Comparison of freight transport centralization and decentralization in the Physical Internet through gamification

Mariam Lafkihi, Eric Ballot and Shenle Pan

Centre de Gestion Scientifique
MINES ParisTech, PSL- Research University

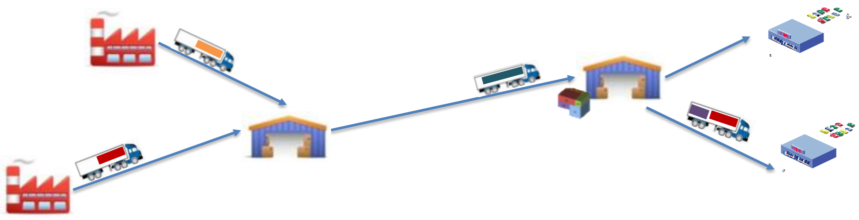
Agenda

- Addressing transport organizations efficiency with interconnection
- Centralized, dedicated and interconnection mechanisms
- Theoretical solutions
- Gamification and behavior
- Conclusion and perspectives

Transport efficiency

- As a function of network organization (among other factors)

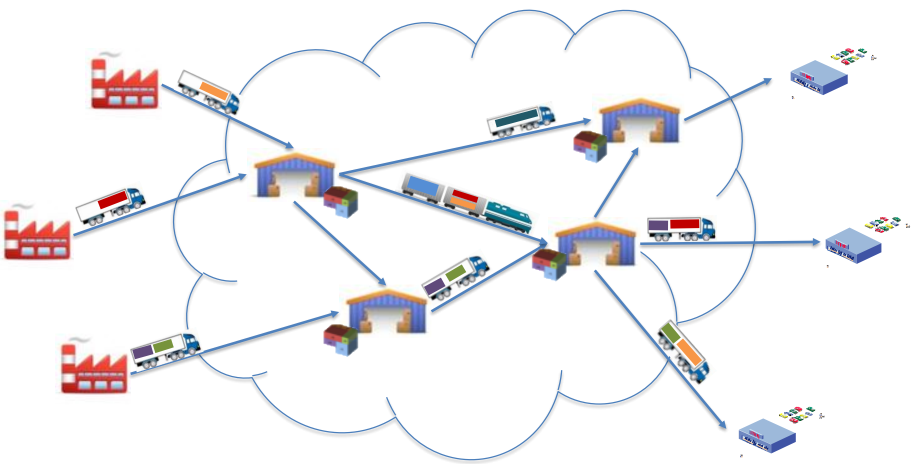
Efficiency =
Fill rate x Not empty run



Dedicated network and resources

50%

= 0.62 x 0.80



Interconnected network and shared resources

80%

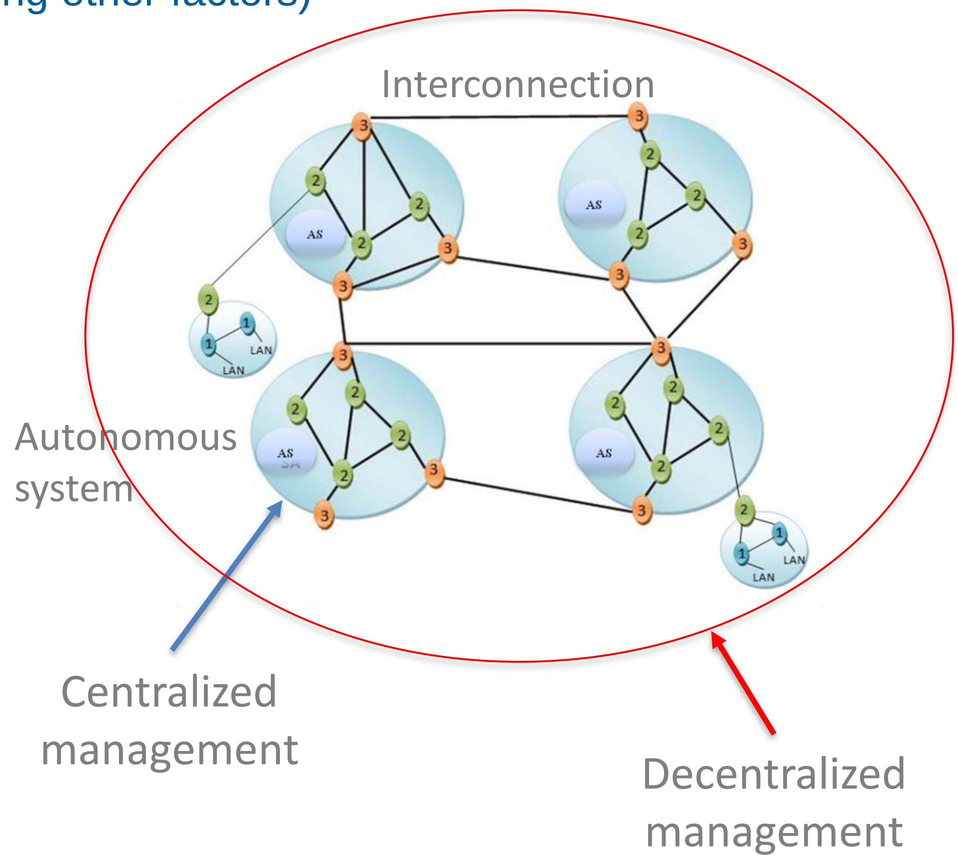
= 0.88 x 0.92

Why it is not happening?

