Approches multiagents pour l'allocation de courses à une flotte de taxis autonomes

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Outline

- Context
- Problem modeling
- Multiagent solution modeling
- Evaluation
- Conclusion

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Context

New Service by Autonomous Vehicles

- **Light Autonomous Vehicle**
  - Big site internal service
  - Last miles shuttle
  - Suburban service
  - Interstice shuttle

- **Heavy Autonomous Vehicle**
  - Automatization of existing bus lines
  - Automatization of public transportation lines

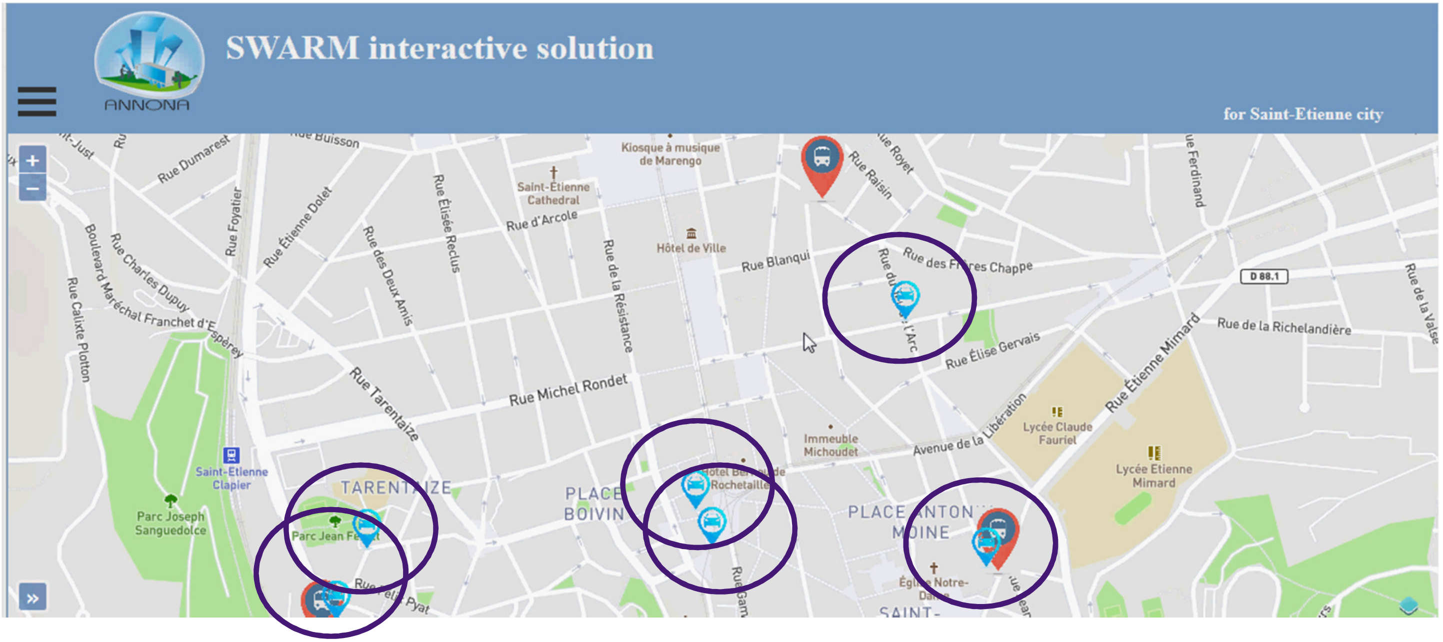
Source: Rapport « ETUDE DES IMPACTS DE LA VOITURE AUTONOME SUR LE DESIGN DU GRAND PARIS »

Context

Fleet of Autonomous, Connected Taxis

Taxis handling the travel requests

- take autonomous decisions
- communicate through inter-vehicular network (VANET) or portal



Compare allocation strategies to satisfy 90% of travel requests in a context of VANET communication and decentralized allocation process

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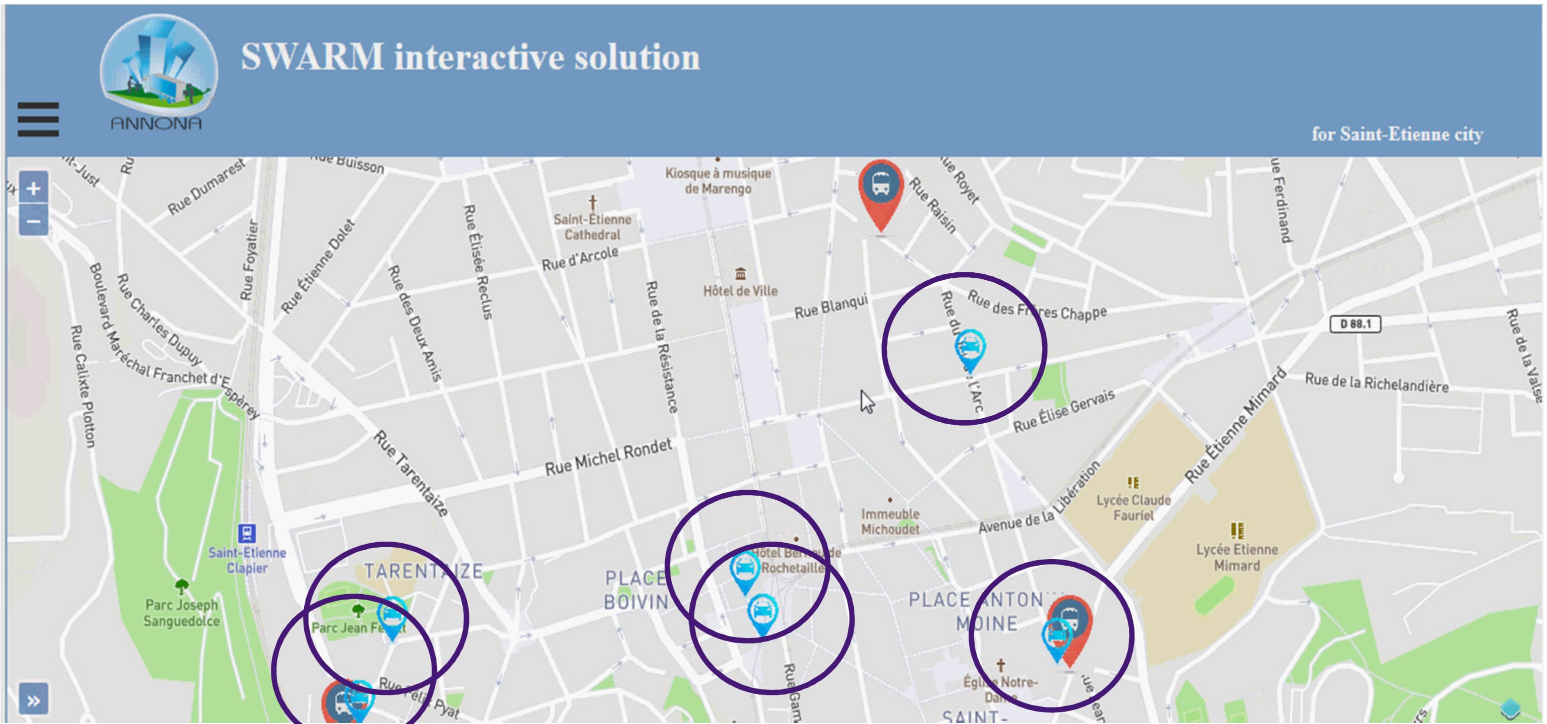
Context

