


IPIC 2023

9th International
Physical Internet Conference

June 13-15, 2023
Athens, Greece

THE PHYSICAL INTERNET LIVING LAB (PILL)

Testing of a first application, based on the physical internet

imec | VUB mobilise analysing mobility, mobilising people | EMPOWERING LOGISTICS

13-15 JUNE 2023 Athens, Greece www.pi.events/IPIC2023

alice Alliance for Logistics Innovation through Collaboration in Europe

Expanding the logistics Scope

AGENDA

- PILL: the road towards a Physical Internet framework, J*oris Finck - imec; Philippe Michiels - imec*
- The PI-client: a blueprint for Physical Internet, *Philippe Michiels – imec*
- Validation of the PI-client and first PI-application, *Dries Van Bever – imec*
- Simulation of a decentralised network, *Shiqi Sun – VUB Mobilise*

imec

Digital technology innovation with a significant impact on the quality of life.

An Cant
Domain research Lead

Joris Finck
Project Manager

Philippe Michiels
Lead Architect

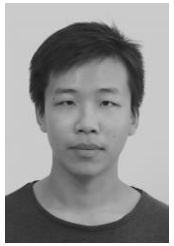
Vitor Lemos
Modelling Engineer

Dries Van Bever
Business Analyst

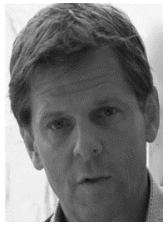
VUB mobilise
analysing mobility, mobilising people

Cathérine Cassan
Research Lead

To accelerate the transition to a more sustainable and socially just mobility and logistics system



Shiqi Sun
Researcher



Geert Verbelen
Project Manager

EMPOWERING LOGISTICS

PILL in a nutshell

The road towards a physical internet framework

Joris Finck – Project manager - imec

Philippe Michiels – Lead Architect - imec

What is the PILL project?

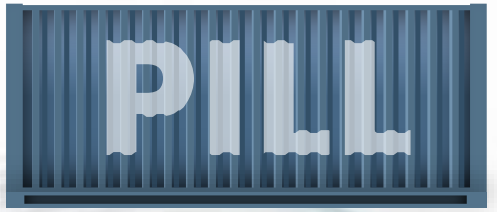
3-year Flemish strategic fundamental research project (cSBO) lead by imec, VUB and VIL

Goals

- Foundation for broad Physical Internet (PI) implementation in Europe and beyond
- Test the academic research on the Physical Internet and its principles in practice

The PILL project will result in

- A blueprint for the Physical Internet as connected network of nodes
- POC: Implementation and field-testing of a first PI application with logistics partners
- A roadmap to get from POC to a commercial PI application



PHYSICAL INTERNET LIVING LAB

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EMPOWERING LOGISTICS

PILL Advisory Board

AirCargoBelgium

DP WORLD

LINEAS
YOUR FREIGHT FORCE

Port of Antwerp Bruges

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Federal Public Service FINANCE

Microsoft

PSA
The World's Port of Call

THE BEACON

De Vlaamse Waterweg nv

GS1

NxtPort

P&G

Vlaanderen
is mobiliteit & openbare werken

Dockflow

LANARK
DIGITAL SUPPLY CHAIN ENGINEERS

POM
West-Vlaanderen

Rombit

ubidata
TRACK-ANALYSE-OPTIMISE

TRI≡VIZOR

Context: Hinterland container transport

- Antwerp harbors some of the world's largest terminals
- Plans for expansion
- Hinterland logistics suffering from congestion
- Modal shift is not happening fast enough

Value Proposition

CURRENT SCOPE
HINTERLAND CONTAINER TRANSPORT

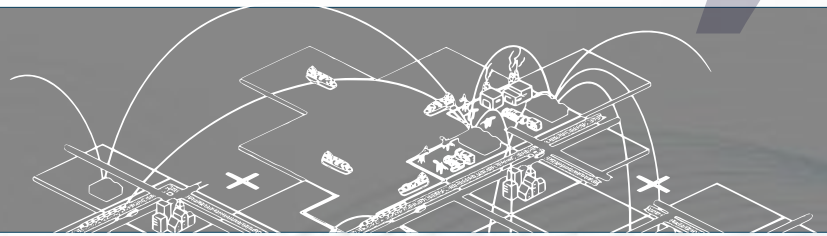
SOCIETAL VALUE	ECONOMICAL VALUE
Green Logistics Circular economy Reduction of excess stock / waste	New digital services - cross-stakeholder - cross-domain
Handling the issue of bottleneck jobs through • Routing • Autonomous transportation	Leverage the network for existing services
Extra regulation (EU / BREXIT) Level playing field	Innovative logistics services

A layered approach to π

Business applications and services for planning, routing, booking, invoicing, real-time data, ….

routing · track trace · planning · real-time data · order & trading · …

Logistics network optimization, Digital twin & Simulations

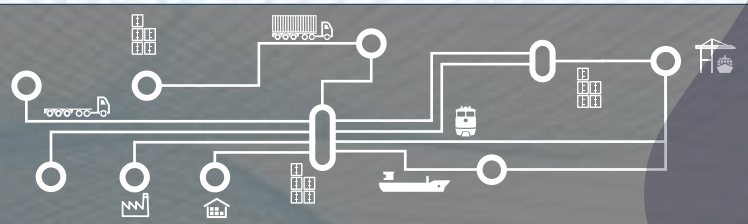


Standards, interoperability, governance & security

secure data sharing · role based access control · standards and interop · decentral trust

Capability-driven decentral network of nodes, connected using a universal client

physical internet client



PLATFORM CONNECTIVITY

π foundation (1): a network of Nodes and Capabilities

TRANSFER

Transfer of π-carriers from their inbound π-vehicles to their outbound π-vehicles.

HUB

The intermodal transshipment of π-containers from an incoming π-mover to a departing π-mover.

STORE

Storage of π-containers during mutually agreed upon target time window.

GATEWAY

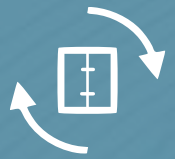
π-depots are nodes were empty π-containers can be retrieved from or returned to their owner.

DEPOT

π-depots are nodes were empty π-containers can be retrieved from or returned to their owner.

COMPOSER

Constructing or deconstructing composit e π-containers from specified sets of π-containers.



SERVICE PROVIDER

Nodes were services around π-containers are provided, such as customs clearance, weighing, fumigation.

More capabilities to be included in the future.

π foundation (2): Movers

SCHEDULED MOVERS

Operating between fixed nodes at scheduled times.

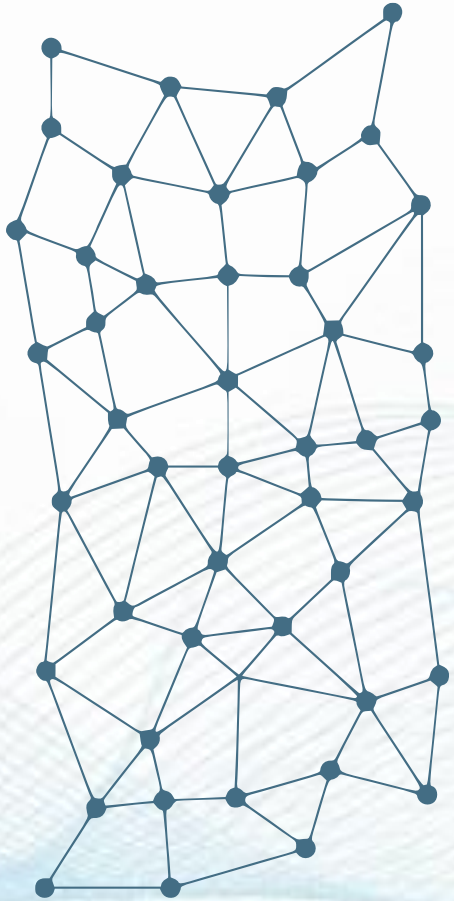
FLEXIBLE MOVERS

Unscheduled operation between variable nodes.

π foundation (3): Network State

centralized

decentralized



fully Decentralized / peer-2-peer → PILL

- Network state (nodes and capabilities) synced across the network
- Foundation for route finding
- No need to share sensitive data

In PILL we use Orbit DB (IPFS) for establishing peer-to-peer data exchange

π foundation (4): Route Finding in PI

$$P_c(s, n) \rightarrow s', n'$$

- Valid transitions from one state to the next
- Tracking the PI container state and the assigned mover
- Used to find routes that satisfy the constraints
- Foundation for a proof-of-concept routing algorithm

Container & Mover State

$s =$

Container state	(full or empty)
Container location	(a π-node)
Container ready	(a point in time)
Mover id	(a π-mover)
Mover modality	(road, rail or inland waterway)
Mover state	(with our without container)
Mover location	(a π-node or a π-vertex

Constraints

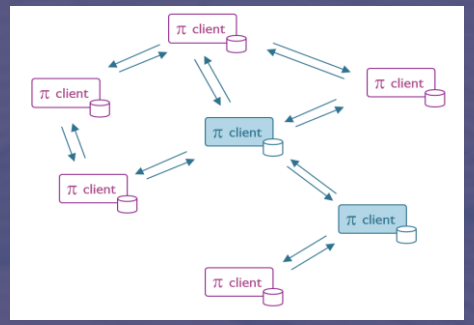
$c =$

order type	(import or export)
pick-up location	(a π-node)
drop-off location	(a π-node)
composer location	(a π-node)
composition time window	(a start and end time)
earliest pick-up	(a point in time)
latest drop-off	(a point in time)

PILL Components

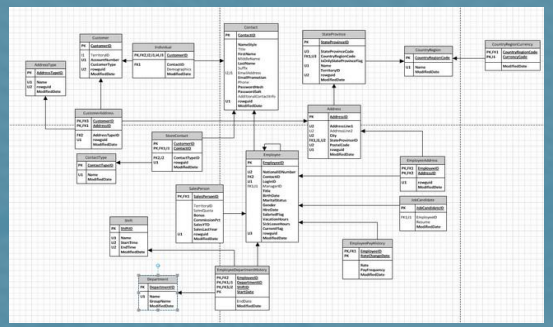
OPEN DECENTRAL NETWORK

"Data-space" connector that connects the stakeholders and enables decentralized information sharing.



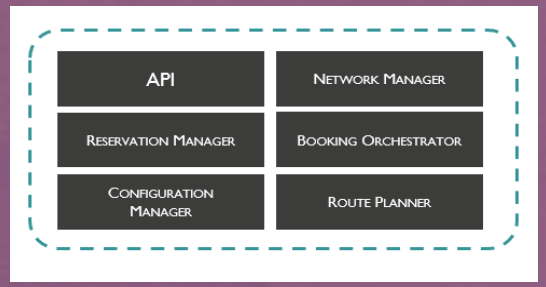
OPEN DATA MODEL

Data standards for information sharing, expanding on the existing DCSA standard.



OPEN SOURCE PI-Client

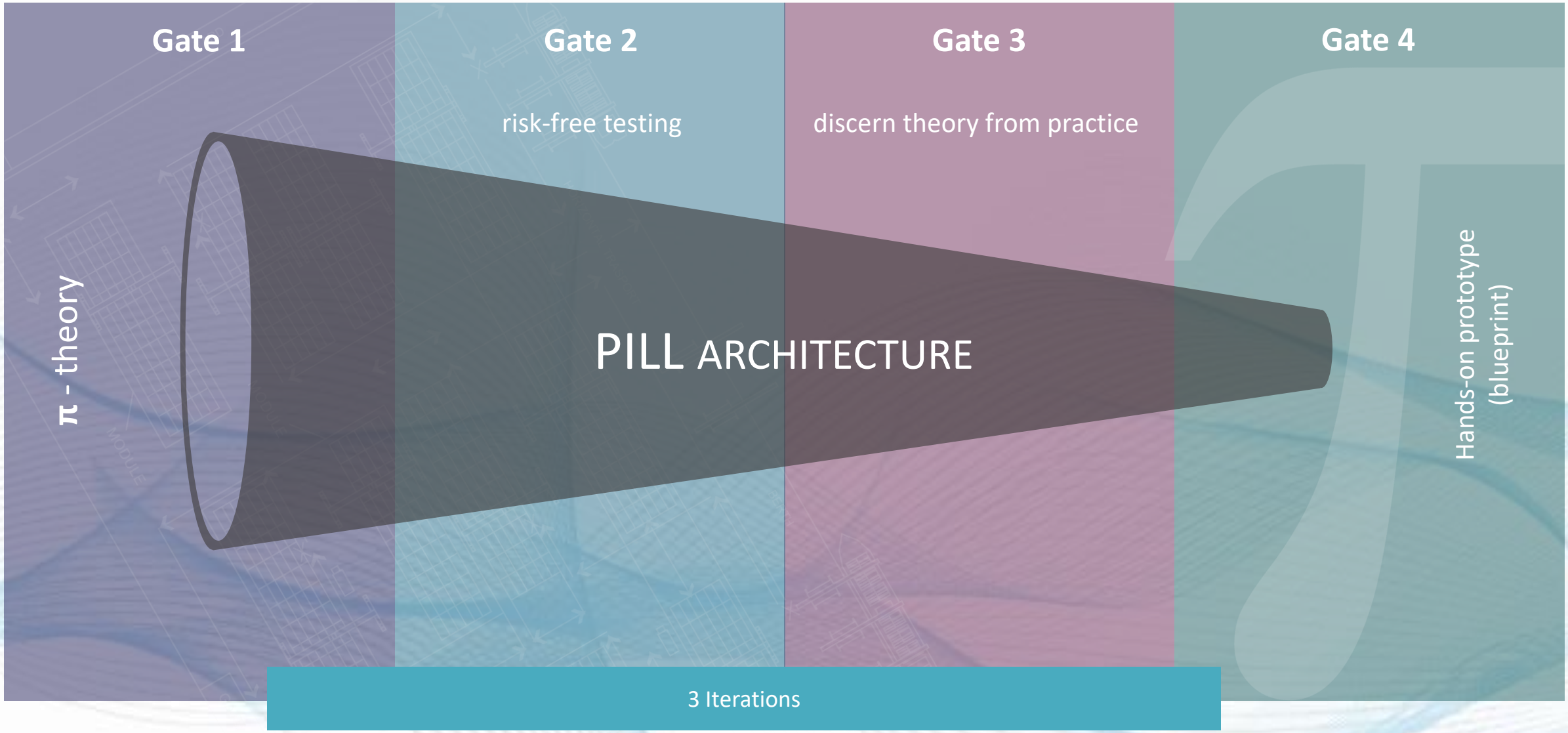
Software component that provides the interface to the PI and orchestrates the interoperability between stakeholders.