Networks interconnection

○ As a function of network organization (among other factors)

- Computers networks
  - Independent computer networks interconnected by routers (orange)

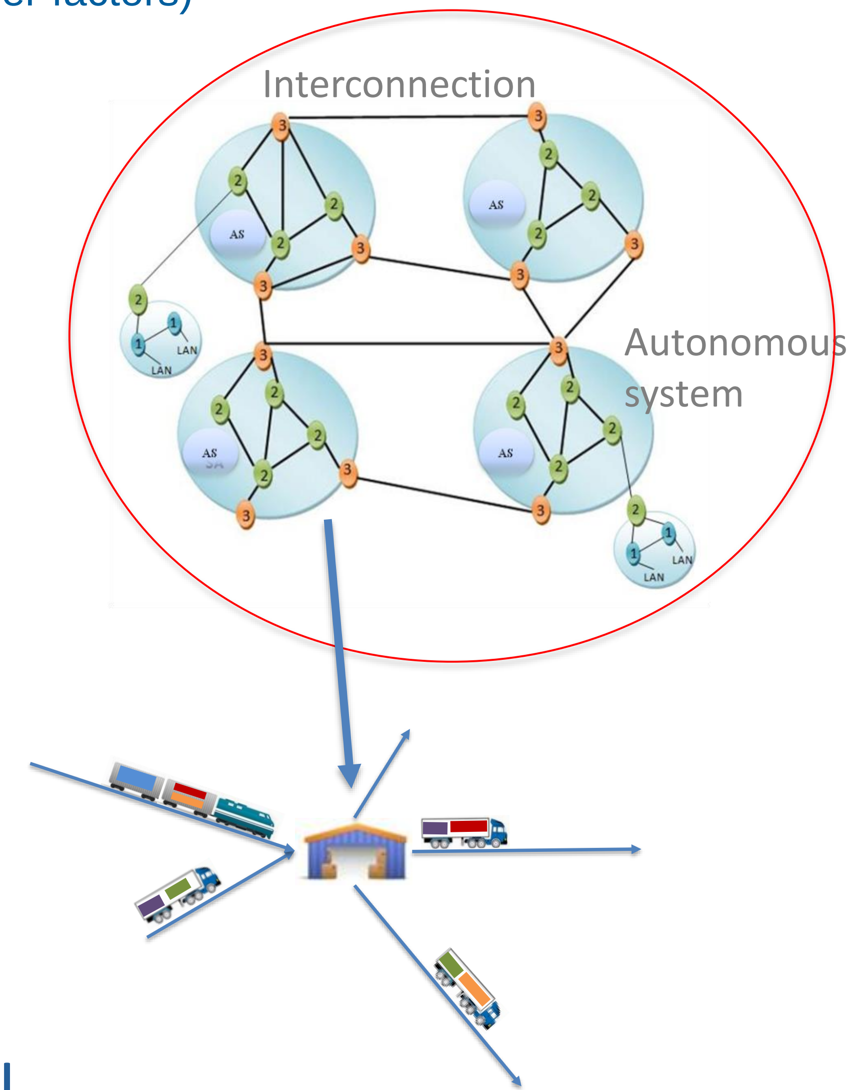


- **The key point is the interconnection to move from a set of independent networks and centrally managed to a more global and globally decentralized network**

Networks interconnection

○ As a function of network organization (among other factors)

- Computers networks
  - Independent computer networks interconnected by routers (orange)
- Logistics networks
  - Most of the research concentrated on dedicated networks (design, planning and operations)
  - The centralization is not scalable and logistic networks will remain very fragmented



To enable interconnection we need to define how it could work in a hub connecting several LSP or carriers service.

How a transport service will be bought?

○ Fragmented markets under innovation pressure

Several markets

- **Spot markets**
- Long term contracts

Several mechanisms

- Tariffs
- Tenders and negotiation
- **Auctions**

- New technologies (IOT…)
- New players
- New expectations from shippers
- New business models

Towards more open, dynamic and decentralized models

Research questions

- What are the barriers towards more a efficient solution: the Physical Internet?
  - Are the purchasing mechanisms a barrier?

- What rules could be defined to enable interconnection?
  - Design and definition?
  - Efficiency?
  - Impact on decision makers?