Assessment Criteria

- **Quality**
  - Quality of Service
  - Average waiting time
  - Gain
- **Scalability**
  - Number of messages
  - Processing time



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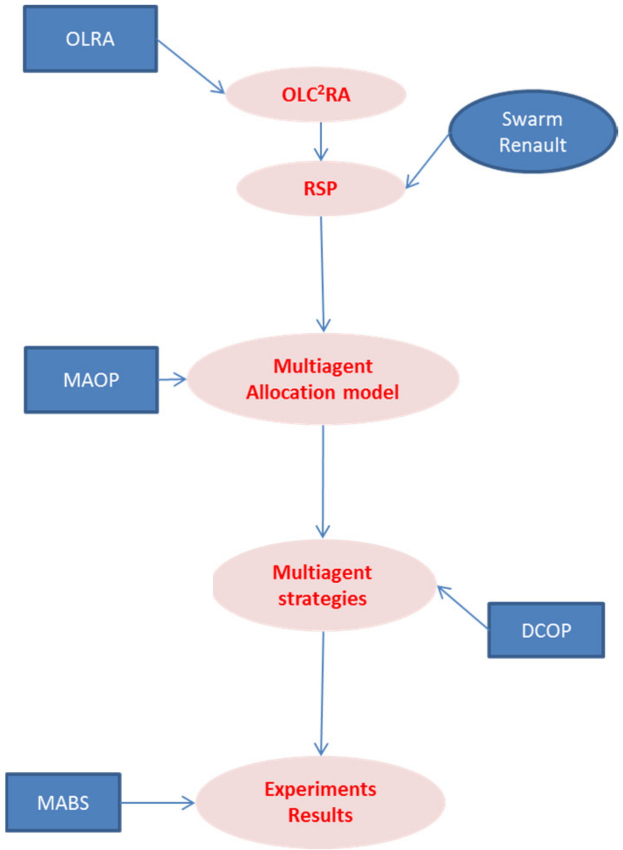
Context

Global approach overview

- **Theoretical background**
  - **OLRA** (Online Localized Resource Allocation)
  - **MAOP** (MultiAgent Oriented Programming)
  - **DCOP** (Distributed Constraint Optimization Problem)
  - **Self Organization Models**
  - **MABS** (MultiAgent Based Simulation)
- **Results**
  - *Models*
    - **OLC²RA**: OLRA extension for communication constraints
    - **RSP** (Renault Swarm Problem): OLC²RA specialization
    - **Multiagent Allocation Model**
    - **Multiagent strategies**: modeling multiagent decision process
  - *Simulation platform*
    - Adaptation to the Swarm project constraints
  - *Experiments & Analyze*



Centralized Coordination
vs
Optimal distributed protocol

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Problem modeling

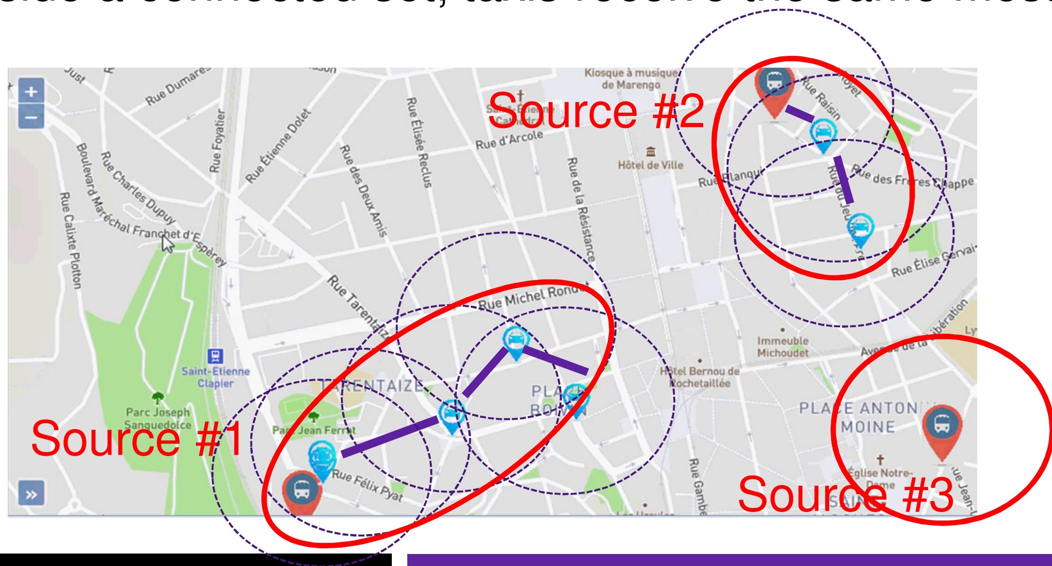
Problem components

- **Transportation network**
  - Graph of nodes and edges
  - Edge with several locations
  - Predefined set of source and destination nodes of travelers
- **Traveler request**
  - Spatial parameters: origin, destination
  - Temporal parameters: time window of validity
- **Taxi**
  - Spatial parameters: location, destination
  - Communication parameter: fixed communication range

