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

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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

50% = 0.62 x 0.80

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 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

<table>
<thead>
<tr>
<th>Rules</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rule 1: En-route improvement</td>
<td>At some hubs in the network, shipments must be reallocated to other carriers proposing a lower price.</td>
</tr>
<tr>
<td>Rule 2: Lowest price and best reputation wins</td>
<td>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.</td>
</tr>
<tr>
<td>Rule 3: No price increase</td>
<td>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.</td>
</tr>
<tr>
<td>Rule 4: Individual responsibility</td>
<td>Each carrier is responsible for any delays they cause and pay the associated penalty.</td>
</tr>
<tr>
<td>Rule 5: No halfway drop-out</td>
<td>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.</td>
</tr>
</tbody>
</table>
Routing improvement illustration

3+2 distance

5+3 load.distance

With reallocation

2+1 distance

3+2 load.distance
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 stakeholders will behave?**

Gamification to understand how the decisions 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

Freight Transportation Game

LSP information
- Carrier’s capacity
- Routes
- Routes costs
- Services

Requests
- Origin
- Destination
- Volume
- Departure time
- Lead time

Bundling optimization model

Bundles
- Bundle price
- Bundle route
- Bundle volume

Bundles allocation optimization model

Allocation decision
- Which request bundle allocated to which carrier in which route and at which price

\[
\min \sum_{m \in M} \sum_{rt \in R_h} \sum_{RB_k \subseteq RB_h; RB_k \subseteq RB_{h,rt}} p^{m}_{rt,RB_k} y^{m}_{rt,RB_k}
\]

Subject to:
1. \[\sum_{rt \in R_h} \sum_{RB_k \subseteq RB_{h,rt}} y^{m}_{rt,RB_k} \leq 1, \quad \forall m \in M,\]

2. \[\sum_{m \in M} \sum_{rt \in R_h} \sum_{RB_k \subseteq RB_{h,rt}; r_i \in RB_k} y^{m}_{rt,RB_k} = 1, \quad \forall r_i \in R_h\]

3. \[\sum_{m \in M} \sum_{rt \in R_h} \sum_{RB_k \subseteq RB_{h,rt}; r_i \in RB_k} R^{mt}_{rt,RB_k} y^{mt}_{rt,RB_k} \leq RC'_{tr_i} \quad \forall r_i \in Rtr_h\]

4. \[y^{m}_{rt,RB_k} \in \{0,1\}, \quad \forall h \in N, \forall m \in M, \forall rt \in R_{ht}, \forall RB_k \subseteq RB_{h}\]

Minimize the total cost for all bundles

Each carrier can have at most one bundle

All requests are allocated

Request Reallocation

Binary variables
Results

KPI and Price of Anarchy

<table>
<thead>
<tr>
<th></th>
<th>Sc.1</th>
<th>Sc.2</th>
<th>Sc.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unallocated Requests</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total delays</td>
<td>50</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>Total cost (€)</td>
<td>100</td>
<td>150</td>
<td>200</td>
</tr>
<tr>
<td>Total price (€)</td>
<td>300</td>
<td>400</td>
<td>500</td>
</tr>
<tr>
<td>Total gain (€)</td>
<td>250</td>
<td>350</td>
<td>450</td>
</tr>
<tr>
<td>Total transport (tonne.km)</td>
<td>75</td>
<td>100</td>
<td>125</td>
</tr>
<tr>
<td>Mean fill rate (%)</td>
<td>80</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>PoA</td>
<td>1</td>
<td>1.14</td>
<td>1.94</td>
</tr>
</tbody>
</table>
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

Choose your road (max length: 3)

Choose your requests

Choose your requests

Freight Transportation Game
# Game results

**Results**

<table>
<thead>
<tr>
<th>Key performance indicators (KPIs)</th>
<th>Game</th>
<th>Centralized solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total transport price ($)</td>
<td>122.83</td>
<td>137.36</td>
</tr>
<tr>
<td>Total benefit of carriers ($)</td>
<td>18.57</td>
<td>26.58</td>
</tr>
<tr>
<td>Mean filling rate (%)</td>
<td>50.00</td>
<td>59.00</td>
</tr>
<tr>
<td>Total transport (tonne-km)</td>
<td>58.00</td>
<td>59.00</td>
</tr>
<tr>
<td>Total travelled distance per requests (km)</td>
<td>62.00</td>
<td>72.00</td>
</tr>
<tr>
<td>Effectiveness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of total delay</td>
<td>2.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Number of unallocated requests</td>
<td>3.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Sustainability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance of empty runs (%)</td>
<td>16.67</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Is interconnection working?

**Simulation**
- Interconnection opportunities: 25
- Interconnections made: 15

**Game**
- Interconnection opportunities: 25
- Interconnections made: 20

Questions mark indicates uncertainty or comparison.
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
- ...

Freight Transportation Game
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