- How the stakeholders could put new mechanisms into practice?

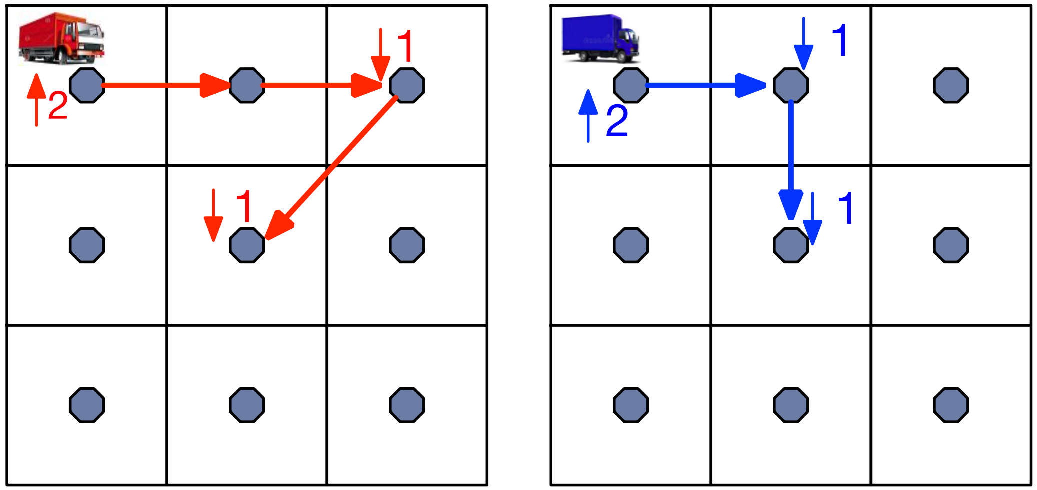
Rules for routing

Rules	Definitions
Rule 1: En-route improvement	At some hubs in the network, shipments must be reallocated to other carriers proposing a lower price.
Rule 2: Lowest price and best reputation wins	If there is competition, shipments must be allocated/reallocated to the carrier proposing the lowest price. If two carriers are tied for the lowest price, then the carrier with the best reputation will win the shipment auction.
Rule 3: No price increase	Once a price is promised to the shipper, it cannot be increased when transferring the request(s) from one carrier to another in the event of reallocation.
Rule 4: Individual responsibility	Each carrier is responsible for any delays they cause and pay the associated penalty.
Rule 5: No halfway drop-out	If there is no possibility of reallocation, the carrier in charge must transport the request acquired from the origin to the destination. Reallocation occurs if and only if the request is taken over by another carrier to the destination.