Problem modeling

Communication

- **The communication range is similar for taxis and sources**
- **Connection relation definition**
  - Distance between two taxis is inferior to the communication range
- **Creation of sets of connected components thanks to the transitivity property of the connection relation.**
  - *Composition*: connected taxis and sources
  - *Property*: Inside a connected set, taxis receive the same messages



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Problem modeling

Problem definition

- **Taxi Allocation Problem (TSAP):** online allocation of active requests to riding or not taxis for a specified communication infrastructure minimizing costs and maximizing quality of services for a period of time

- **TSAP(t)**: allocation of active requests at time *t*
  - *With a linear programming formalism:*

$$\min_{v_{ij}^t} \quad \sum_{v_{ij}^t} c_{ij}^t . v_{ij}^t$$

$$\textbf{\textit{avec}}$$

$$\forall i \in \mathcal{A} \quad \sum_{j \in \mathcal{R} \cup \{\emptyset\}} v_{ij}^t = 1$$

$$\forall j \in \mathcal{R} \quad \sum_{i \in \mathcal{A}} v_{ij}^t \leq 1$$

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Multiagent solution modeling

Agent Behavior

- **Generic simulated taxi agent behavior**
  1. Reads messages
  2. Updates believes about requests and taxis
  3. Decides next destination
  4. Drives to one step to the destination
  5. Sends messages about requests and taxis

- **Decision process**
  - Filters Request (delete not satisfiable requests)
  - Computes request assessment
  - Chooses the *best*

Multiagent solution modeling

Agent Behavior

- **Similar cooperative request ranking criteria**
  - *The ratio of taxis which are further of the source:* a taxi chooses the requests which penalize other taxis if it is not chosen by him.

$$\kappa^{\mathbf{coop}}_{\mathbf{dist}}(v_i, r_j, t) = \frac{1}{closerFree(v_i, r_j, t) + closerRiding(v_i, r_j, t) + 1}$$

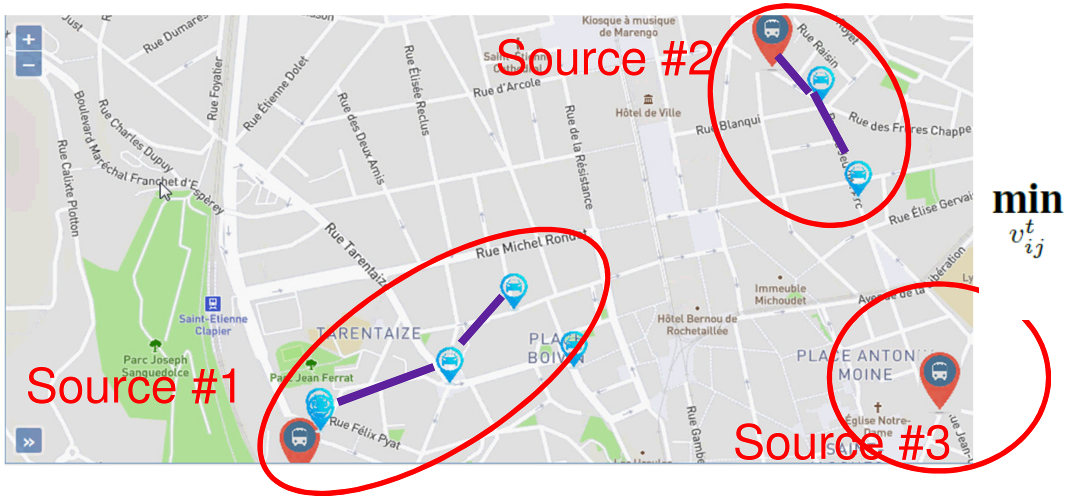
  - *the ratio of travelers who are waiting less than the traveler of the request r:* a taxi chooses the request which is the more penalized if it is not chosen by him.

$$\kappa^{\mathbf{coop}}_{\mathbf{time}}(v_i, r_j, t) = \frac{free(v_i, t)}{\sum_{r_k \in KR(v_i,t)} worst(pos(v_i, t), r_k, r_j, t) + 1} - \frac{(1 - free(v_i, t))}{\sum_{r_k \in KR(v_i,t)} worst(pos(dest(r_j), t), r_k, r_j, t) + 1}$$

Multiagent solution modeling

Proposed allocation process solution

- ***d-alloc*** **solution description**
  - Each taxi decides on its requests
  - Coordination is done connected set by connected set with a DCOP approach
  - Allocation is challenged at each time step