ROUTING ENGINE & SIMULATION MODEL

Calculate the flow of goods, based on the new data standard.

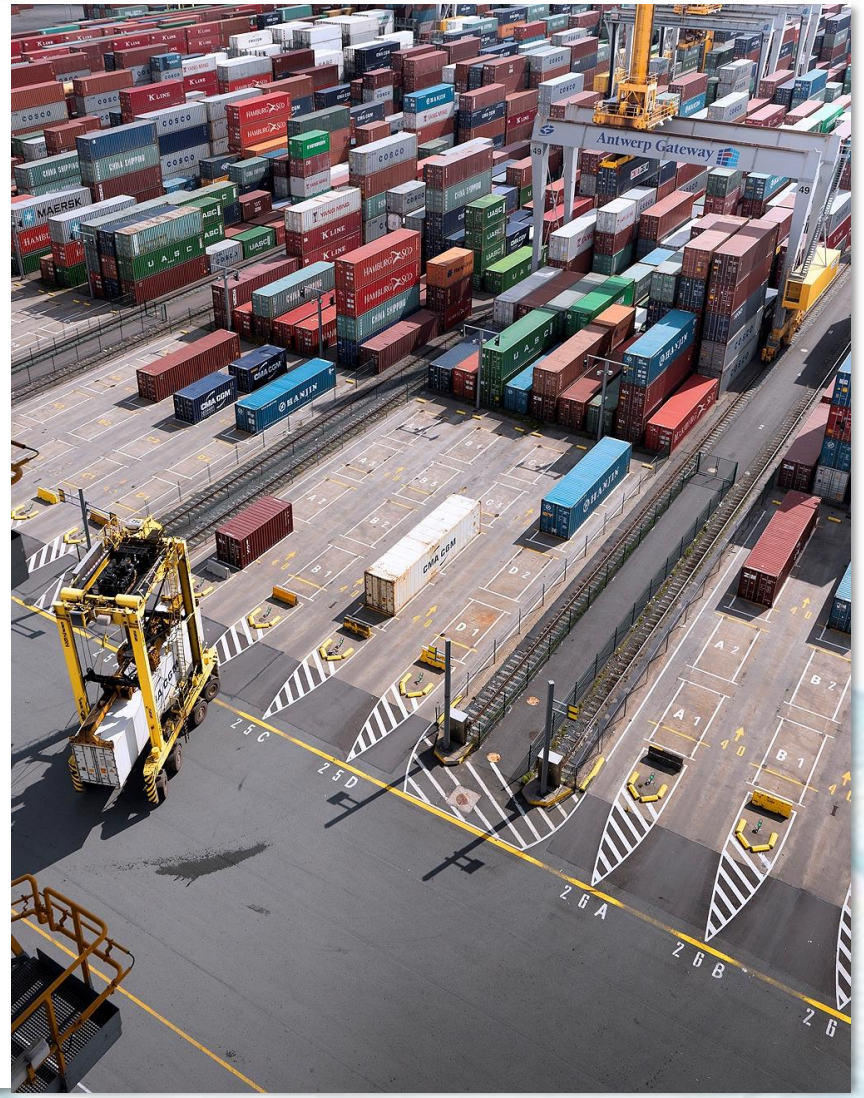
PILL Steppingstones



The π-client

A blueprint for Physical Internet

Philippe Michiels – Lead Architect - imec



The importance of an open network

no open network
⇓
no decentralization
⇓
no trust

- An open network for all to connect
  - Peer-to-peer
  - Discoverability
- Trust
  - Bilaterally, based on verifiable credentials
  - Can be done using a central 3rd party
- Governance
  - On top of the network foundation
  - At community level

PILL Data model

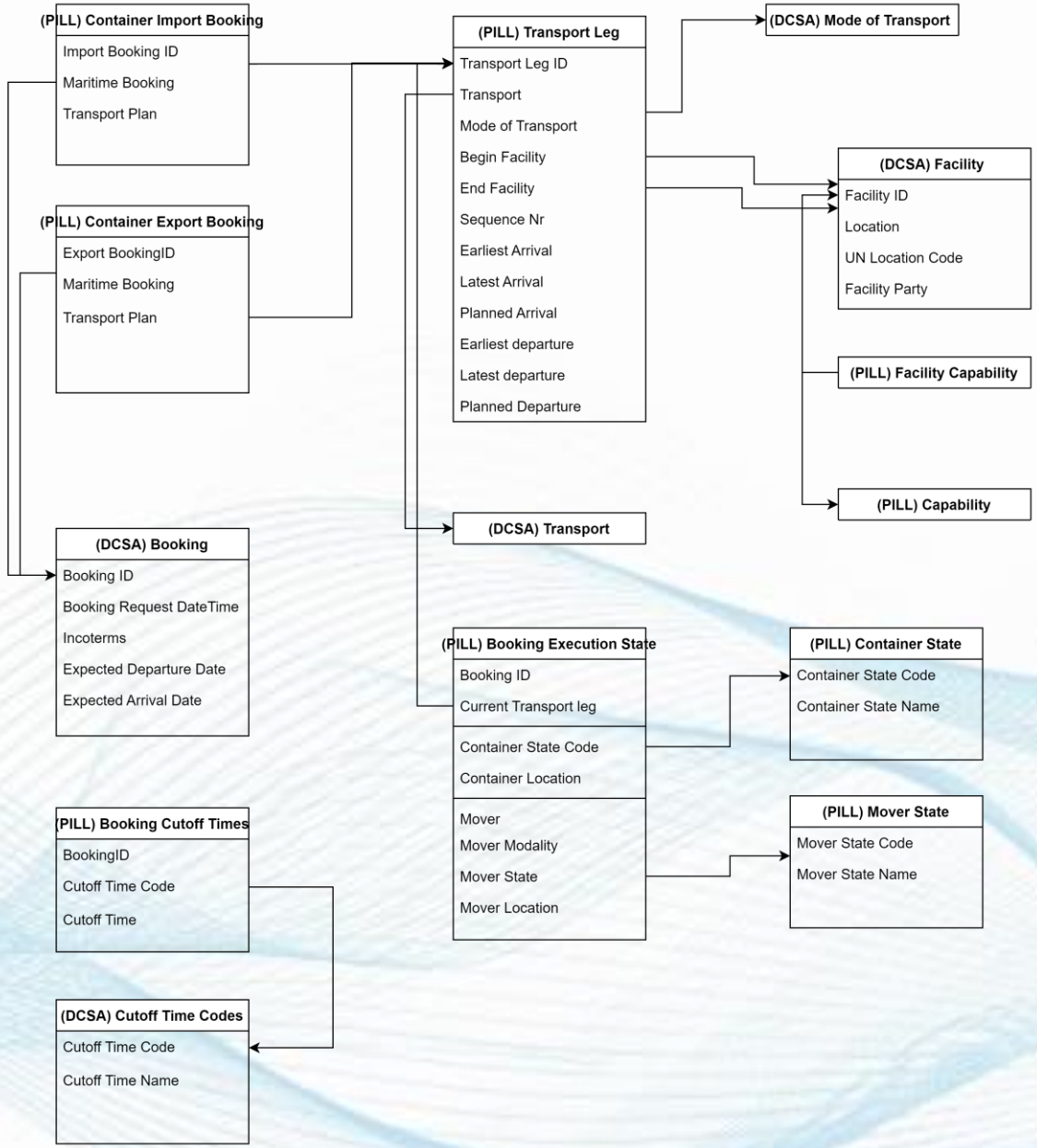
Fit-for-purpose data model

Based of DCSA's
- Operational Vessel Schedules
- Track and Trace

In turn rooted in UN/CEFACT

TODO: Semantic mapping to and convergence with sematic model of FEDeRATED
[Documentation (federatedplatforms.eu)]

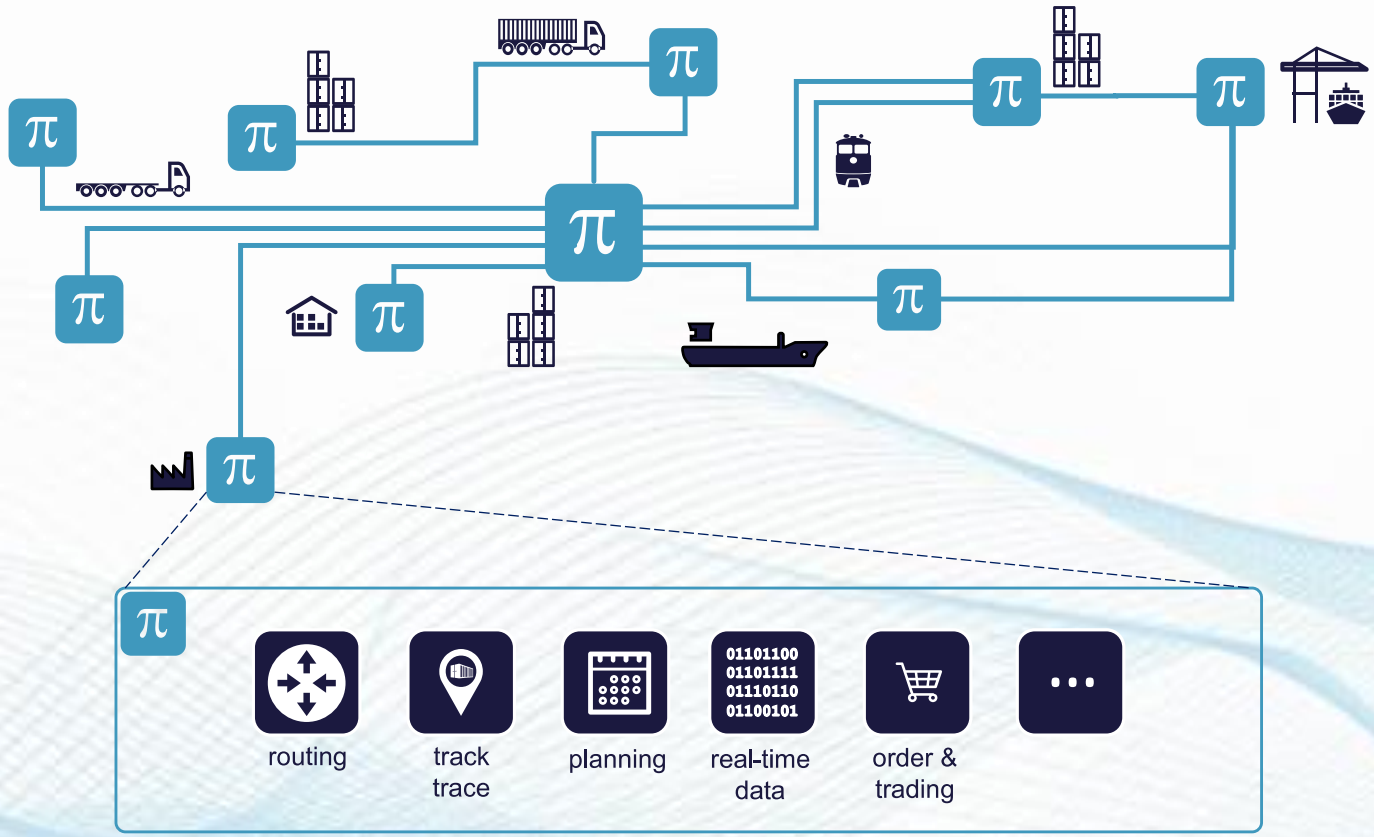
Different logistics processes
- Use fit-for-purpose standards
- But are covered semantically with a unified vocabulary



Deliverable: the PILL π-client

CONNECTOR TO THE DECENTRALIZED INTERNET

- De PI-client acts as a connector for a logistics data space
- The client acts as a platform for 3rd party applications and services
- Apps allow for digital transformation of supply chain processes
- Services provide automation and optimizations
- The network offers the possibility to push notifications for tracking events and disruptions



π-client components

Interface to other
Π- clients

- Keeps track of the Π-network in a local database
- Advertises capabilities and capacity
- Communicates changes to the network