Routing improvement illustration

3+2
distance

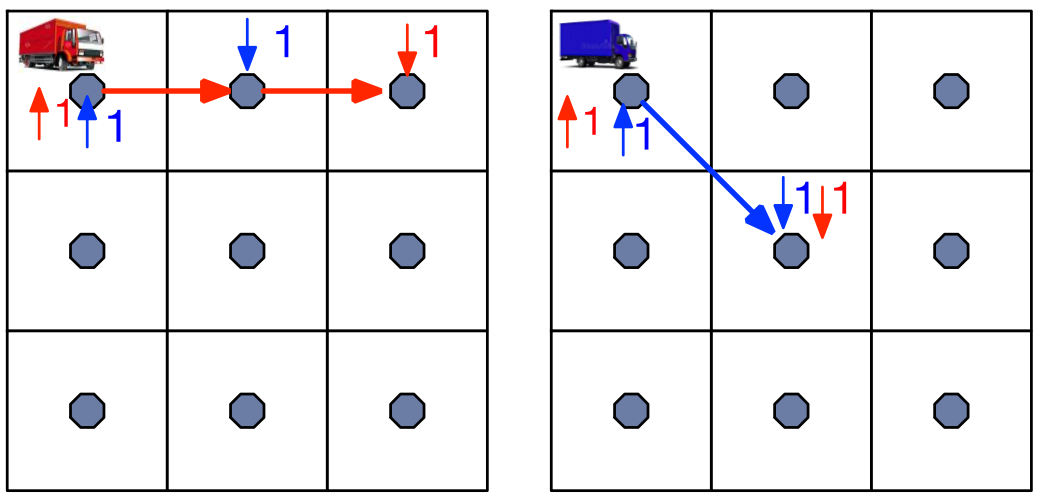
5+3
load.distance



With
reallocation

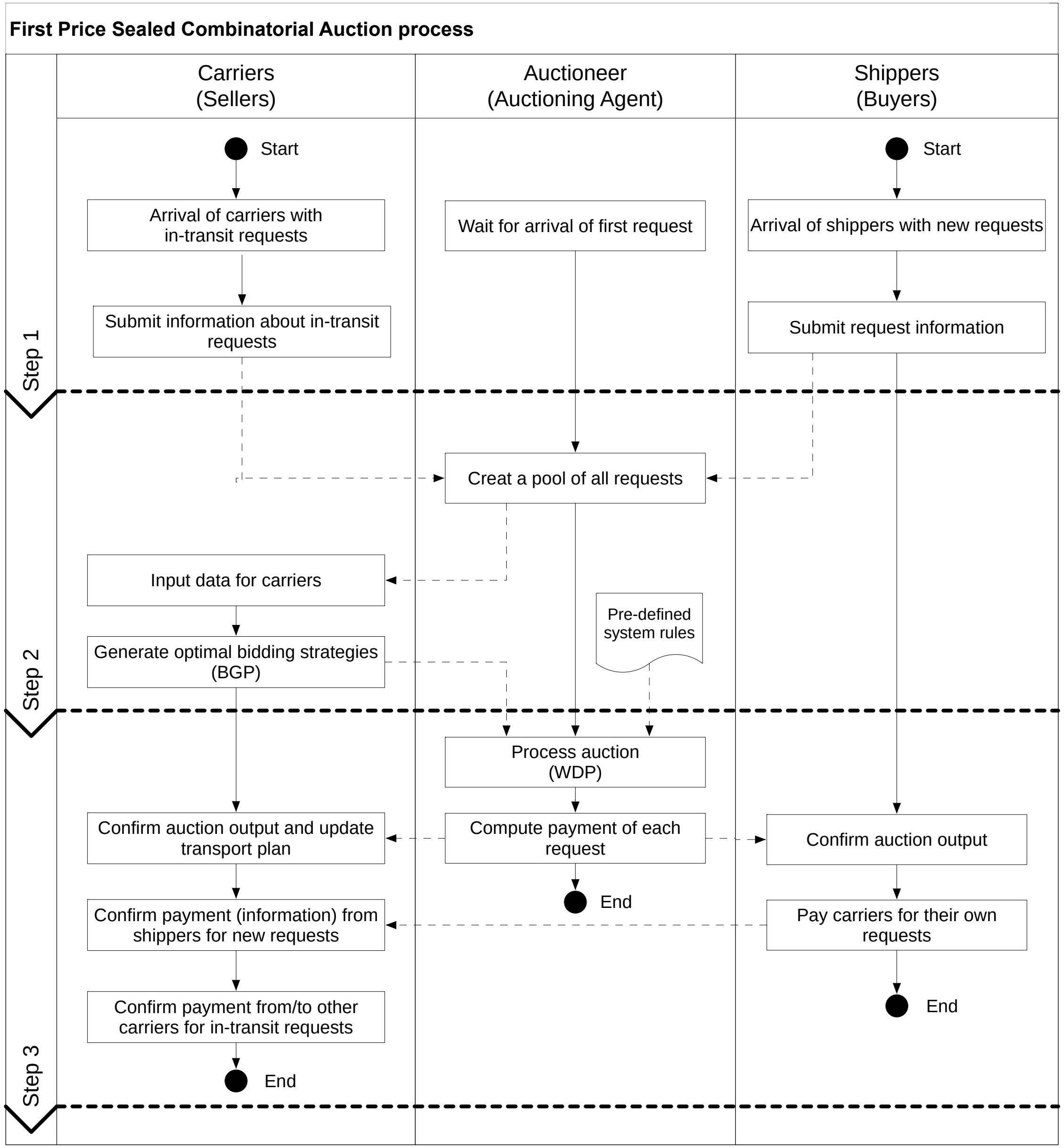
2+1
distance

3+2
load.distance



Mechanism implementation at hub level

A marketplace on top of each hub to enable rerouting when between networks when it makes sense



Methodology

- To test transportation purchasing mechanisms

Simulation of the theoretical framework

Multi-agent simulation to represent the rational behavior of a set of players

How the stake holders will behave?

Gamification to understand how the decision are taken by real players
(Hamari et al., 2014)

Simulation of the theoretical framework

- 3 scenarios

Sc.1 centralized planning

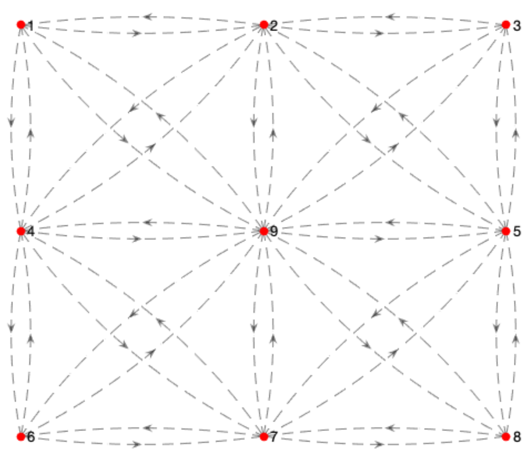
A central entity optimizes all the transportation orders

