Transport Intelligent, usage du paradigme multiagent

Le cas Renault de gestion de flotte de taxis autonomes.

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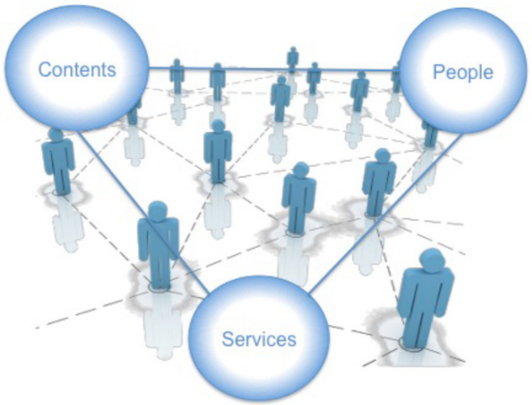
Présentation

- **Connected Intelligence**
  - https://connected-intelligence.univ-st-etienne.fr
- **Objectifs**
  - Définition de modèles, algorithmes et architectures logicielles pour l'interconnexion des contenus, services et objets, personnes



- **Défis**
  - Coopération, Décentralisation, Ouverture, Passage à l'échelle
  - Evolution, Agilité, Robustesse
  - Interopérabilité des contenus, services, objets et machines

Présentation

- **Représentation des connaissances & raisonnement**
  - Comment traiter, représenter et raisonner sur des connaissances dans des environnements ouverts et distribués ?
- **Multiagent & services**
  - Comment coordonner et adapter des systèmes autonomes déployés à large échelle dans des environnements ouverts, décentralisés et dynamiques ?
- **Questions transverses**
  - Confiance, Privacy, Ethique

Intelligent Transport Systems?

"Intelligent Transport Systems" (ITS) are systems to support transportation of goods and humans with information and communication technologies in order to efficiently and safely use the transport infrastructure and transport means (cars, trains, planes, ships).

(ETSI EG 202 798)

Cooperative Intelligent Transport Systems (C-ITS) allow road users and traffic managers to share information and use it to coordinate their actions. C-ITS are based on technologies which allow vehicles to "talk" to each other, and to the transport infrastructure. In addition to what drivers can immediately see around them, and what vehicle sensors can detect, all parts of the transport system are thus able to share information

Definition

- **Transportation System**
  - Transportation network
  - Transportation assets
  - Travelers

- **ICT components**
  - Sensors
  - Communication network
  - Computer sciences
  (hardware, software)

- **Objectives**

Improving existing functionalities

Supporting new functionalities

Multiagent approach

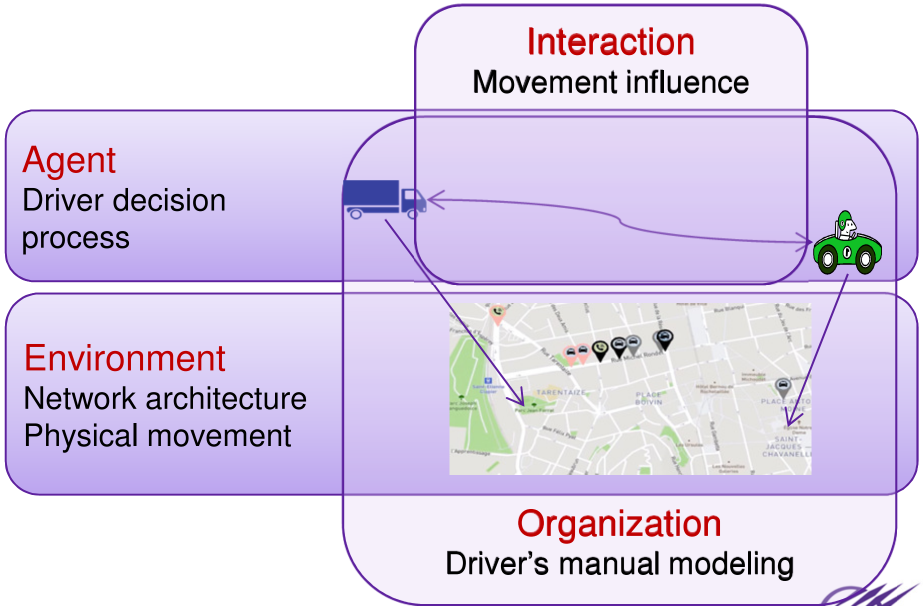
bottom-up approach for problem resolutions

- **Principle**

  The modeler defines behavior at individual level, and the global behavior emerges as a result of many (tens, hundreds, thousands, millions) individuals, each following its own behavior rules, living together in some environment and communicating with each other and with the environment.