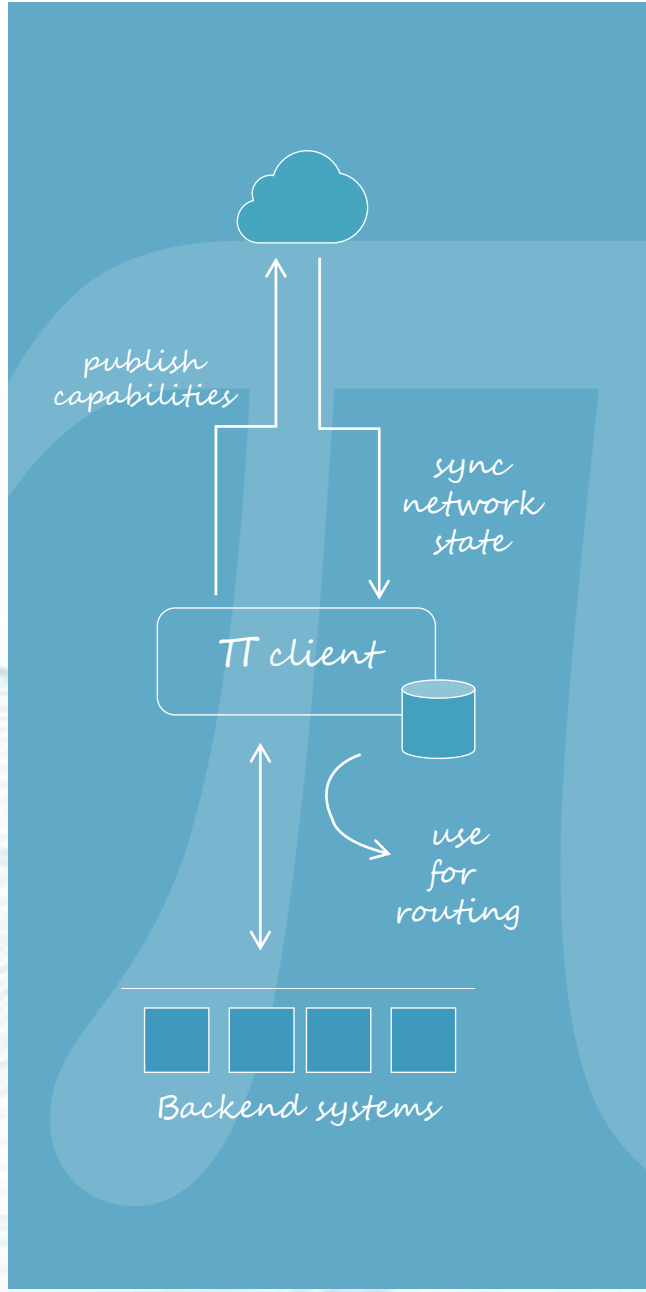
API	Network Manager
Reservation Manager	Booking Orchestrator
Configuration Manager	Route Planner

Connects with backend ERP systems for validating capacity and registering reservations

Manages bookings, saves and compares the routes, takes care of reservations with other clients

Keeps Π-client configuration, entity details and node config and capabilities

Plug-in module that uses the locally stored network state for route planning



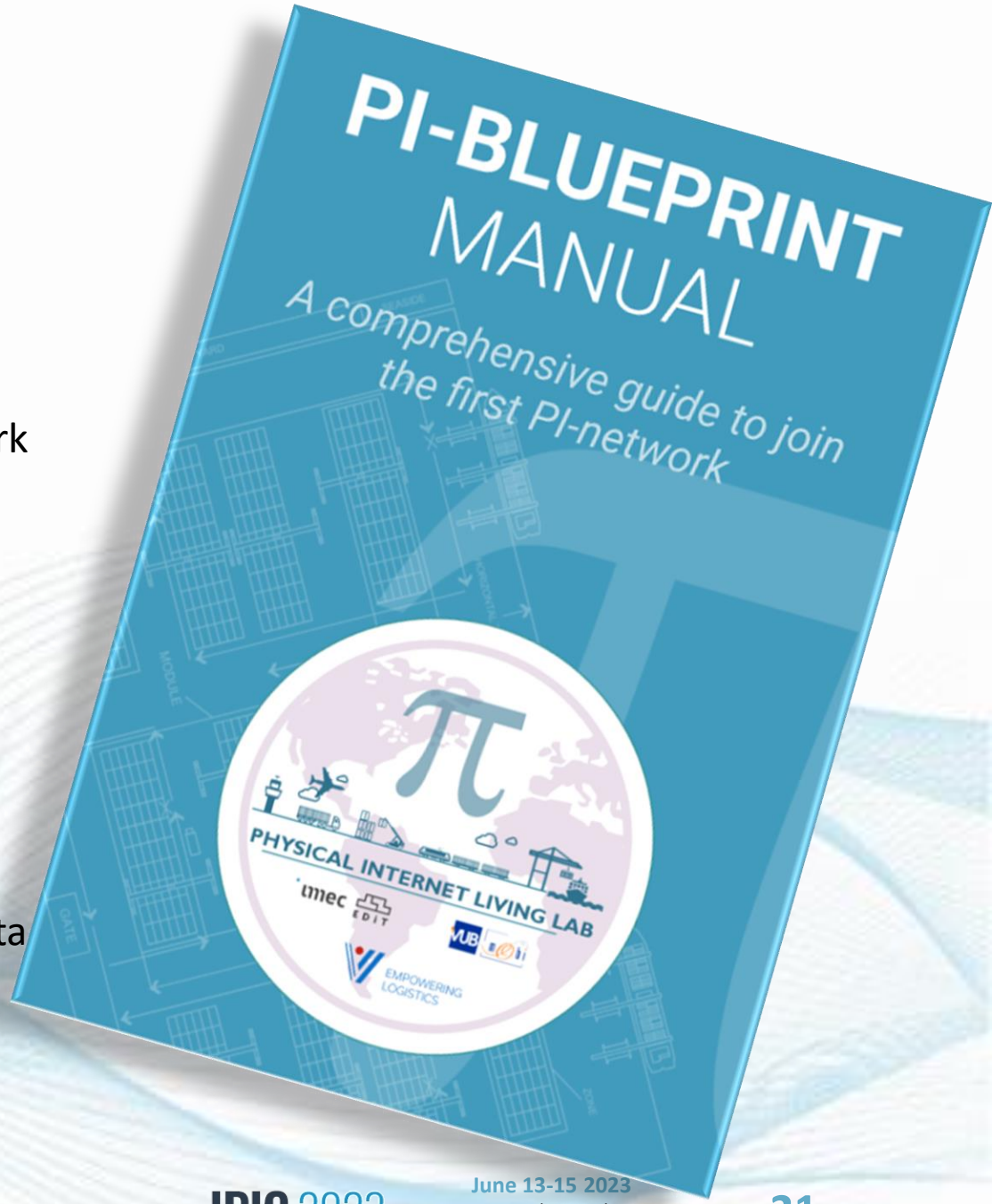
Deliverable: π-blueprint

PILL will lead to the setup and rollout of an experimental Physical Internet network.

The outcome of the PILL project will result in a guide for logistics companies to onboard to and use the first PI-network and applications

The PI-blueprint includes

- Overview & onboarding instructions
- An explanation of the different functions (or capabilities) a node can take up
- Standards and technical interface specifications
- A technical explanation of the decentralized network & data sharing mechanisms
- The PI-client: open-source connector



Connection with Data Spaces

REAL-TIME DATA

real-time data

track & trace

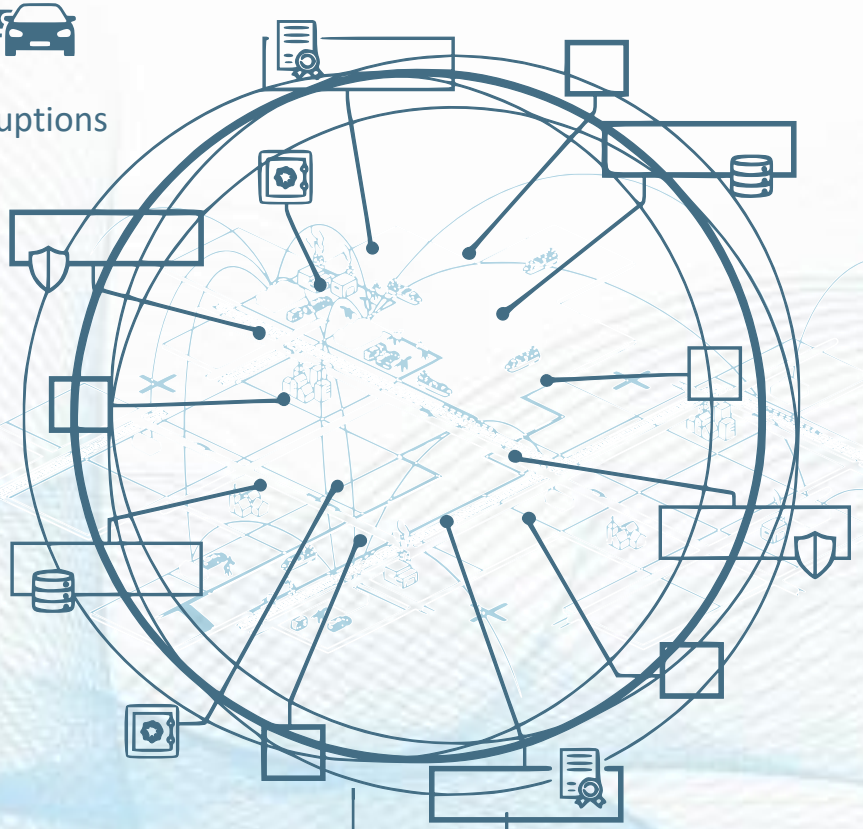
disruptions

OPERATIONAL APPS & SERVICES

Bill of Lading & documentary

Planning & execution

Privacy sensitive data



ALGORITHMS

Routing & optimization

Simulation & prediction

HISTORICAL DATA

01101
01101
01110

Execution logs & traces

Aggregated data

Simulation results

Validating the π-blueprint

Development & testing of the PILL POC

Dries Van Bever – Business Analyst – imec

Shiqi Sun – Simulation model researcher – VUB Mobilise

Physical Internet Key Principles

DECENTRALISED NETWORK

- Level playing field for logistics
- Fully decentralised storage of data
- Privacy-sensitive data sharing

PLANNING & RESILIENCE

- Shared view of the network state
- Holistic container planning
- Real-time response to changes

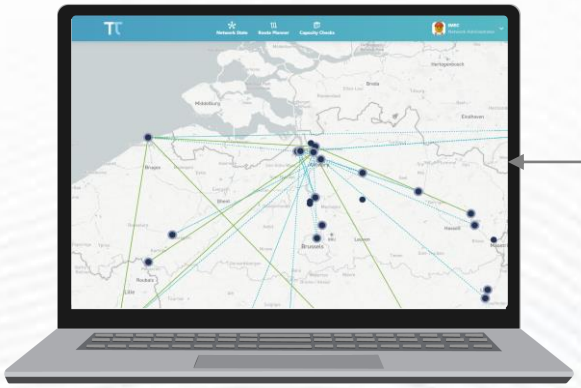
INTEROPERABILITY & AUTOMATION

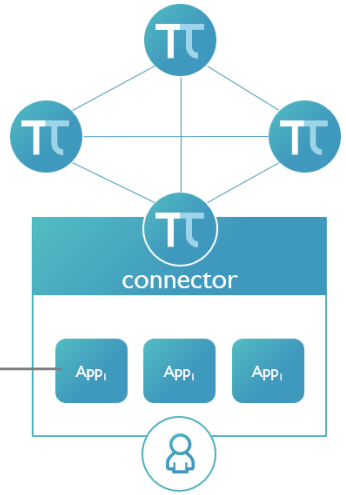
- Fit-for-purpose standards
- Dynamic process-defined access control
- Dynamic trust based on verifiable credentials

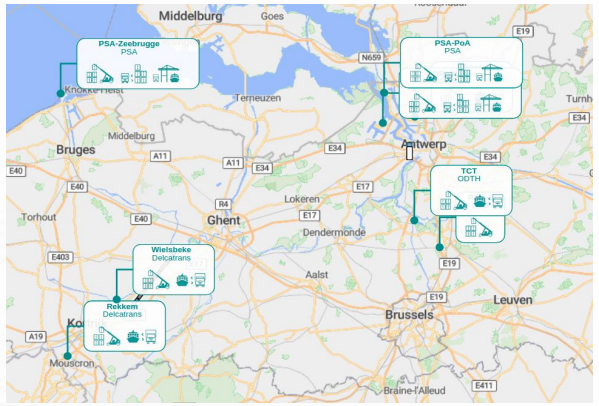
AGENT-BASED SIMULATION

- Resilience stress testing
- Infrastructure optimization
- Scalability

PILL POC components







PI-application

ROUTE PLANNER

- Local hosting & storage of data
- Based on PILL data standards
- Holistic container planning
- Interoperable with all PI apps

→ ***INTEROPERABILITY & AUTOMATION***

→ ***PLANNING & RESILIENCE***

Backend connector

PI-CLIENT

- Forms decentralised network
- Enforces data model
- Orchestrates data sharing
- Manages PI-applications

→ ***DECENTRALISED NETWORK***

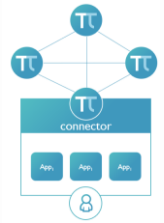
PI-application

SIMULATION MODEL

- Strategic stress testing
- Infrastructure optimization
- Access (historic) network data

