# Decentralized decision power and information sharing in horizontal logistics collaboration

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# Agenda

1. Introduction
2. The network design - multicommodity flow problem
3. Allocation rule
4. Three systems with central authority
5. Fully Decentralized Iterative Cooperative System
6. Computationally results
7. Conclusions

# Introduction

# Horizontal logistics collaboration

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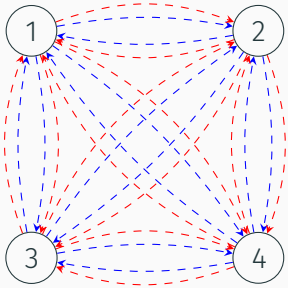
**Edges:**

| | Capacity | Activation cost |
|---|---|---|
| $\forall$ edge | 2 | 5 |




Original network.

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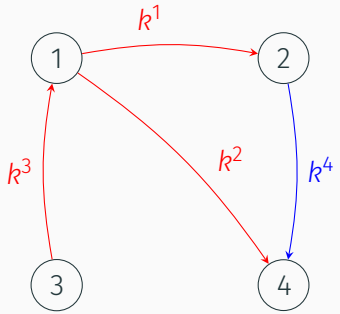


Solution without cooperation.

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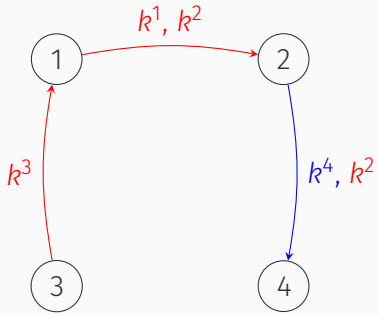


Cooperative solution.

# Allocation rule

# Allocation rule

1. The revenues generated by any served commodity are allocated to its owner.
2. The activation cost of any active edge is paid by its owner.
3. The price of using an unit of capacity on an edge $e \in E$ owned by agent $w(e)$ for any other member of the coalition, $i \in N \setminus \{w(e)\}$, is equal to $\frac{c_e}{q_e}$.

Three systems with central authority

# Three systems with central authority

- A central authority with certain decision power.
- Agents have to share certain amount of information to cooperate.
- 3 systems:
  - Fully centralized cooperation system (FCCS),
  - Partial cooperation system (PCS),
  - Residual cooperation system (RCS).

# Three systems with central authority

## Fully centralized cooperative system (FCCS)

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- A central planning system $\Longrightarrow$ Central authority with full information and all the decision power.
- Commodities and edges of all the agents are aggregated into a single bigger problem.
- Final profit allocation must be individually rational.

# Three systems with central authority

## Partial cooperative system (PCS)

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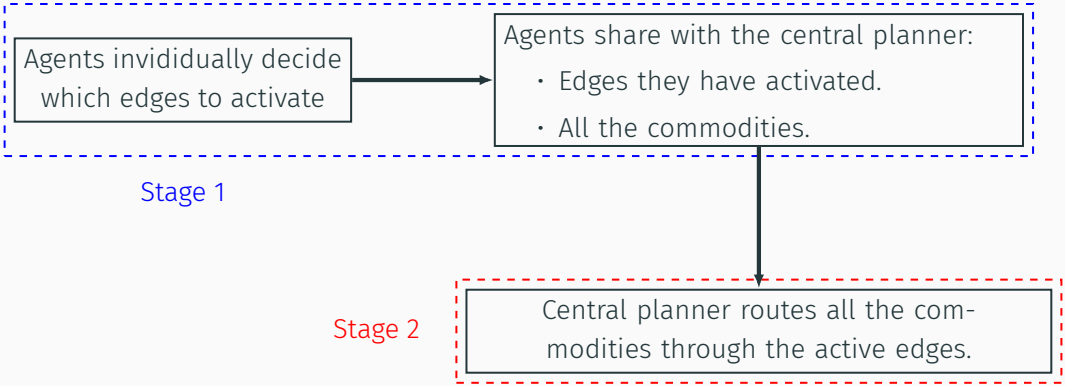

# Three systems with central authority

## Residual cooperation system (RCS)

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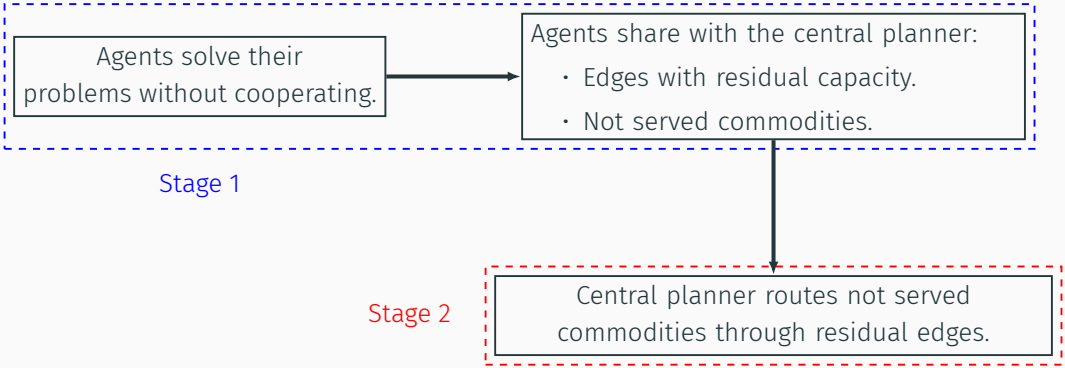