Sc.2 Interconnected with a coordinator and no information sharing

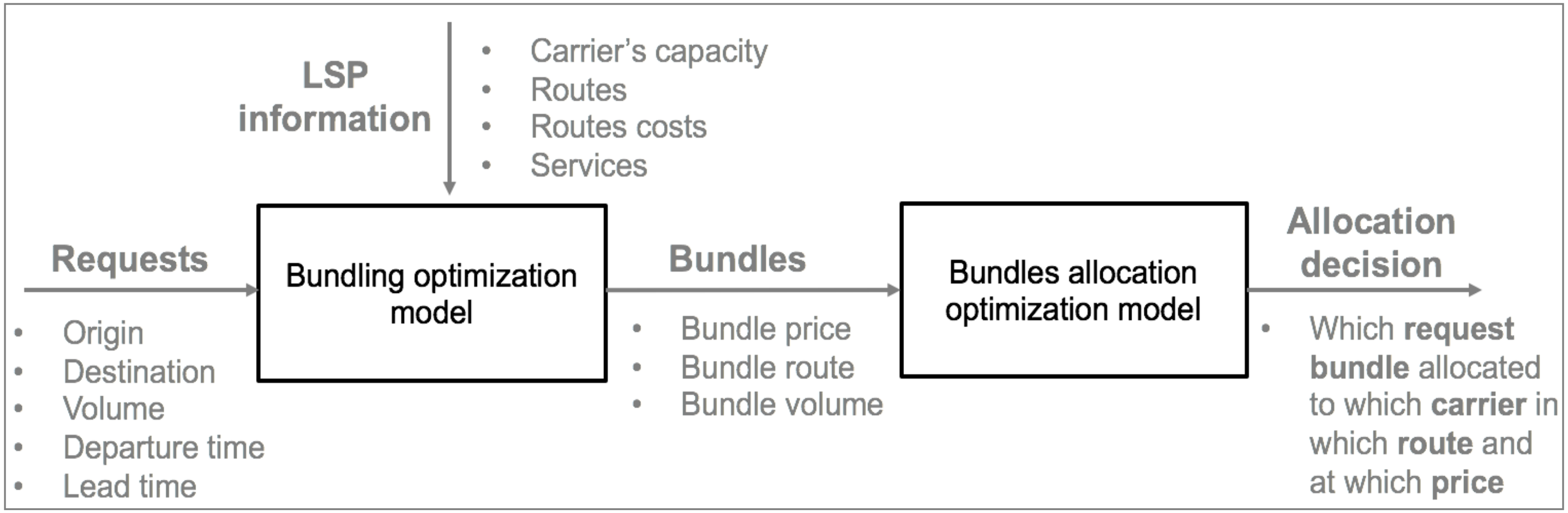
No information is shared between carriers or LSP

Sc.3 Interconnected with a coordinator and limited information sharing

The average price is shared on the market



Model and mathematical formulation



$$\min \sum_{m\in M}\sum_{rt\in Rt_h}\sum_{RB_k\subseteq RB_h;RB_k\subseteq RB_{h,rt}} P^m_{rt,RB_k}\, y^m_{rt,RB_k} \qquad 5.1$$

Minimize the total cost for all bundles

Subject to

$$\sum_{rt\in Rt_h}\sum_{RB_k\subseteq RB_{h,rt}} y^m_{rt,RB_k} \le 1, \qquad \forall\, m \in M, \qquad 5.2$$

Each carrier can have at most one bundle

$$\sum_{m\in M}\sum_{rt\in Rt_h}\sum_{RB_k\subseteq RB_{h,rt};\, r_i\in RB_k} y^m_{rt,RB_k} = 1, \quad \forall\, r_i \in R_h \qquad 5.3$$

All requests are allocated

$$\sum_{m\in M}\sum_{rt\in Rt_h}\sum_{RB_k\subseteq RB_{h,rt};\, r_i\in RB_k} RP^{mt}_{rt,RB_k}\, y^{mt}_{rt,RB_k} \le RC'_{tr_i} \quad \forall\, tr_i \in Rtr_h \qquad 5.4$$