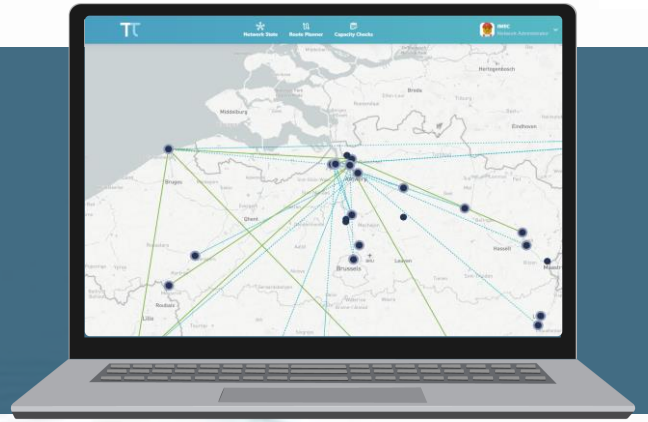
→ ***AGENT-BASED SIMULATION***

PILL validation plan



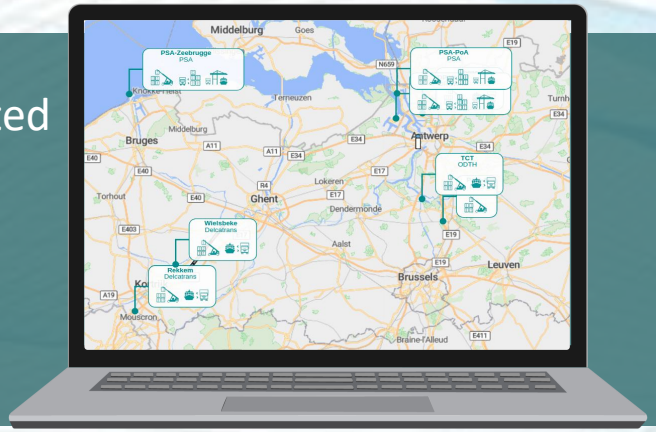
1 π-CLIENT LIVING LAB

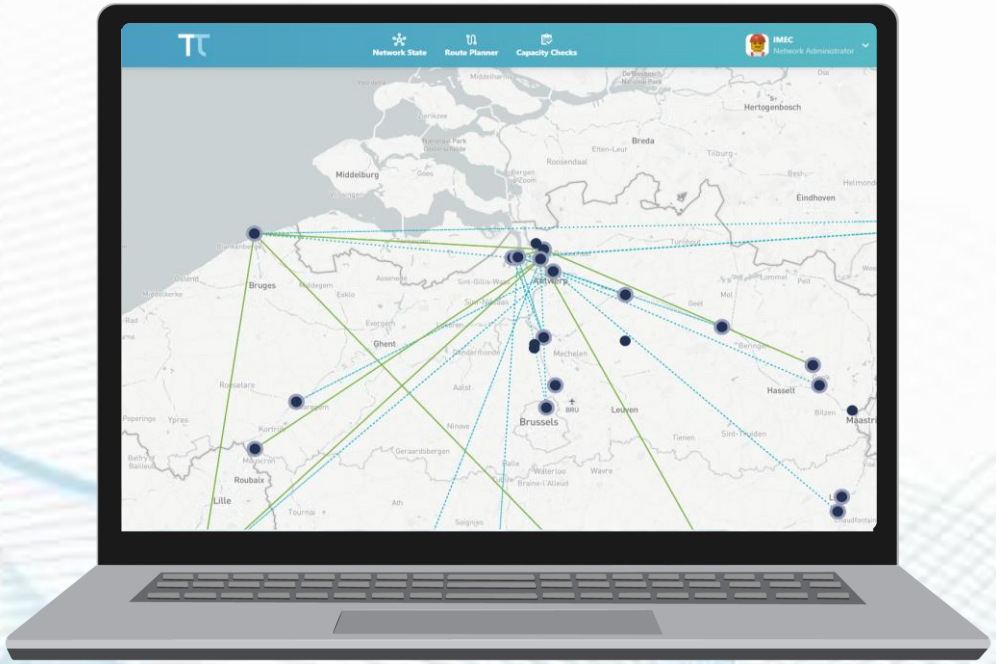
- Field testing of software with stakeholders
- Validate Decentralization & Interoperability
- Realtime data & Real container



2 ABM SIMULATION TESTING

- Risk-free scenario testing in simulated environment
- Validate the routing algorithm, Scalability & predictive capacity
- Historic data & Fictional scenarios

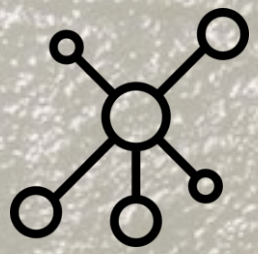




THE π-CLIENT LIVING LAB

Validation of the PI-client and route planner

FOCUS NEEDED TO KICKSTART THIS PROJECT



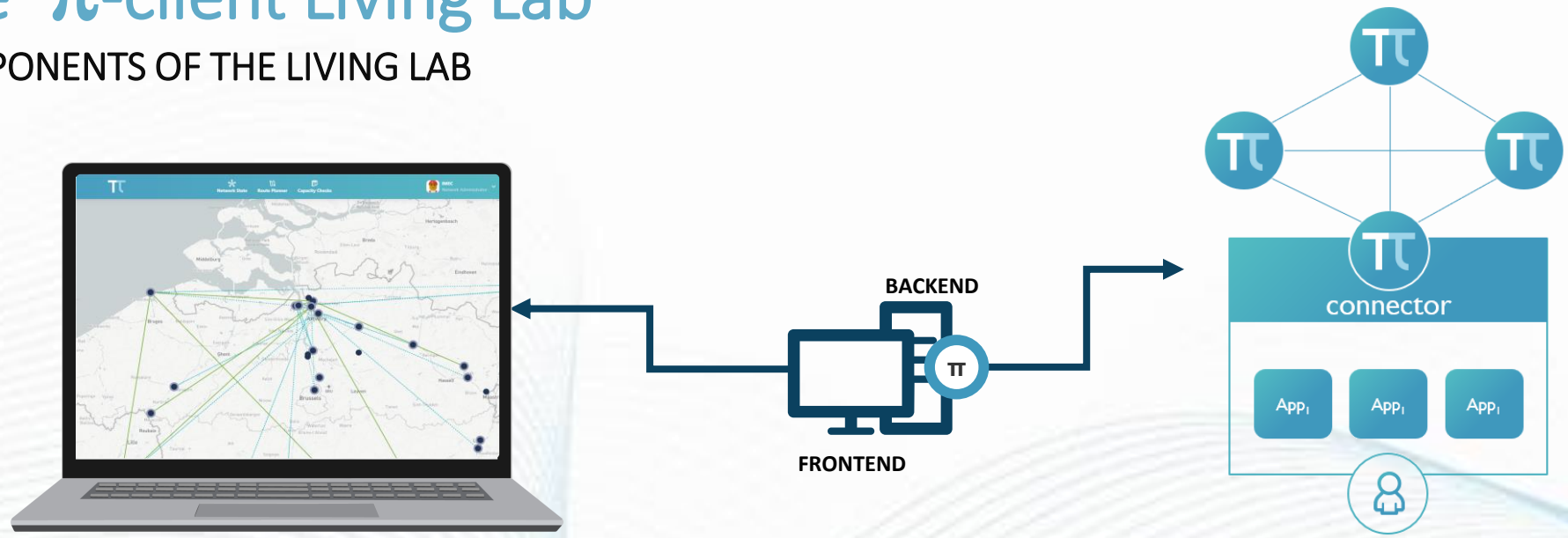
LOGISTICS NETWORK

SPOT CONTAINER TRANSPORT

HINTERLAND CONNECTION

The π-client Living Lab

COMPONENTS OF THE LIVING LAB



PI ROUTE PLANNER

Decentralized application, connected to the PI-network

- Local hosting & storage of data
- Based on PILL data standards
- Holistic container planning
- Interoperable with all PI applications

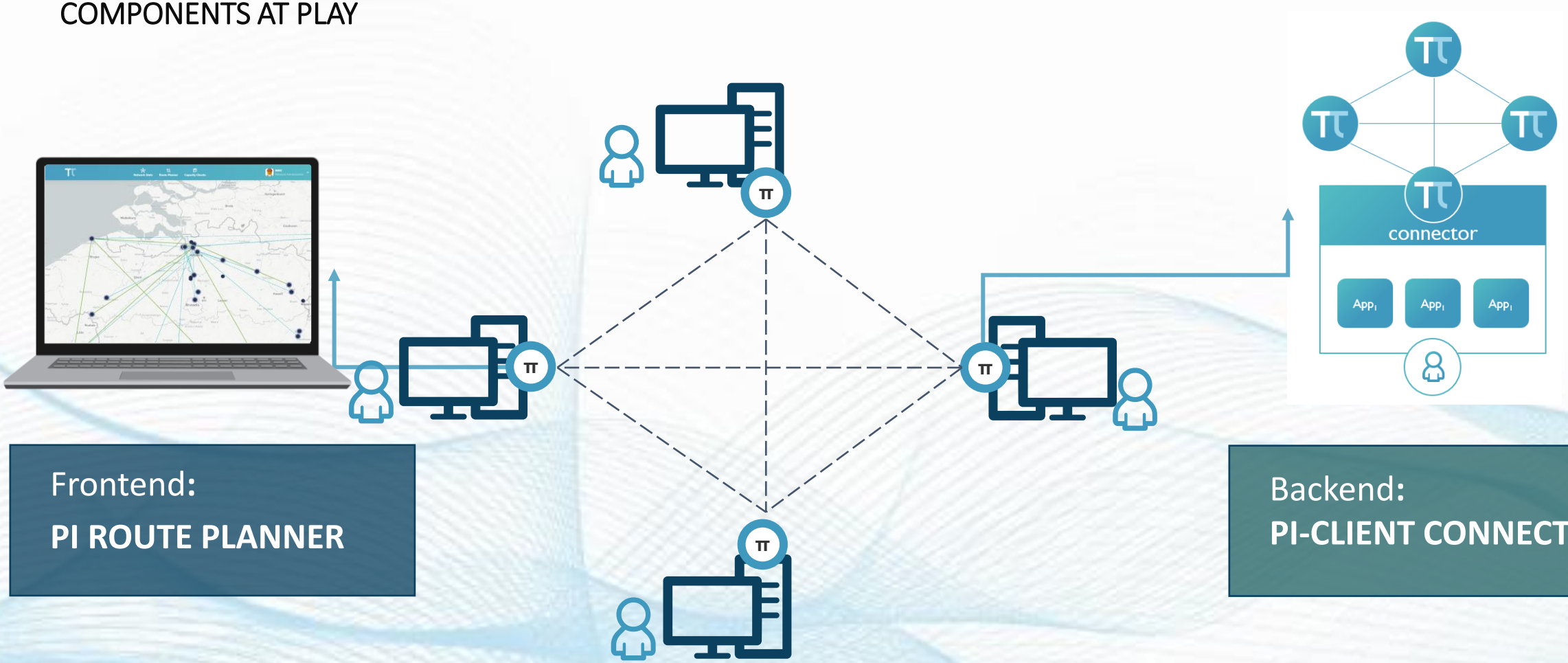
PI-CLIENT

Connector to form the decentralized, open network

- Represents a node in the decentral network
- Enforces data model
- Orchestrates data sharing
- Manages PI-applications

The π-client Living Lab

COMPONENTS AT PLAY



Frontend:
PI ROUTE PLANNER

Backend:
PI-CLIENT CONNECTOR

The π-client Living Lab

THE PI ROUTE PLANNER

The route planner is the first POC of a logistics application that **operates on a PI-network**.