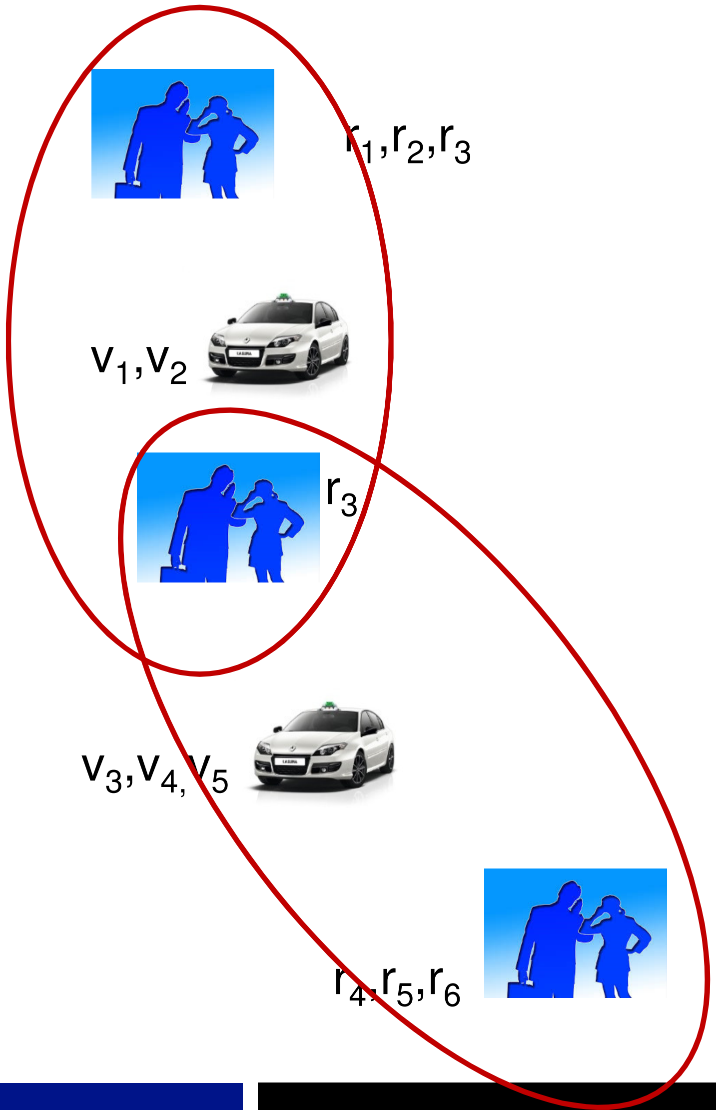
- **DCOP resolution**
  - Objective

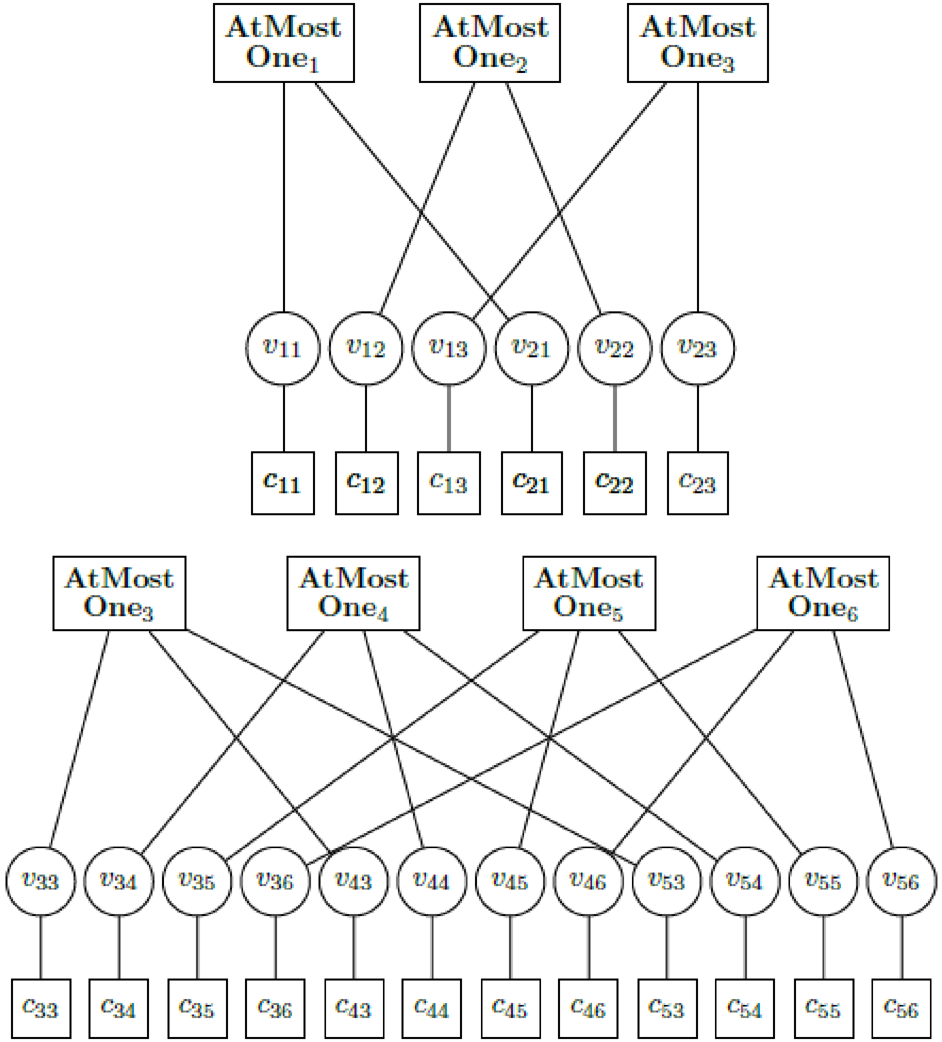
$$\min_{v_{ij}^t} \sum_{v_{ij}^t} c_{ij}^t(v_{ij}^t) + \sum_{\substack{C\in CSet_{\mathcal{A}}(t)\\ r_j \in KR(C,t)}} \mathrm{AMO}_j^t(v_{1j}^t,\ldots,v_{|C|j})$$

  - Protocol: Max-Sum

Multiagent solution modeling

Proposed allocation process solution





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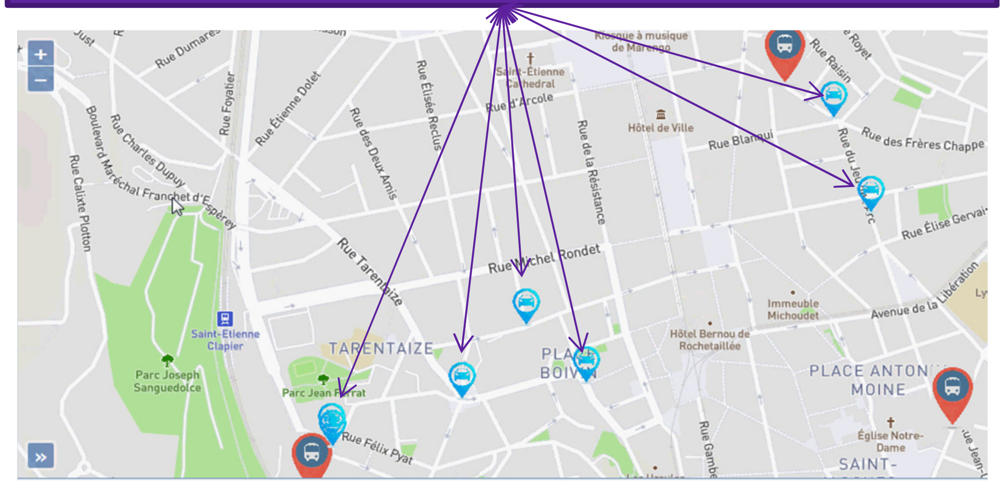
Multiagent solution modeling