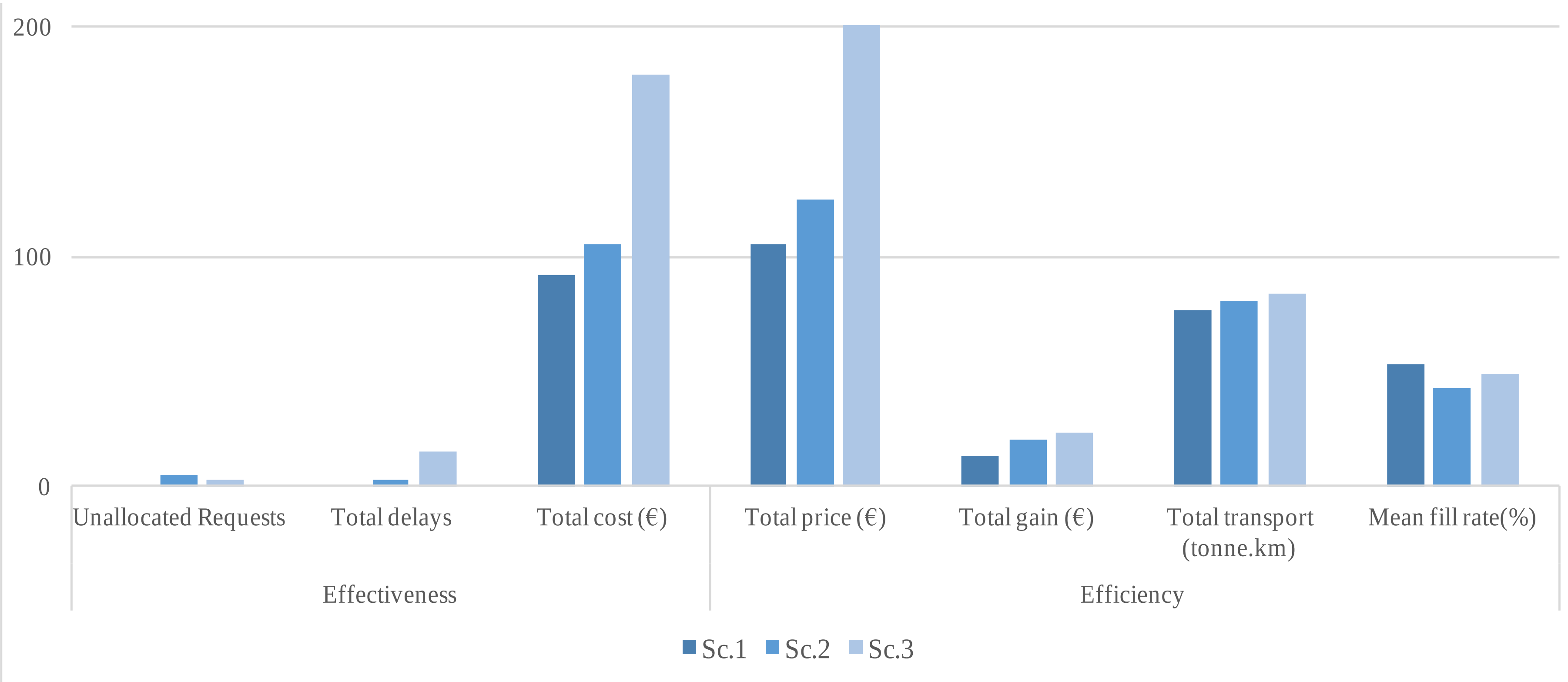
Request Reallocation

$$y^m_{rt,RB_k} \in \{0,1\}, \quad \forall\, h \in N, \forall\, m \in M, \forall\, rt \in Rt_h, \forall\, RB_k \subseteq RB_h \qquad 5.5$$