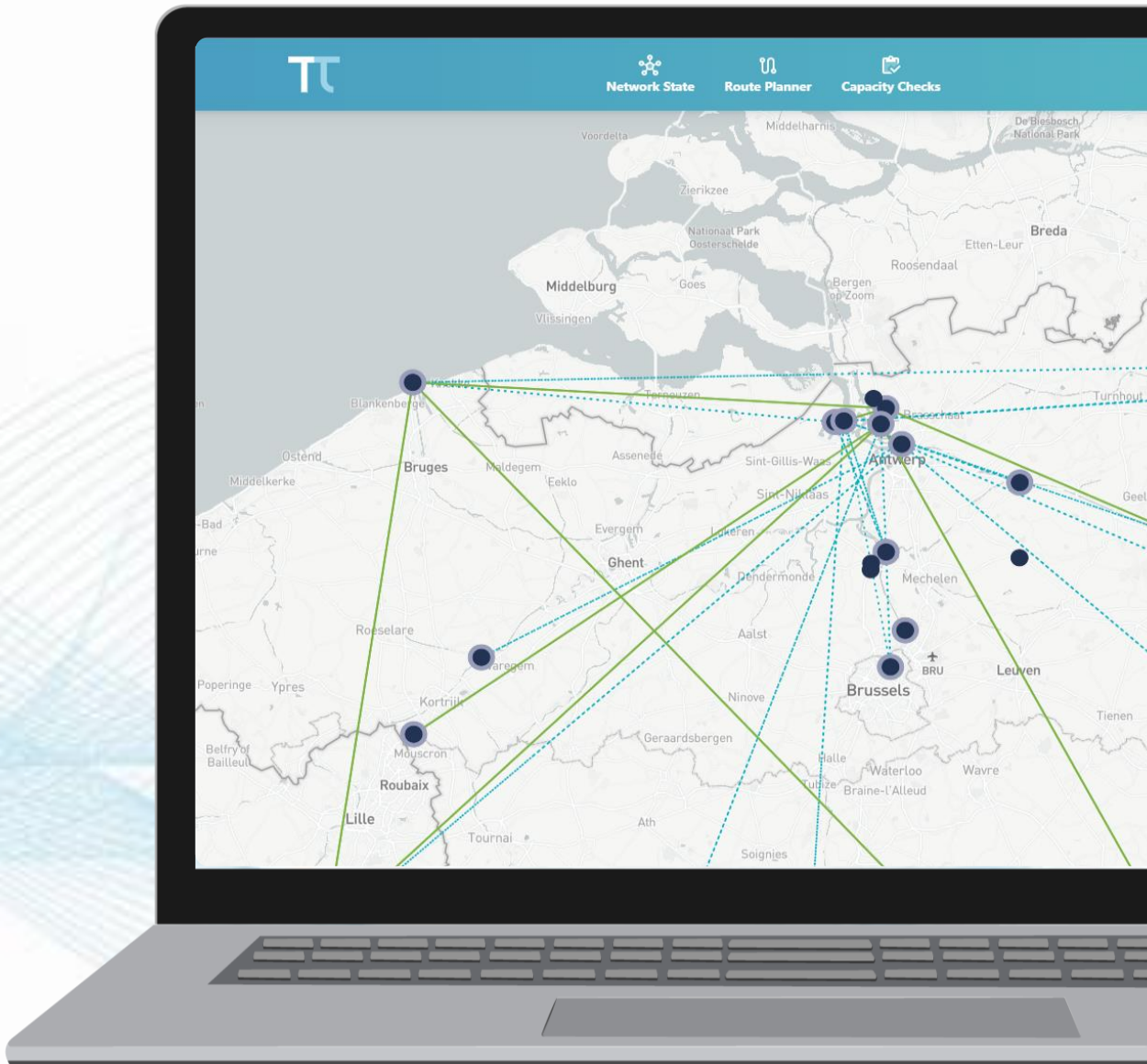
Route planning forms the cornerstone to optimize **planning & resilience** of a logistics network.

The PI-Route planner enables **data sharing & interoperability** across stakeholders on the PI

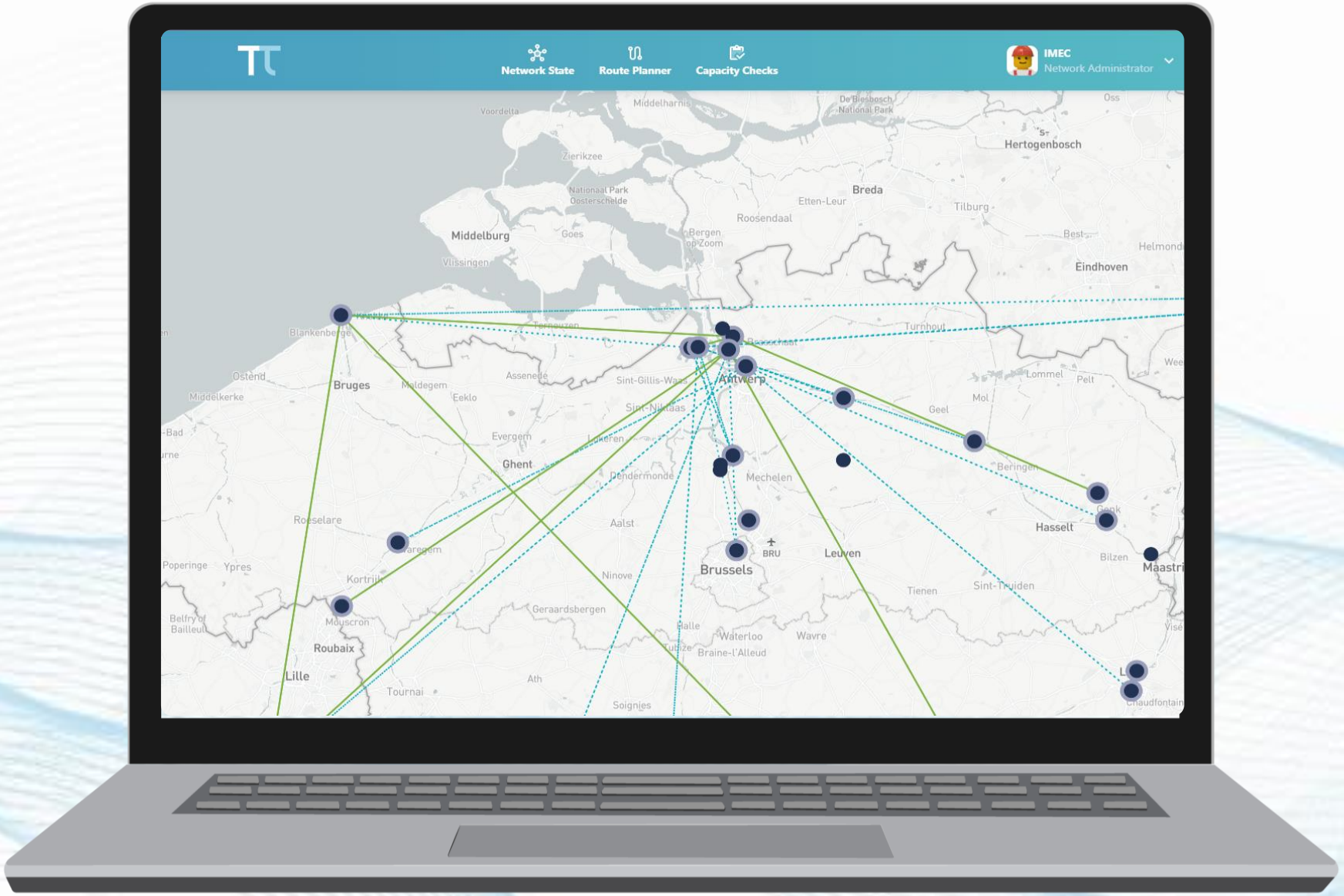
Capabilities:

- Share & view the network state data
- Route planning, using the live network state data
- Anonymized Capacity Requests

Network state =



Demo


Network State
Route Planner
Capacity Checks
IMEC
Network Administrator
Middelburg
Vlissingen
Breda
Tilburg
Eindhoven
Hertogenbosch
Bruges
Ostend
Antwerp
Ghent
Mechelen
Brussels
BRU
Leuven
Hassell
Roeselare
Kortrijk
Ypres
Roubaix
Lille
Tournai
Waterloo
Wavre
Sint-Truiden

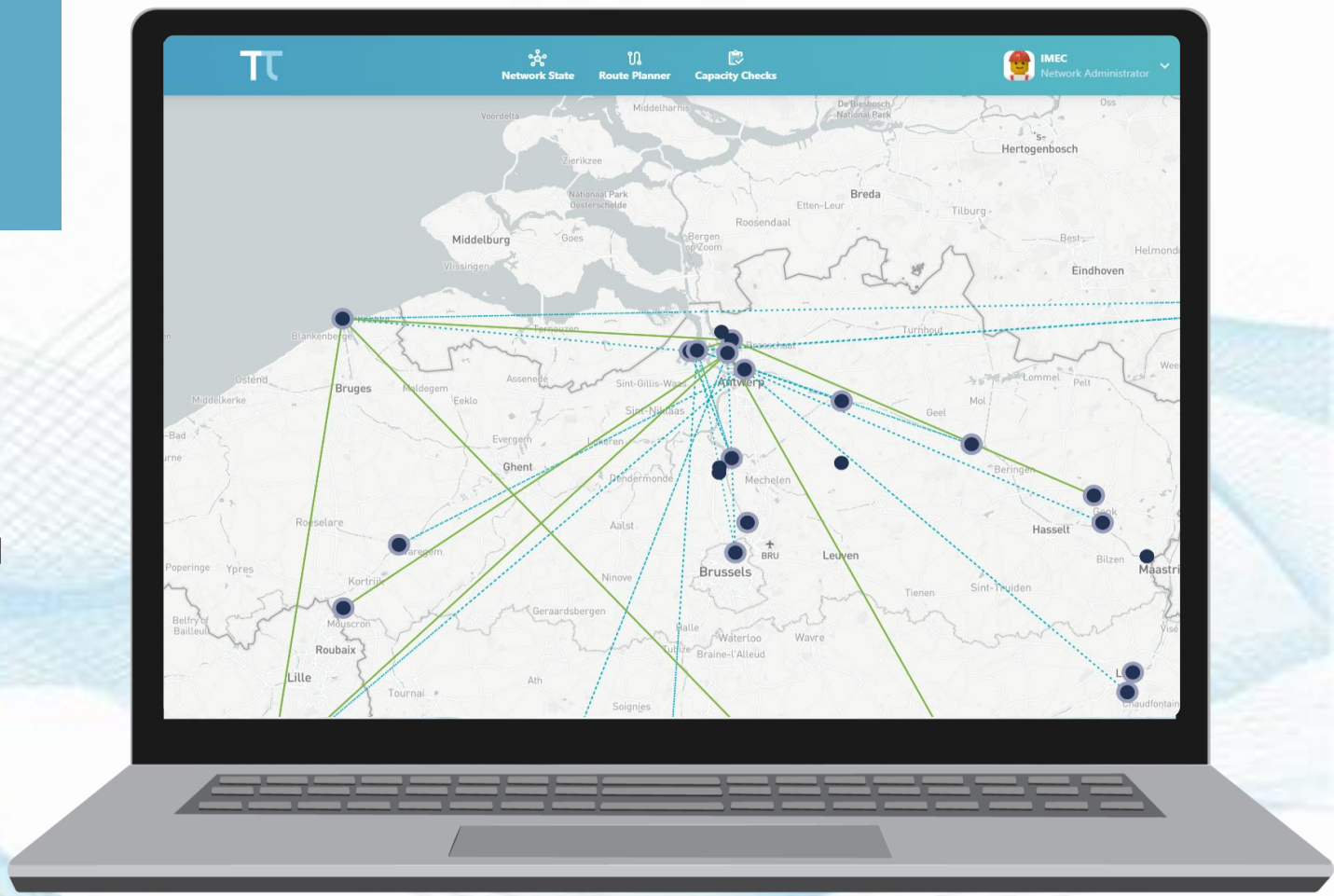
The π-client Living Lab

LIVING LAB TEST

10 logistics players tested out the Application & PI-client.

For 2 weeks all their spot orders on the corridor of the Albert Canal were planned & organized using the route planner

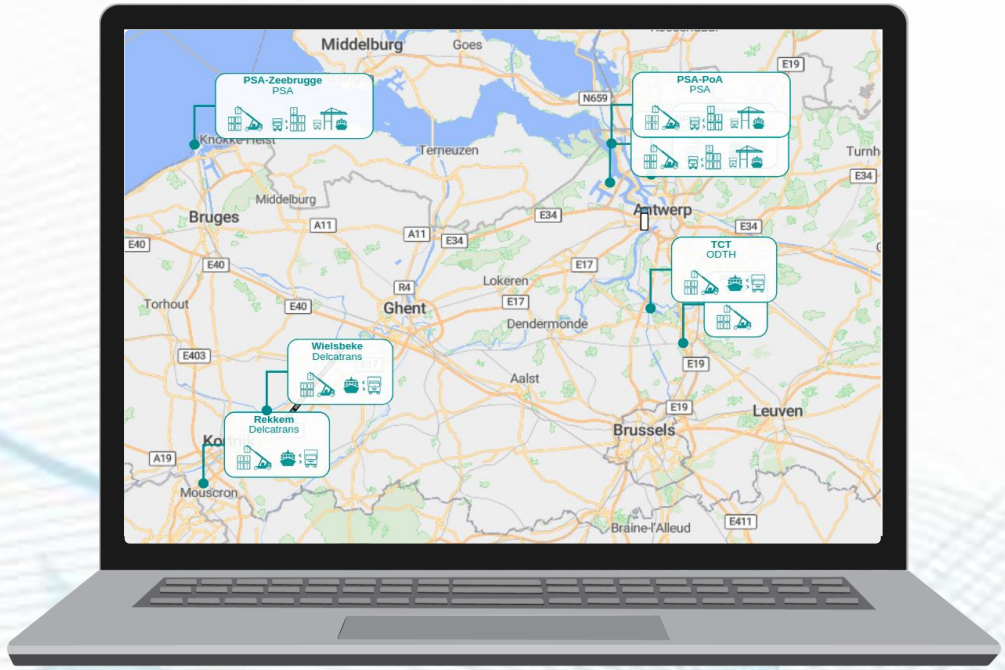
- 2-week operational test (April 2023)
- 10 participants: Truck, Rail, Barge, Terminals, Forwarders
- Real data, real containers
- Open data sharing, based on the PILL data model
- 1on1 (anonymized)capacity checks, followed by offline finalisation



The π-client Living Lab

CONCLUSIONS OF LIVING LAB

DECENTRALISED NETWORK Can we run a software on a decentralized network?	It is possible to onboard and connect data bases with each other without a central orchestrator
DATA MODEL Can we create a data standard for container planning?	The current data model is correct, but not yet complete
INTEROPERABILITY: Can we use data on a decentralized network to calculate & plan transport?	Open and 1on1 data sharing is possible on a decentralized network
PI BUSINESS VALUE What is the value of open collaboration on a decentralized network?	The concept is experienced as answering the needs of the sector. Still the living lab was too limited to prove this.