Comparative allocation process solution

- ***p-alloc*** **Solution description**
  - A portal contains all active requests
  - Taxis pick their chosen request at portal
  - Allocation is never challenged

Shared information system



Bidirectional communication

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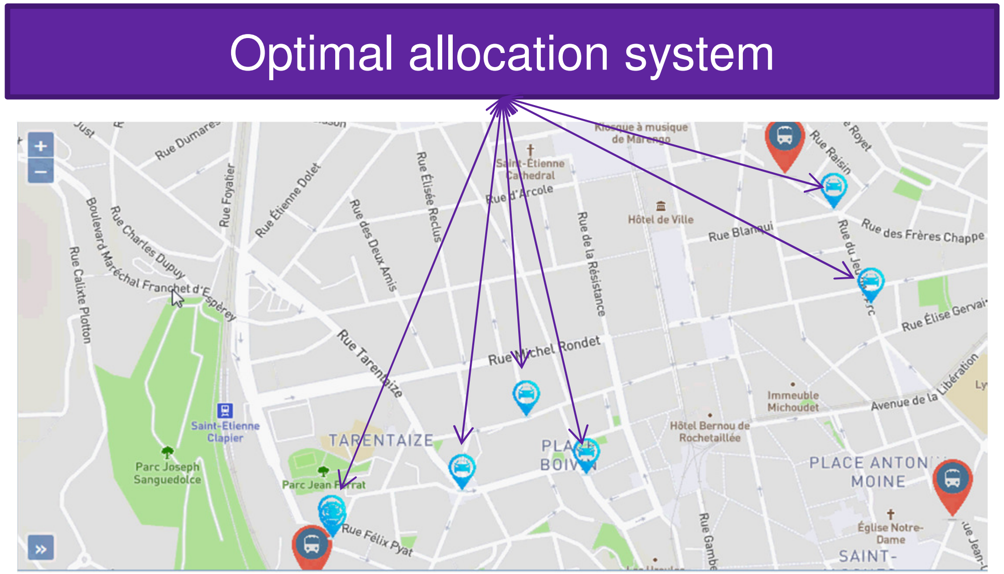
Multiagent solution modeling
Comparative allocation process solution

- ***c-alloc*** **Solution description**
  - A global infrastructure of communication supports the collection of taxi locations and allocation decisions.
  - A central dispatcher allocates optimally requests to taxis
  - Allocation is challenged at each time step