Binary variables

Results

KPI and Price of Anarchy



	Sc.1	Sc.2	Sc.3
PoA	1	1.14	1.94

Methodology

- To test transportation purchasing mechanisms

Simulation of the theoretical framework

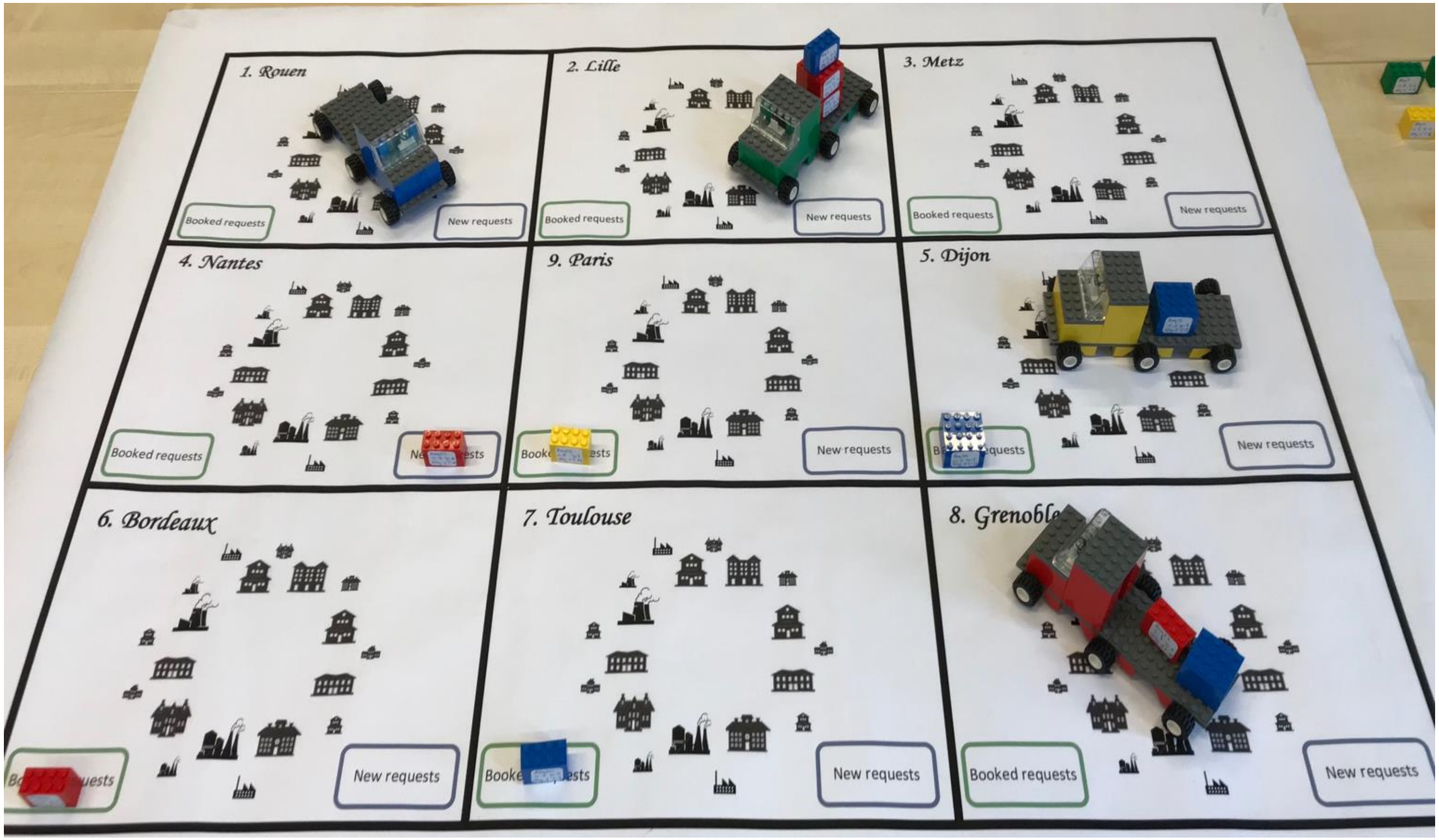
Multi-agent simulation to represent the rational behavior of a set of players

How the stake holders will behave?

Gamification to understand how the decision are taken by real players
(Hamari et al., 2014)

The Freight Transportation Game

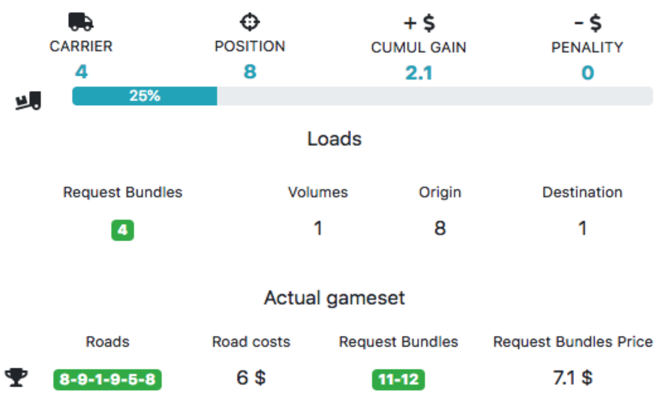
2018 version

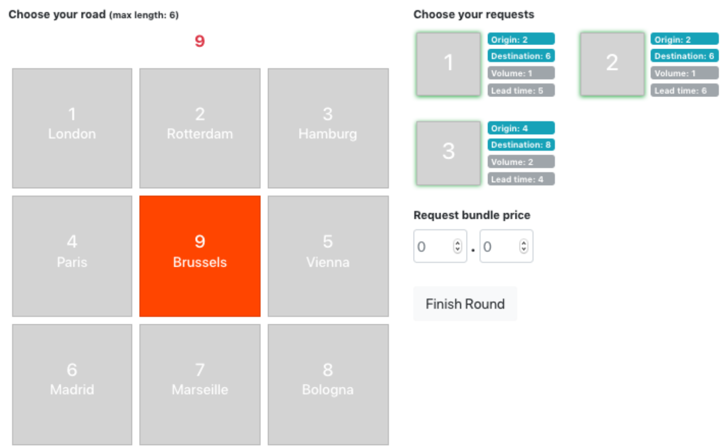


The Freight Transportation Game

- Two main objectives
  - Education: raise awareness by doing
  - Research: understand why interconnection happens or not
- Free to use! (You can apply at: chaire-ip@mines-paristech.fr)

