ledgers
    - Mapping between datatypes and their semantics
    - Warning: it may not be possible to map all functionality in case end-user services are different

- Vertical interoperability
  - Any two ledgers with complementary functionality – linking two transaction trees (buying with logistics)
  - Technical interoperability – technical data sharing between two ledgers
  - Functional interoperability

DATA SHARING INFRASTRUCTURE GOVERNANCE (BASED ON INTERNET GOVERNANCE)

- Policies and standards
  - Future developments - **Architectural Board** supported by **Engineering** – and **Research Task Force**
  - Policies and rules set by (inter-)governmental organizations and enterprises - **Governance Forum**
  - Standards - standards organizations e.g. ISO, CEN CENELEC, W3C
- Operation and services
  - Operating the infrastructure – **Ledger operators' Group**
  - Developing the (open source) software code – **Developers Group**
- Data – available to **Research and Academia** for experiments
- Proprietary services – governed by individual operators

GOVERNANCE STRUCTURE

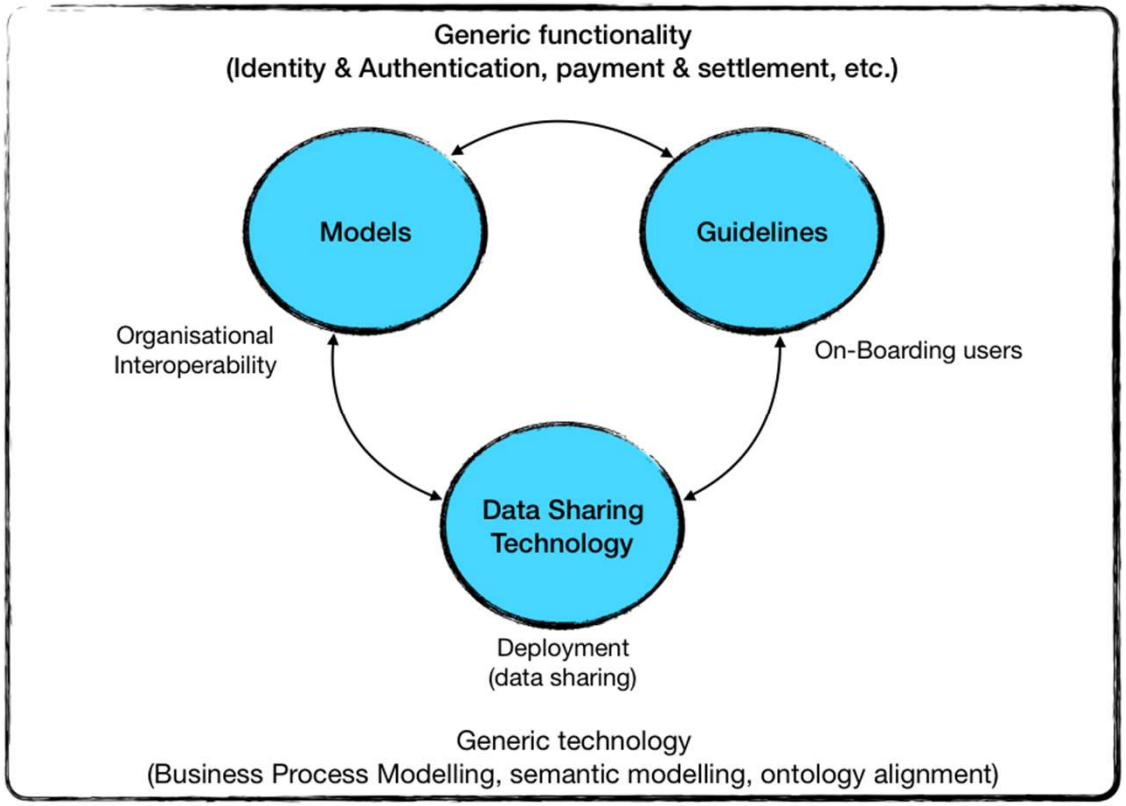


Governance Forum

Developers Group

Operators Group

COMPONENTS OF OUR SOLUTION



QUESTIONS?

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