Bidirectional communication

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Results

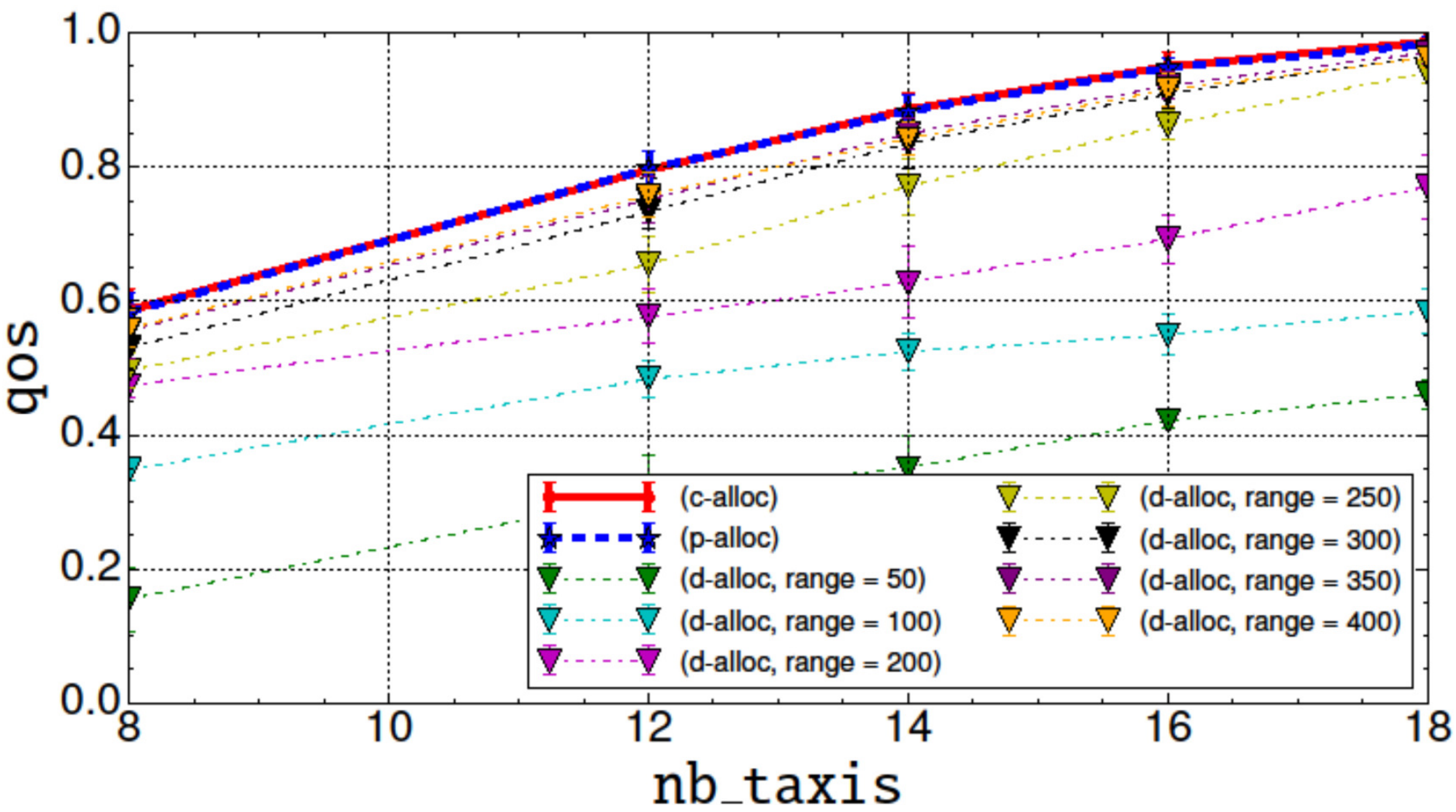
Experimental Conditions

Experiments

- 13 combinations
  - Taxi Decision process
  - Request information infrastructure: VANET, Portal
  - Allocation location
- Topology
  - City: Saint Etienne
  - Distance between sources: {1.6, 3, 4} km
- Taxi:
  - Number: between 8 and 20
  - Simulated speed: 30 km/h
  - Communication range between 0,25% and 16% of the total surface area(similar to the sources)
- Simulation
  - One simulation cycle equivalent to 5 seconds
  - duration: 3,5h (2500 cycles), 4h (3000 cycles) or 8h (6000 cycles)
- Request
  - [0; 2] requests by cycle
  - Request scenario
    - *Uniform*: uniform random choices of the origin and destination requests
    - *Concentrate*:
      - S1 is the origin of 50% of the requests
      - every 100 cycles creation of [1, 6] requests at source S1
    - *Decoupled:* S1 cannot be the origin of a request
- Energy
  - Autonomy: 100 Km (2325 cycles), 215 Km (5000 cycles)
  - Recharge duration: 30 min (360 cycles)