2019 version





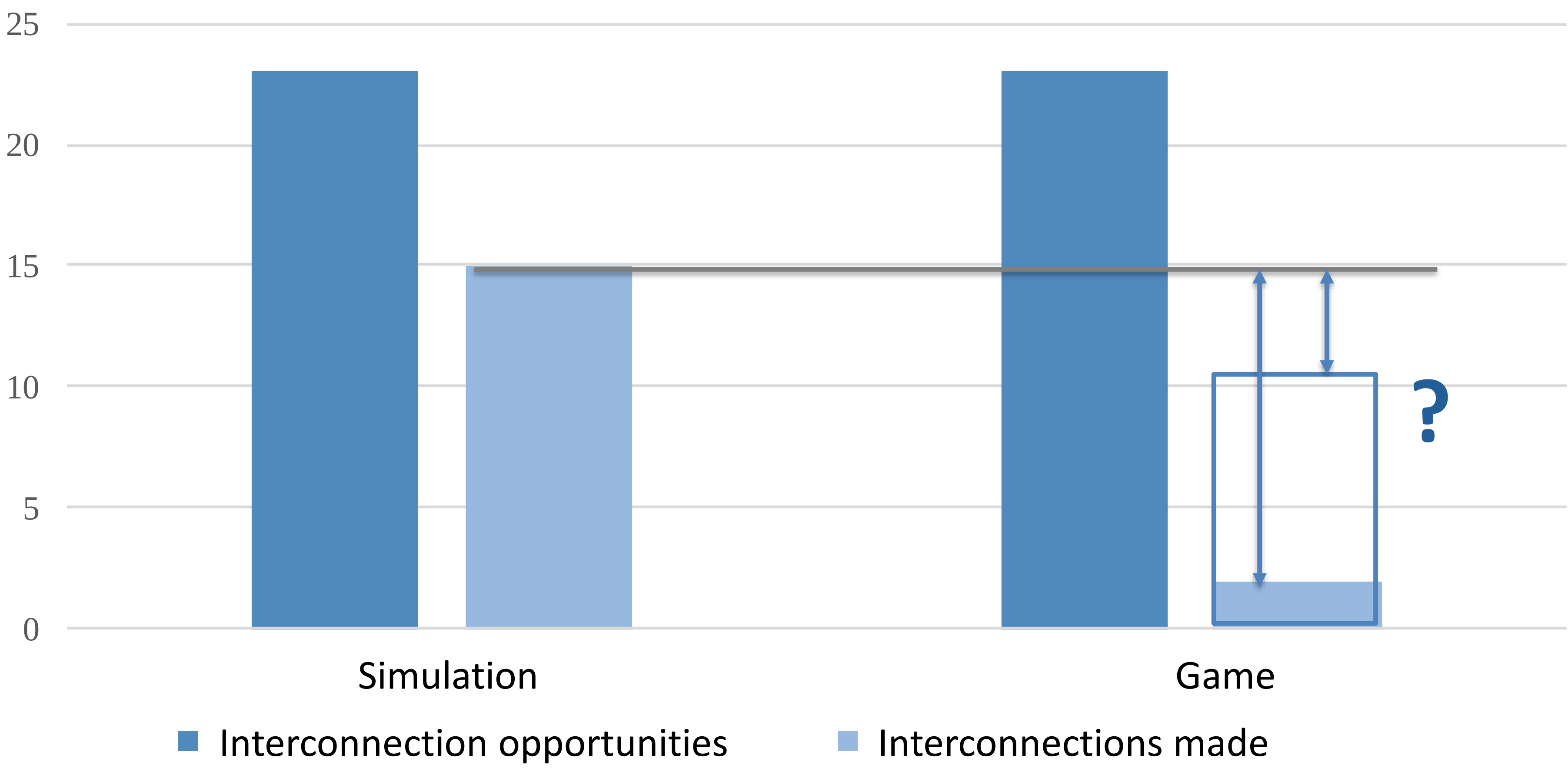
Game results

IPIC PhD Workshop

Results

	Key performance indicators (KPIs)	Game	Centralized solution
Efficiency	Total transport price ($)	122.83	137.36
	Total benefit of carriers ($)	18.57	26.58
	Mean filling rate (%)	50.00	59.00
	Total transport (tonne-km)	58.00	59.00
	Total travelled distance per requests (km)	62.00	72.00
Effectiveness	Number of total delay	2.00	5.00
	Number of unallocated requests	3.00	0.00
Sustainability	Distance of empty runs (%)	16.67	0.00

Is interconnection working?



First results

Players' behaviors

- Same stable strategy by player
- If a player doesn't win quickly he lowers its price until success
- In a market with a high level of competition the interconnection is more difficult to observe
- Interconnection works even with very low margins
- …

Conclusion and perspectives

- A first set of rules to route unit loads between LSP or carrier is proposed
- The efficiency and effectiveness was assessed in a multi-agents simulation framework
- More research is underway to identify decision biases against or in favor of interconnection
- A foundation for a routing protocol between logistics networks