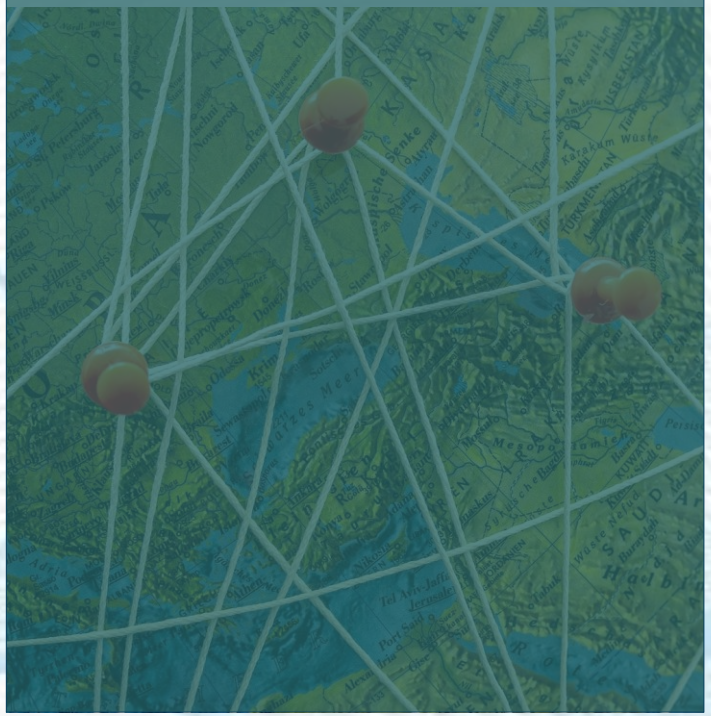


ABM SIMULATION TESTING *(ongoing)*

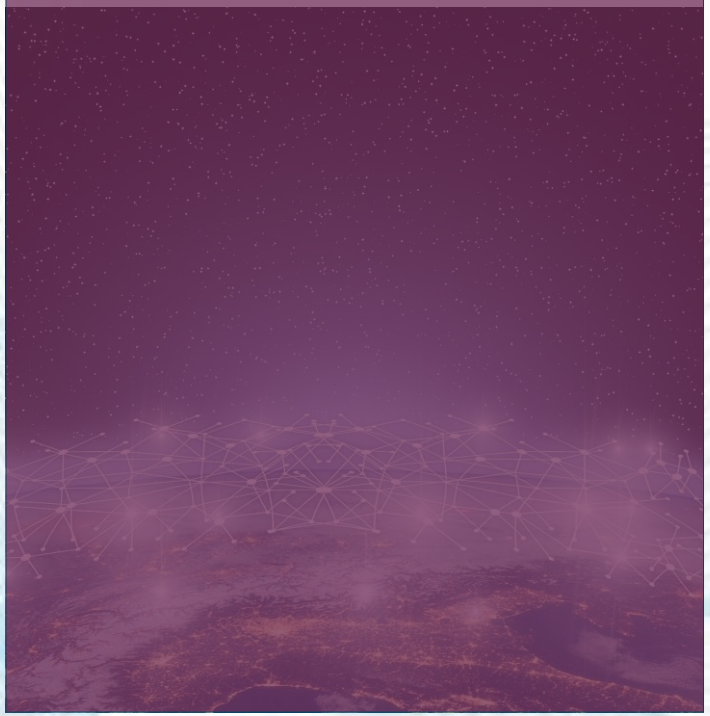
Validation of a decentralized network of PI-clients through an agent-based simulation model