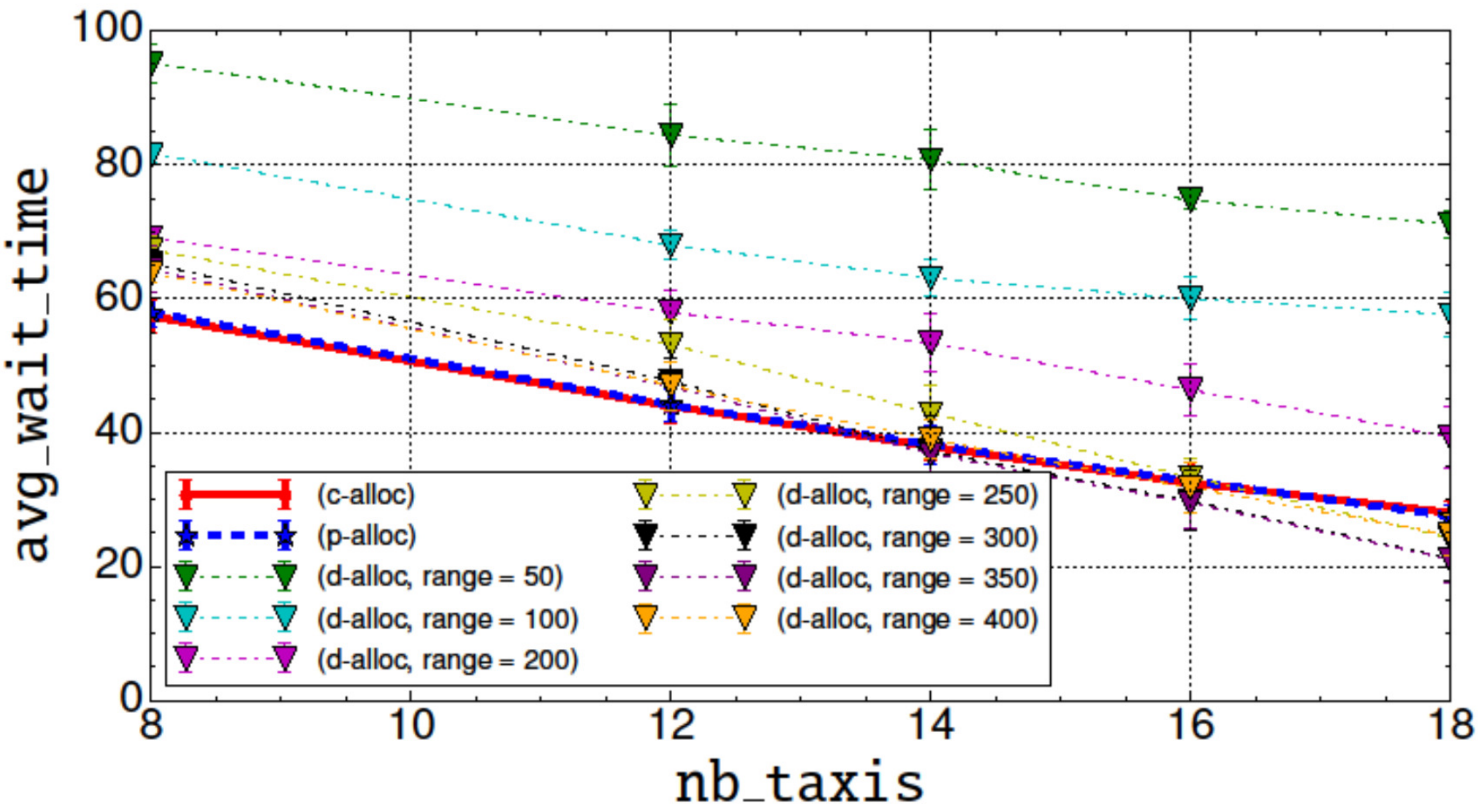
Evaluation

Quality



Evaluation

Quality



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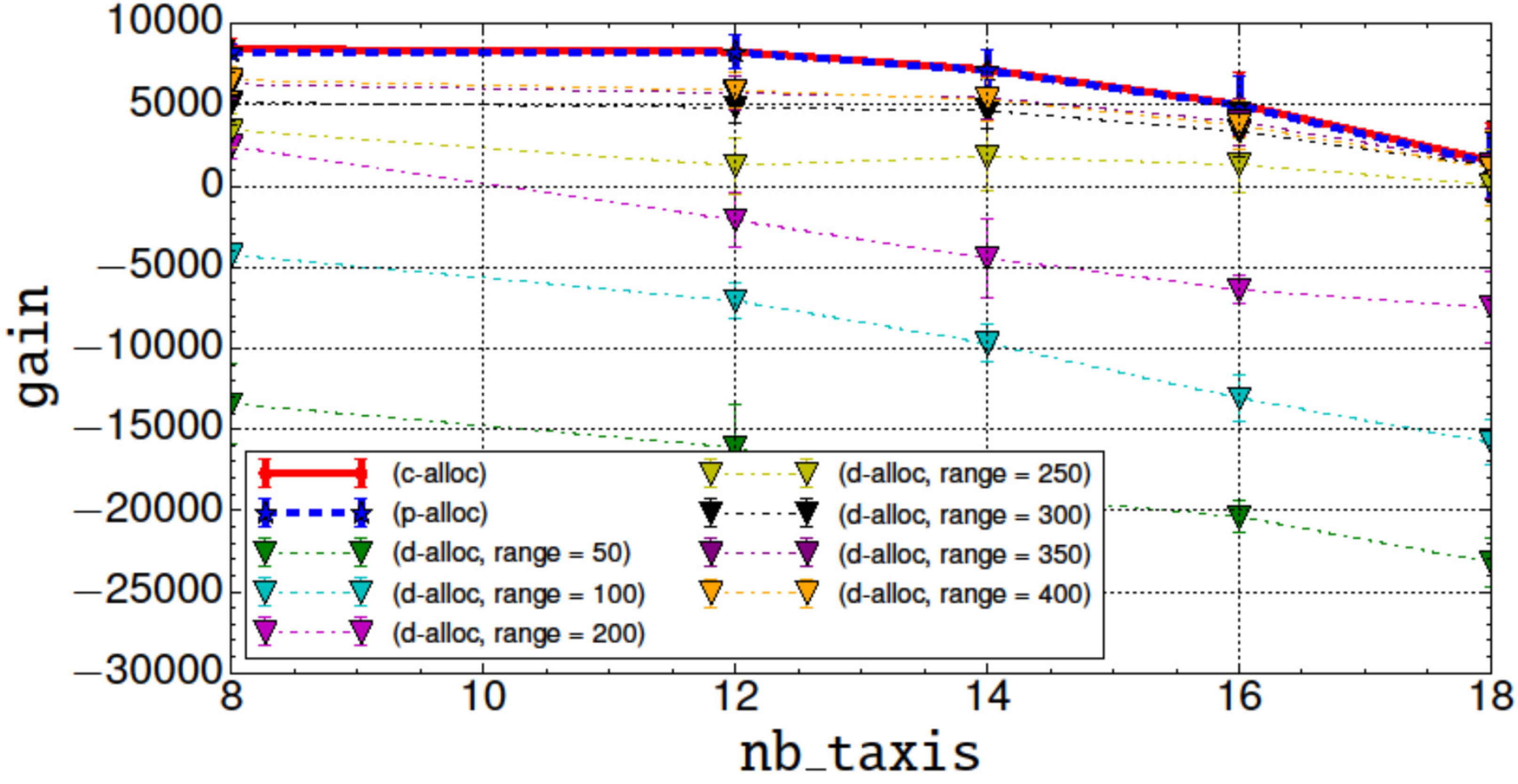
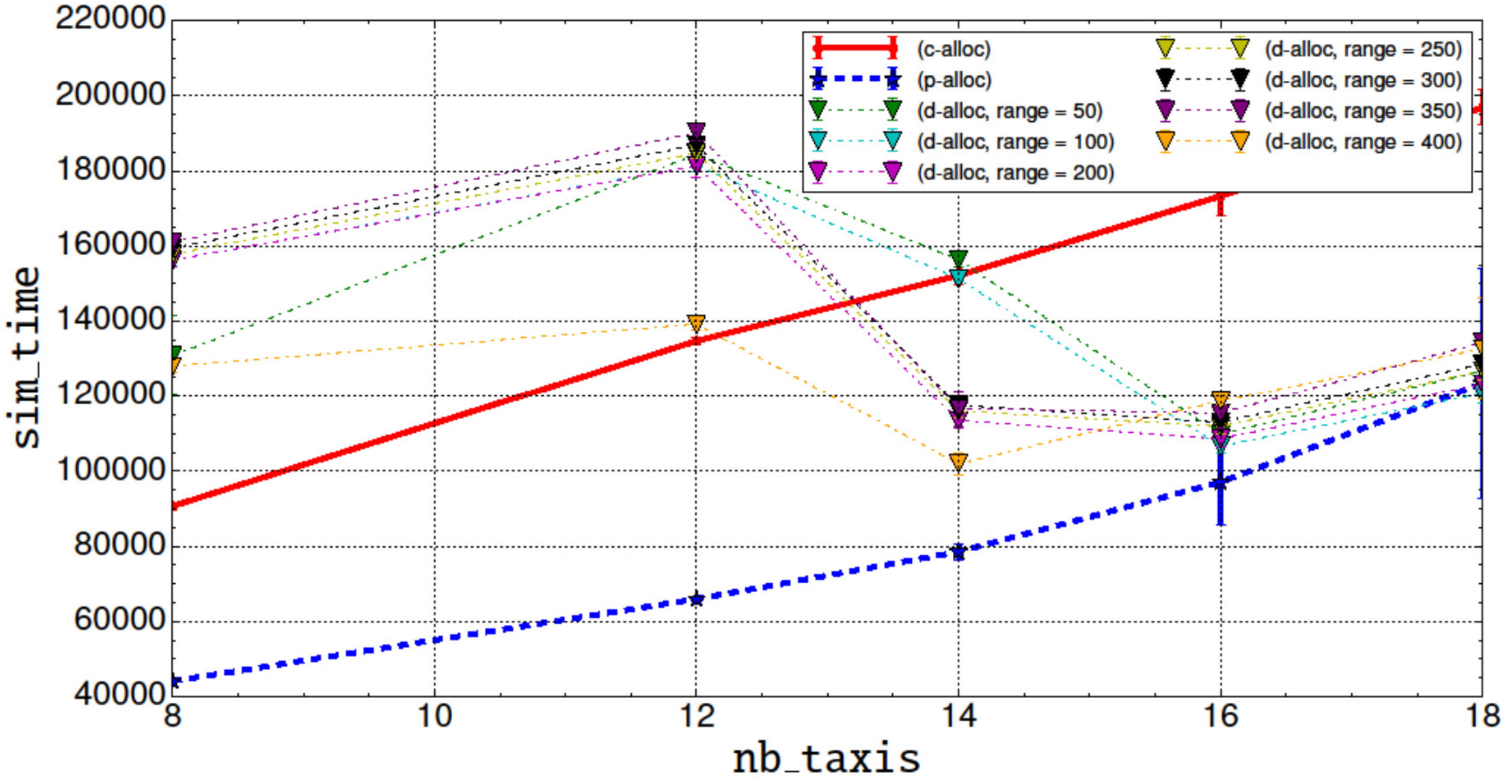
Evaluation