# Fully Decentralized Iterative Cooperative System

# Fully Decentralized Iterative Cooperative System

Some characteristics:

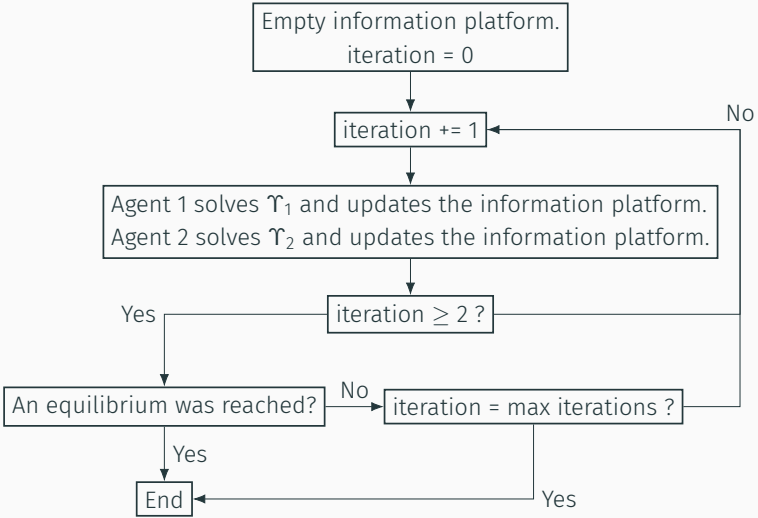
- Developed only for two agents.
- There is NOT a central authority with decision power, but only an information platform.
- Agents exchange information and make decisions in an iterative process.
- In each iteration, agents solve an optimization problem and update the information platform.

# Information platform

An agent can share in the information platform:

1. Which edges he is planning to active leaving residual capacity on them.
2. Which edges previously shared by the other agent he would like to use, indicating:
   - The capacity he would like to use in each edge.
   - Which “combinations” of that edges he requires for each commodity, as well as the size of that commodity.

# Fully Decentralized Iterative Cooperative System

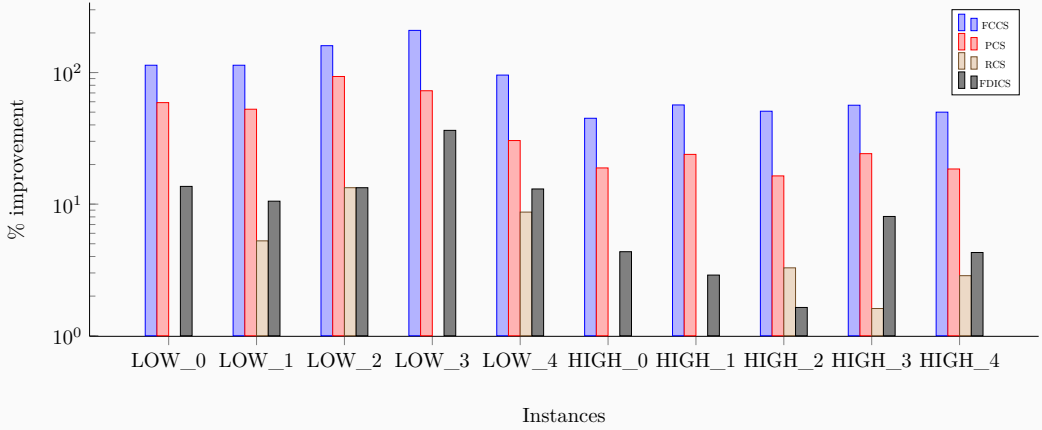


# Computationally results

# Instances

- 10 instances with 2 agents and 10 with 5 agents.
- All the parameters selected from uniform distributions.
- Instances with edges with LOW or HIGH capacity.

# Results: Instances with 2 agents



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- In terms of solution quality: FCCS > PCS > FDICS > RCS.
- Relevance of amount of information shared and decision power allocation.
- Extension of FDICS to more agents might be interesting.

Thank you for the attention.

# Extra slides

Extra slides.

# Example

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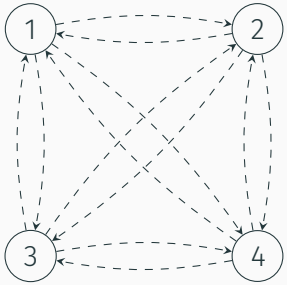


Original network.

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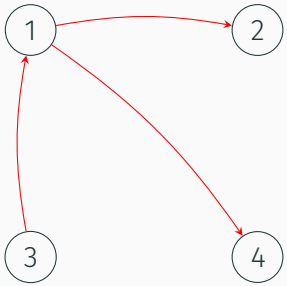


Design of the network.