Importance of the Agent-based Model

Validation of Routing & Optimization Algorithms

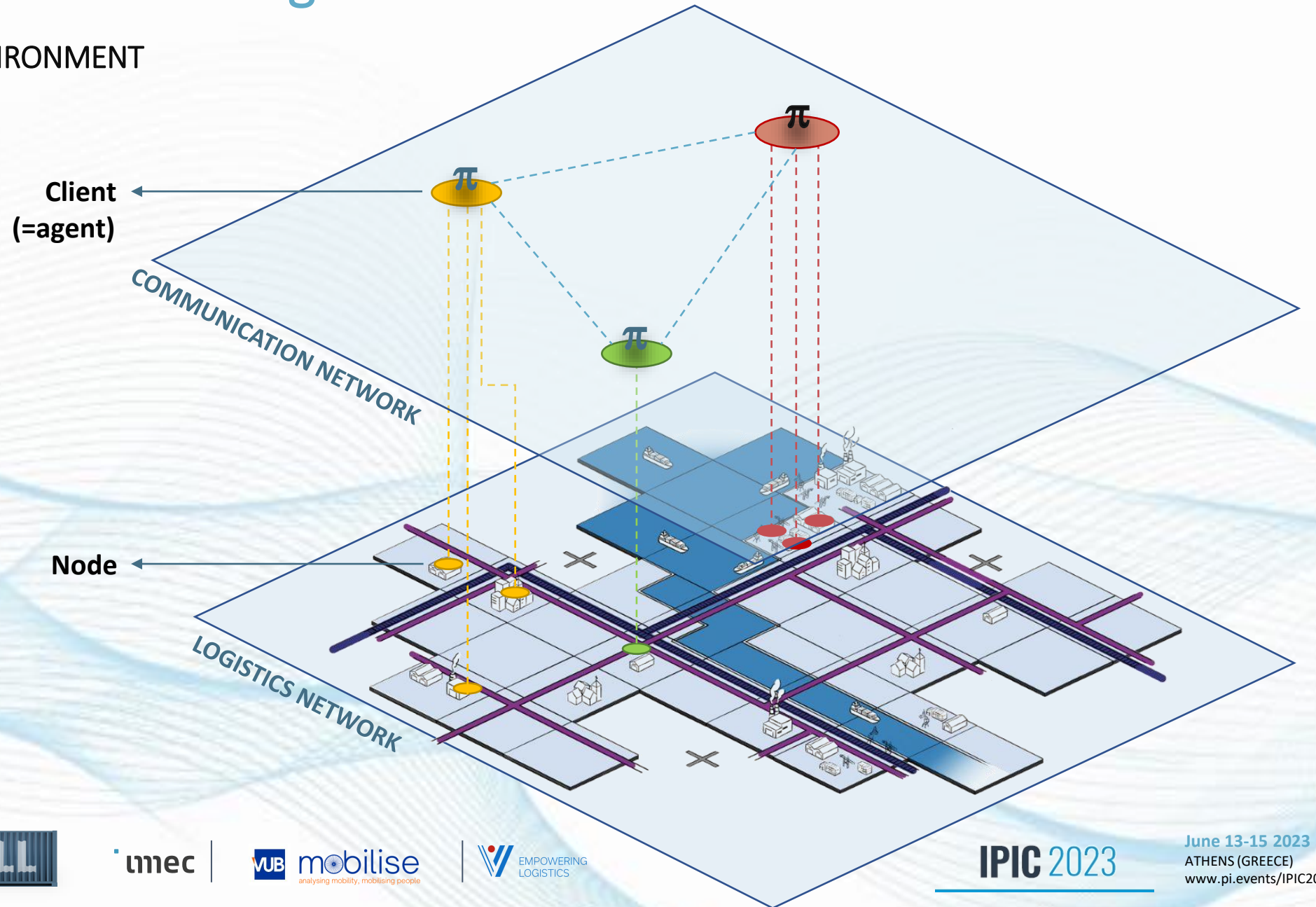


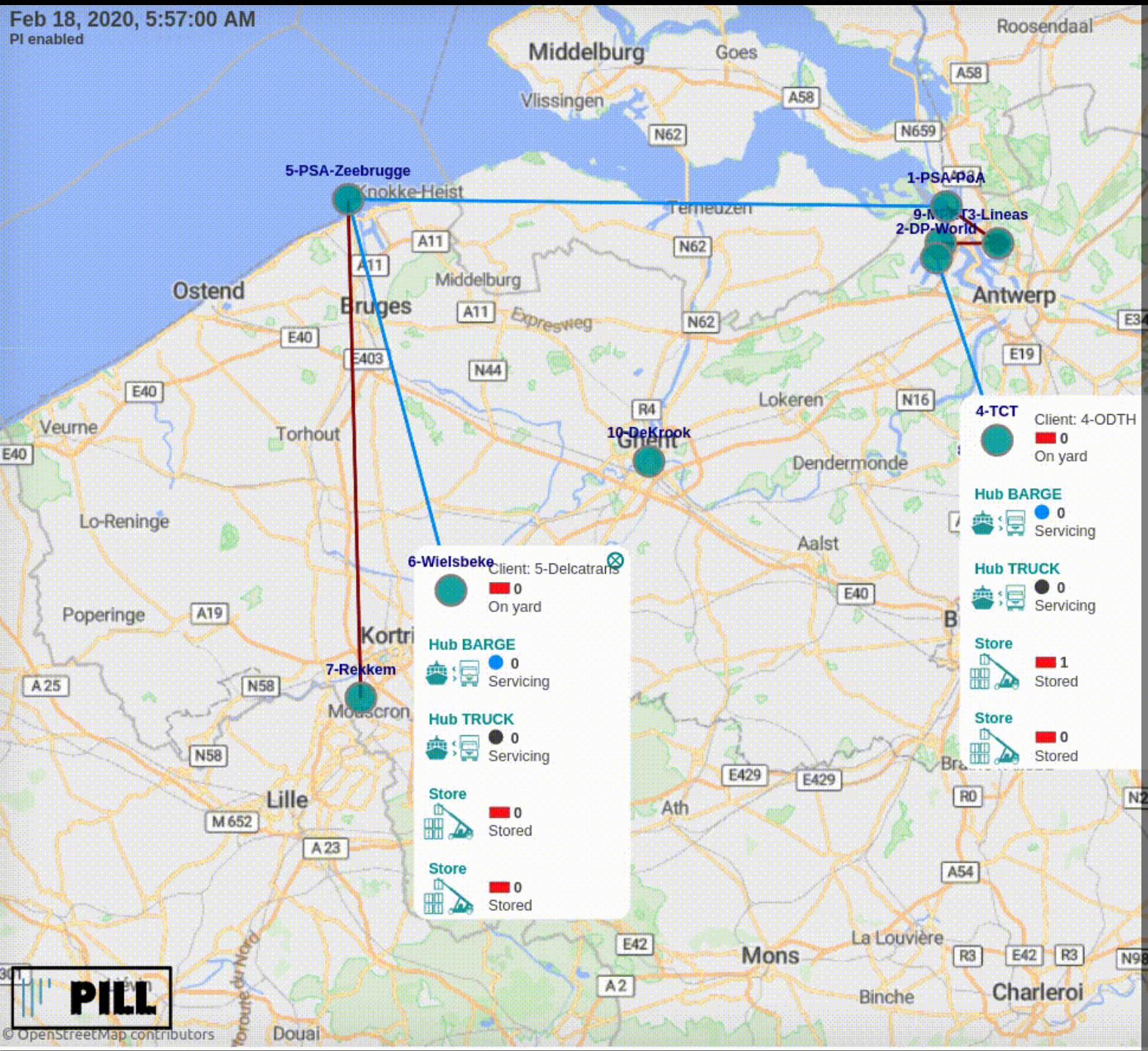
Scalability Testing

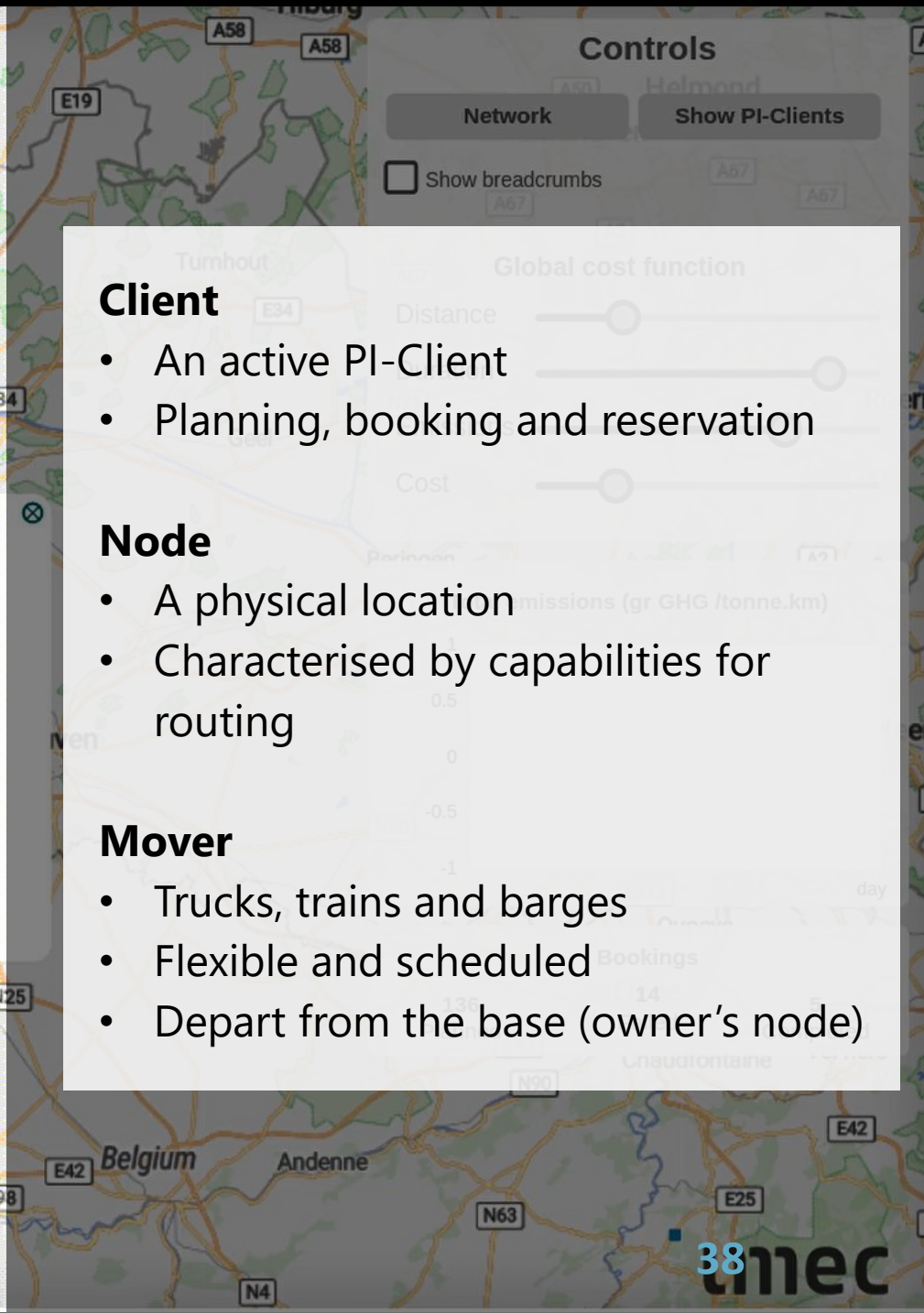


Predictive Analysis

Clients & the Agent-based Model







Client

- An active PI-Client
- Planning, booking and reservation

Node

- A physical location
- Characterised by capabilities for routing

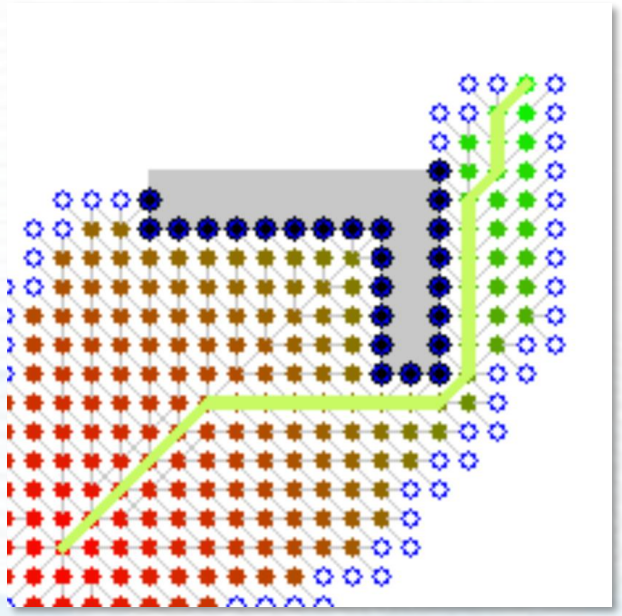
Mover

- Trucks, trains and barges
- Flexible and scheduled
- Depart from the base (owner's node)

Routing algorithms

PIA* – SNAPSHOT PLANNING

- A* Algorithm



- Besides, PIA*…
  - is a one-step routing solution for cargo owners (at loadis)
  - consider movers finding
  - does not need full information on the network
  - defines neighbours by location and **time**

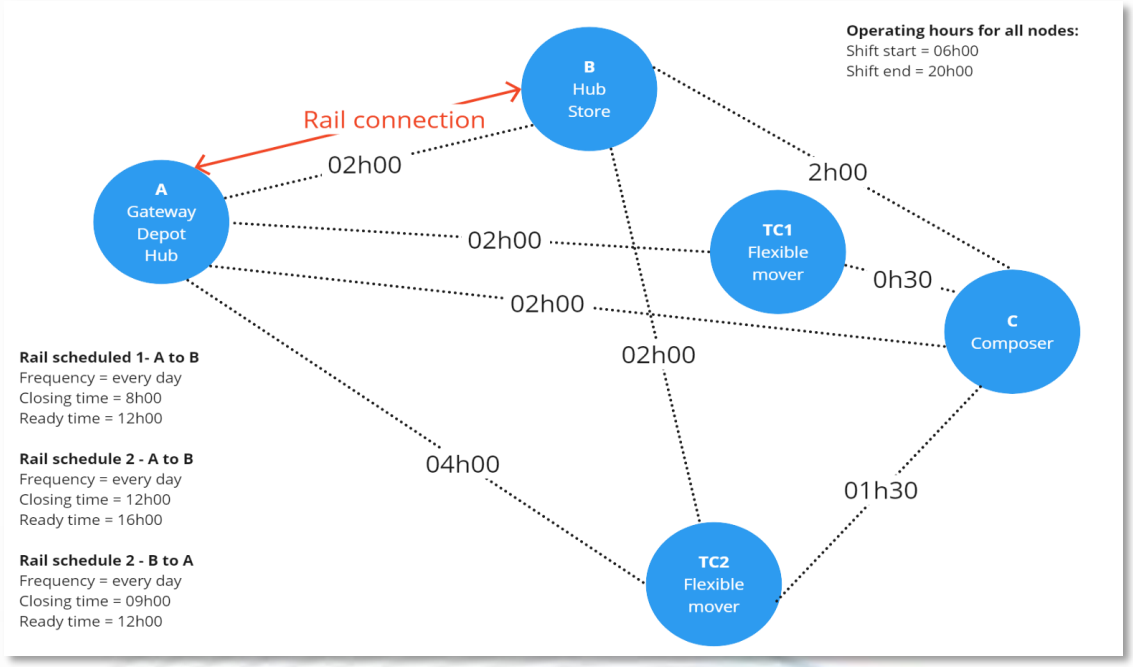
A* example by Subh83, CC BY 3.0 <https://creativecommons.org/licenses/by/3.0>, via Wikimedia Commons

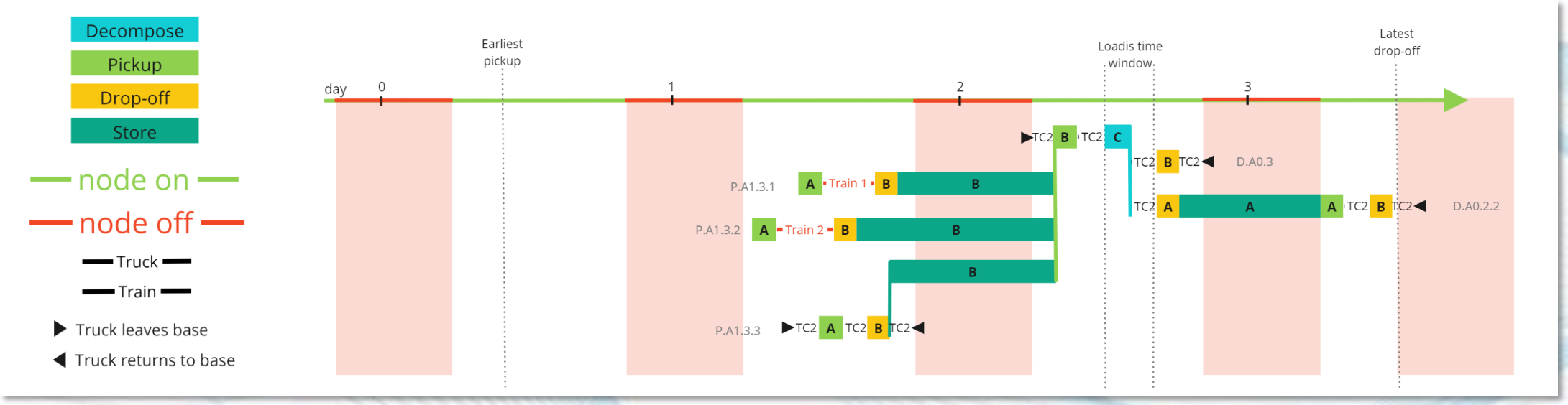
Routing algorithms

PIA* – SNAPSHOT PLANNING

Export

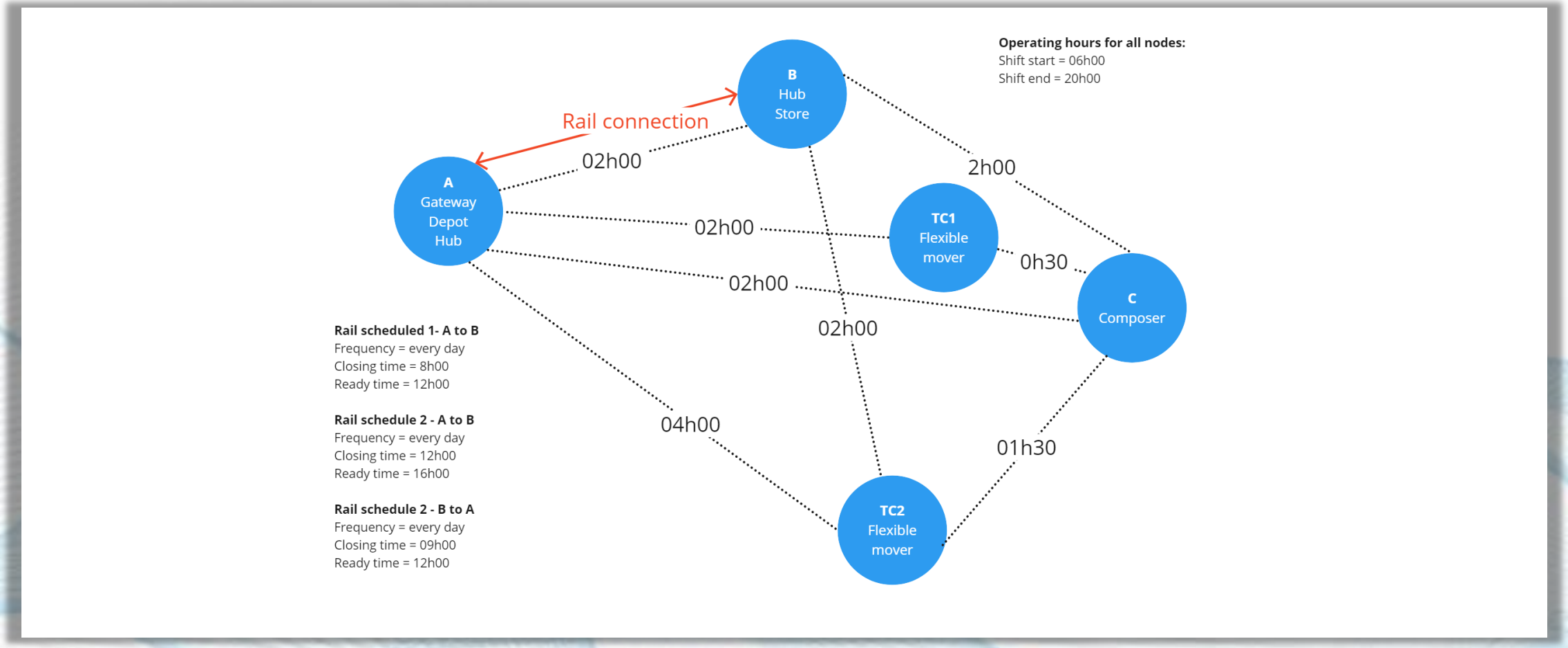
- Back tracking: empty container from A to C
- Forward tracking: loaded container from C to A





Routing algorithms

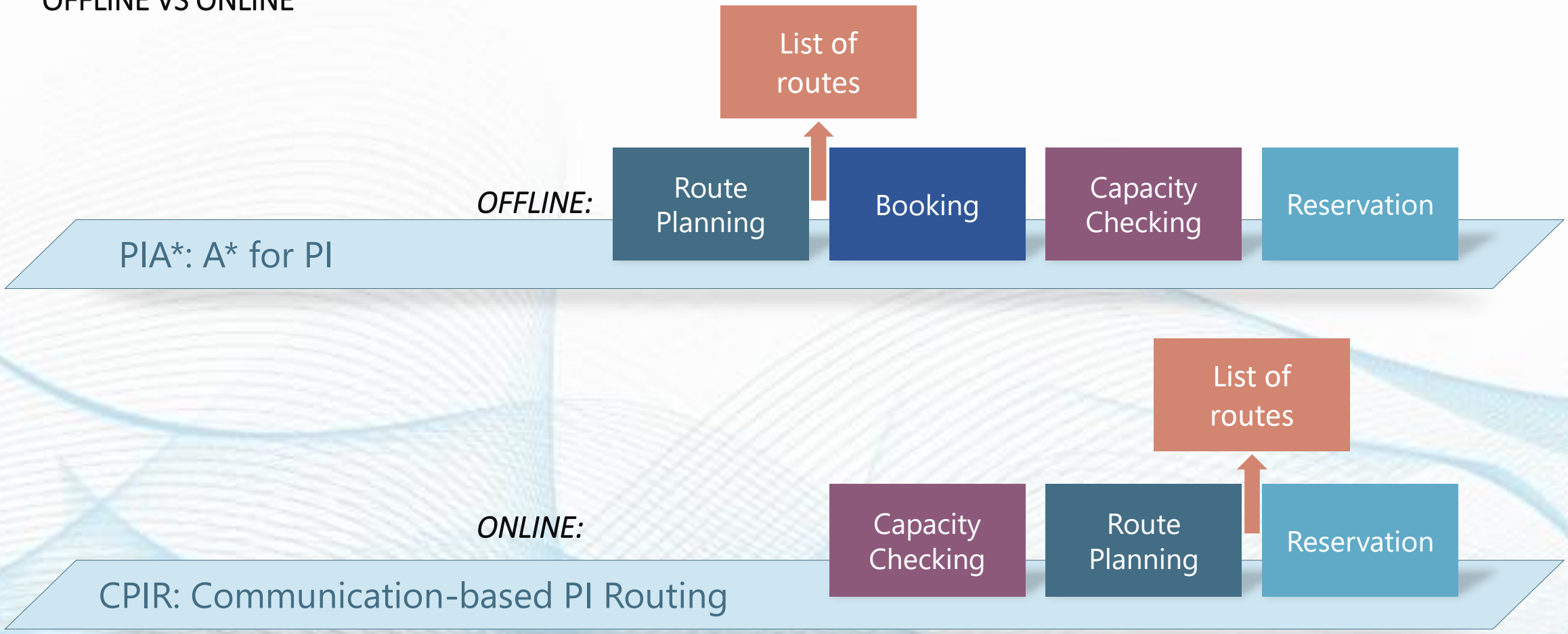
CPIR – ON-DEMAND PLANNING



Sun, S., Cassan, C., & Macharis, C. (n.d.). Communication is Computation : a Privacy-Protecting Routing Algorithm for Physical Internet. Unpublished Manuscript.