Quality



Evaluation

Scalability



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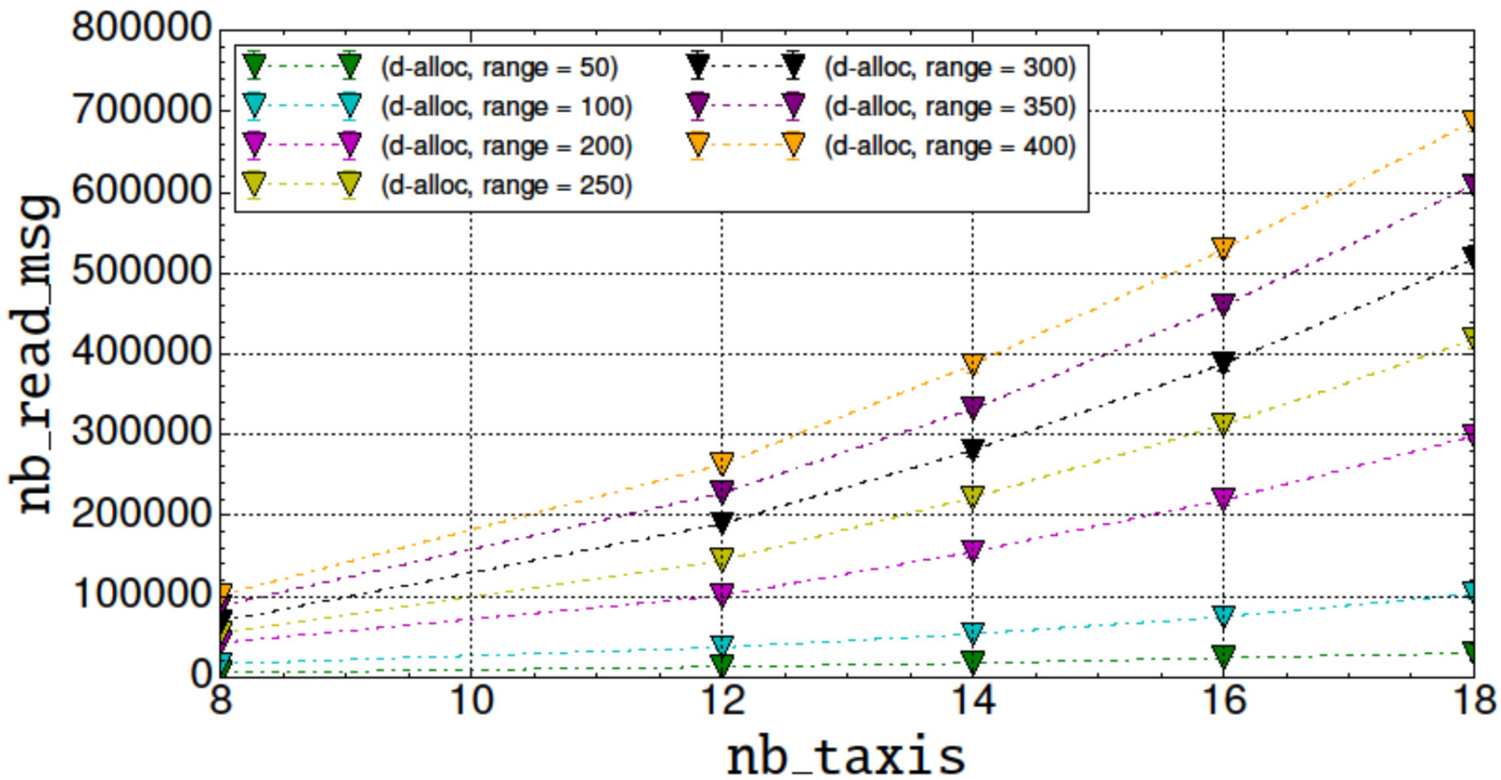
Evaluation

Scalability



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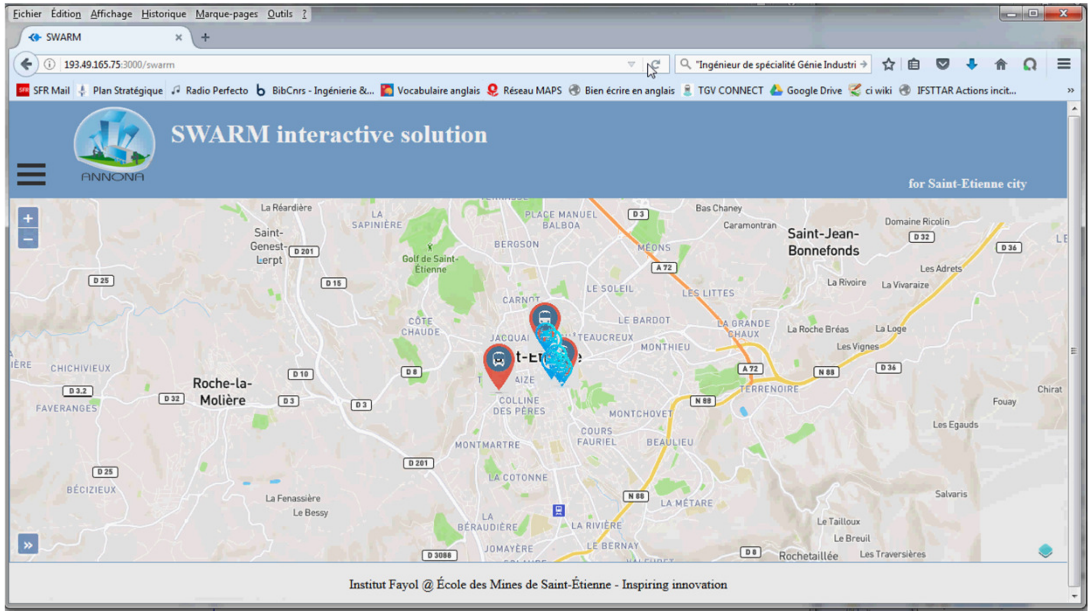

- **Three allocation strategies were compared**
- **Quality results of the DCOP proposal are quite similar for *QoS* measure and better for *average waiting time* measure**
- **Centralized solutions are penalized with several taxis for Scalability measure**

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