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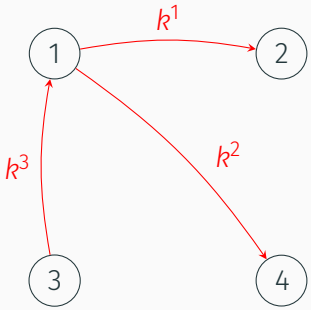



Route the commodities.

# Differences

Allocation of the decision power.

| | | Coop. systems with central authority | | |
|---|---|---|---|---|
| | | FCCS | PCS | RCS |
| Agents | Activate edges | No | Yes | Yes |
| | Route flow | No | No | Yes |
| Central Authority | Activate edges | Yes | No | No |
| | Route flow | Yes | Yes | Yes* |

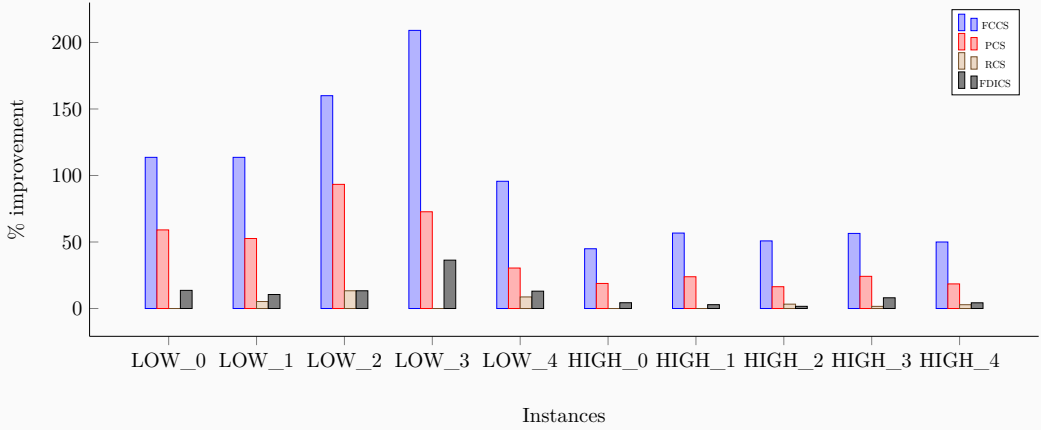
* Only the residual commodities through the residual capacities of the active edges.

# Differences

## Information to be shared by the agent with the central authority

| | | Coop. systems with central authority | | |
|---|---|---|---|---|
| | | FCCS | PCS | RCS |
| Commodities | $o(k), t(k)$ | $\forall\, k \in \Theta$ | $\forall\, k \in \Theta$ | $\forall\, k \in \Theta_R$ |
| | $w(k)$ | " | " | " |
| | $d_k$ | " | " | " |
| | $r_k$ | " | " | " |
| Edges | $o(e), t(e)$ | $\forall\, e \in E$ | $\forall\, e \in E_A$ | $\forall\, e \in E_R$ |
| | $w(e)$ | " | " | " |
| | $c_e$ | " | " | — |
| | $q_e$ | " | " | — |
| | $\frac{c_e}{q_e}$ | " | " | $\forall\, e \in E_R$ |
| | $q_e^R$ | — | — | " |

# Results


FCCS
PCS
RCS
FDICS
% improvement
200
150
100
50
0
LOW_0
LOW_1
LOW_2
LOW_3
LOW_4
HIGH_0
HIGH_1
HIGH_2
HIGH_3
HIGH_4
Instances

# Results: Analysis of order relevance in FDICS

| | Total payoffs | | % Dif. | Nº iterations | | Dif. |
|---|---|---|---|---|---|---|
| | Order:1-2 | Order:2-1 | | Order:1-2 | Order:2-1 | |
| 2_low_0 | 25.0 | 25.0 | 0.00 | 4.0 | 3.0 | 1.0 |
| 2_low_1 | 21.0 | 21.0 | 0.00 | 3.0 | 3.0 | 0.0 |
| 2_low_2 | 17.0 | 17.0 | 0.00 | 3.0 | 3.0 | 0.0 |
| 2_low_3 | 15.0 | 15.0 | 0.00 | 4.0 | 4.0 | 0.0 |
| 2_low_4 | 27.0 | 26.0 | 3.70 | 3.0 | 3.0 | 0.0 |
| 2_high_0 | 73.0 | 72.0 | 1.37 | 3.0 | 3.0 | 0.0 |
| 2_high_1 | 70.0 | 69.0 | 1.49 | 3.0 | 3.0 | 0.0 |
| 2_high_2 | 65.0 | 63.0 | 3.08 | 3.0 | 3.0 | 0.0 |
| 2_high_3 | 68.0 | 67.0 | 1.47 | 4.0 | 4.0 | 0.0 |
| 2_high_4 | 74.0 | 73.0 | 1.35 | 3.0 | 3.0 | 0.0 |