Routing algorithms

OFFLINE VS ONLINE



Importance of the Agent Based Model

Validation of Routing & Optimization Algorithms

- Routing optimality
- Privacy
- Disruptions treatment

Scalability Testing

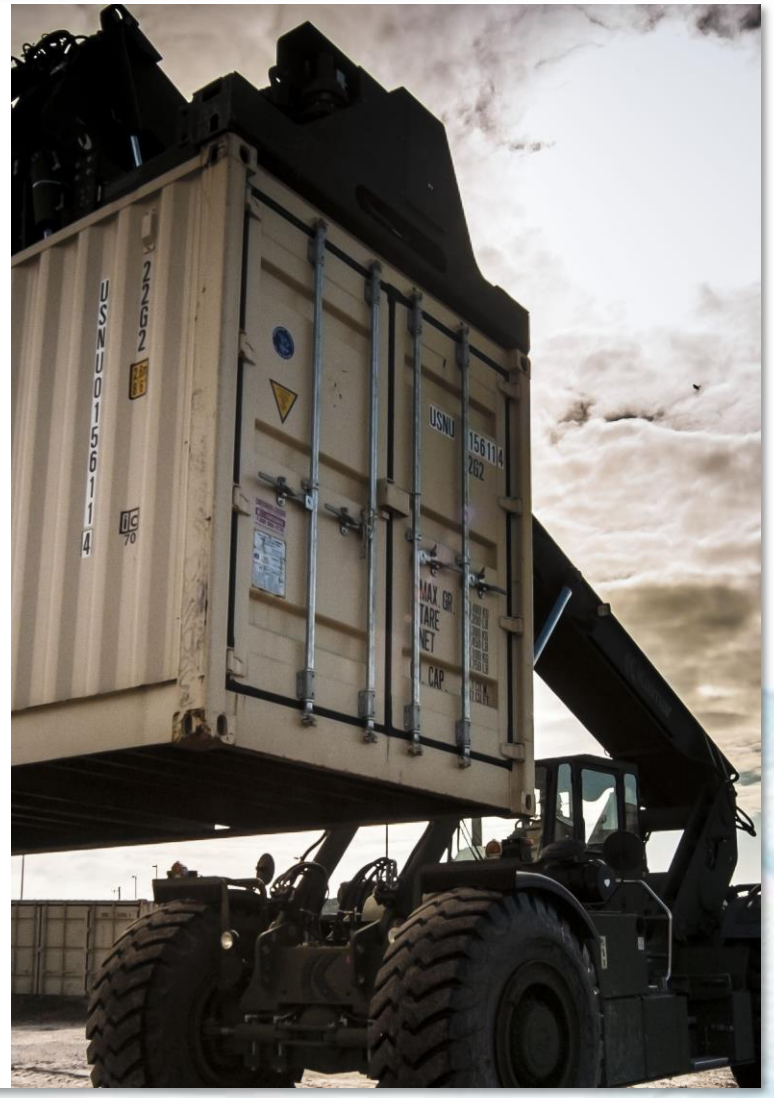
- More nodes
- More constraints
- More capabilities

Predictive Analysis

- Towards Digital Twin
- What if…
- Risk management

What's next for PILL ?

Key takeaways & follow-up initiatives



Joris Finck –Project manager - imec

KEY TAKE-AWAY #1

- A mature version of the Living Lab platform and PI-client would improve day-to-day logistics operations
- The most expected impact is on optimizing fill rate
- The current POC scope was too small to measure actual impact

> The PILL solution has proven to answer several logistics challenges

KEY TAKE-AWAY #2

- By limiting the # of required data, the PI-client increases trust in data sharing
- The key factor to enable a decentralized sharing of data is trust between stakeholders
- Governance will be a basic pillar of the supporting capabilities of the network
- Anonymity is not a desired functionality in a trusted network
- Full automation is not desired (yet), control is still a big factor in trust in the network

> Trust and control are driving factors to build a data sharing network

KEY TAKE-AWAY #3

- Planning optimization on a PI only works from a certain volume of users
- Improving a logistics network via PI will only fully work if the majority in that network are on it
- To increase adoption, it is important to integrate with existing platforms in a first stage

> Achieving a critical mass is crucial to the value proposition of PI

KEY TAKE-AWAY #4

- Data sharing forms the basis of a PI network. A unified Data standard is integral to enable (automated) data sharing
- UNCEFACT data standards are the most widely adopted and should be the basis for PI standards
- Translating current platforms to a PI data standard will be an important step in onboarding existing platforms

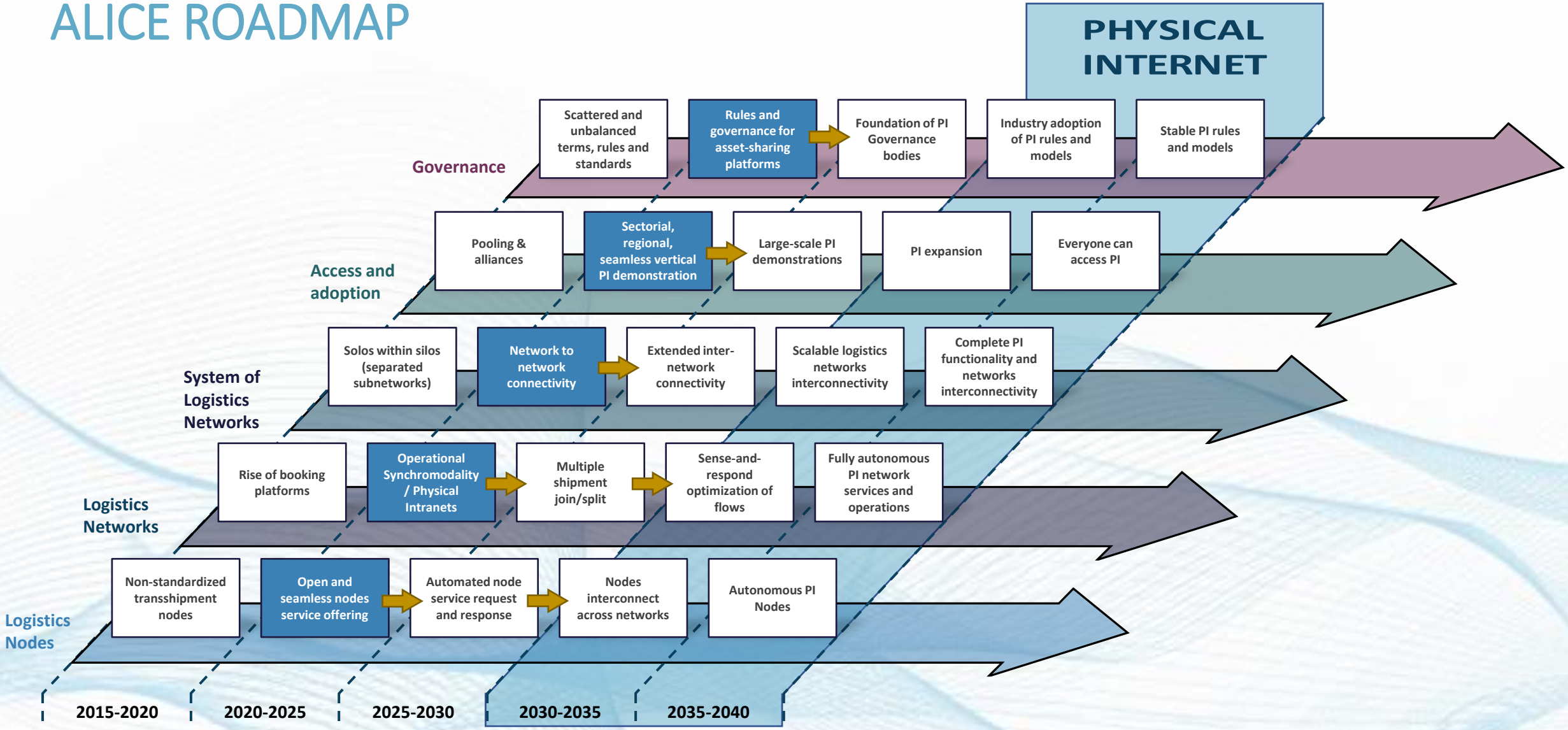
> Data standards are the basis for a PI network

KEY TAKE-AWAY #5

- New collaborative components will need to be built to facilitate interoperability and trusted data sharing
- The need for these components will give rise to a variety of new digital services that
- Software providers play a crucial role in creating these components

> The revolution of PI will be enabled by the emergence of new digital services

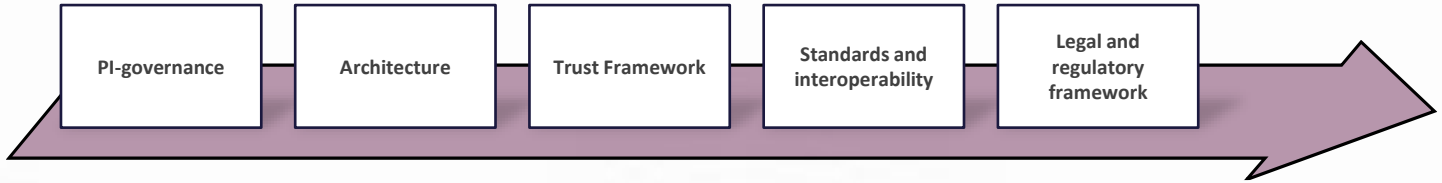
ALICE ROADMAP



PILL ROADMAP

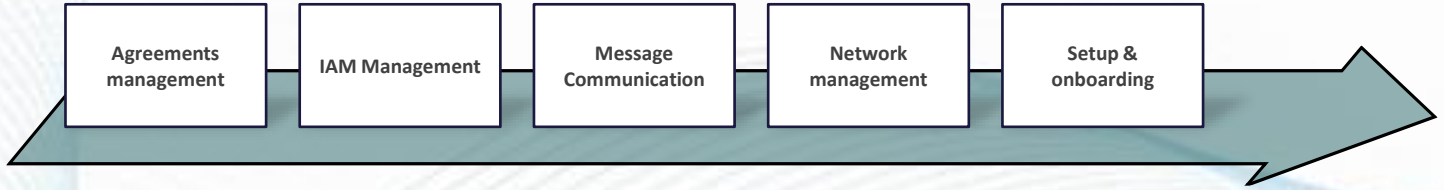
PI-Client Framework

Universal functionalities that are embedded in the PI-client framework



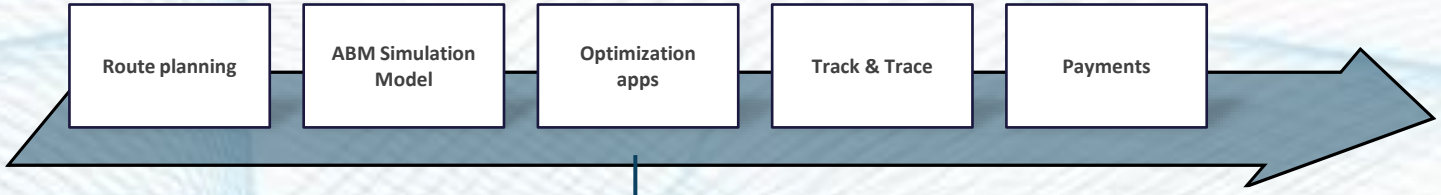
Collaborative components

Components that enable collaboration between parties.



Physical Internet App Marketplace

Apps that support different logistics processes



Roadmap in terms of projects and use cases

PILL synergies

PIONEERS

Sustainable ports through synchromodal intra-port logistics

DISCO

Data space connectors in Urban logistics

SYTADEL

Reference implementation of a data space to the context of logistics synchromodal planning.

FLEMISH SMART DATA SPACE

Enabling smart urban mobility by using the Flemish sensor dataspace.

We are looking for project partners to further build the PI roadmap!

Thank You

PHYSICAL INTERNET LIVING LAB

imec VUB mobilise
analysing mobility, mobilising people

EMPOWERING LOGISTICS