Real System: a transportation network

Modeling



Multiagent approach advantages

- **Adapted to the domain**
  - Analogy easy to understand by experts, scalable
- **Model the environment complexity**
  - incertitude, openness, heterogeneity, continuous time, dynamic, ...
- **High level concepts**
  - privacy, trust, communication acts, ...
- **Simplify multi-level, multi-scale modeling**
  - An adaptable model granularity
- **Algorithms and models that integrate distributivity and mobility**

Past projects

- **Parking spots management**
  - Dynamic resource allocation
- **Bimodal traffic regulation**
  - Negotiation protocol
- **Traveler information**
  - Information sharing
- **Autonomous Taxi fleet**
  - Dynamic resource allocation with communication constraint

C-ITS: Dial a ride with a fleet of autonomous taxis

Renault use case

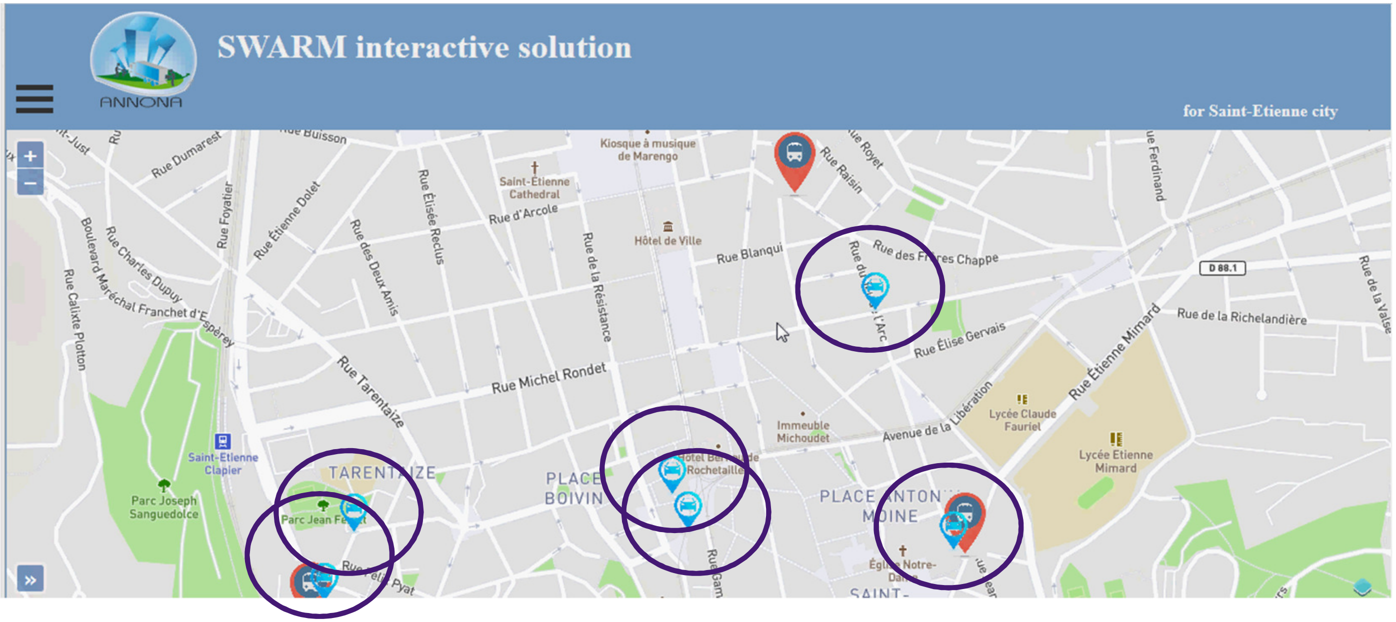
F. Balbo, O. Boissier, G. Picard

Context

Fleet of Autonomous, Connected Taxis

Taxis handling the travel requests

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

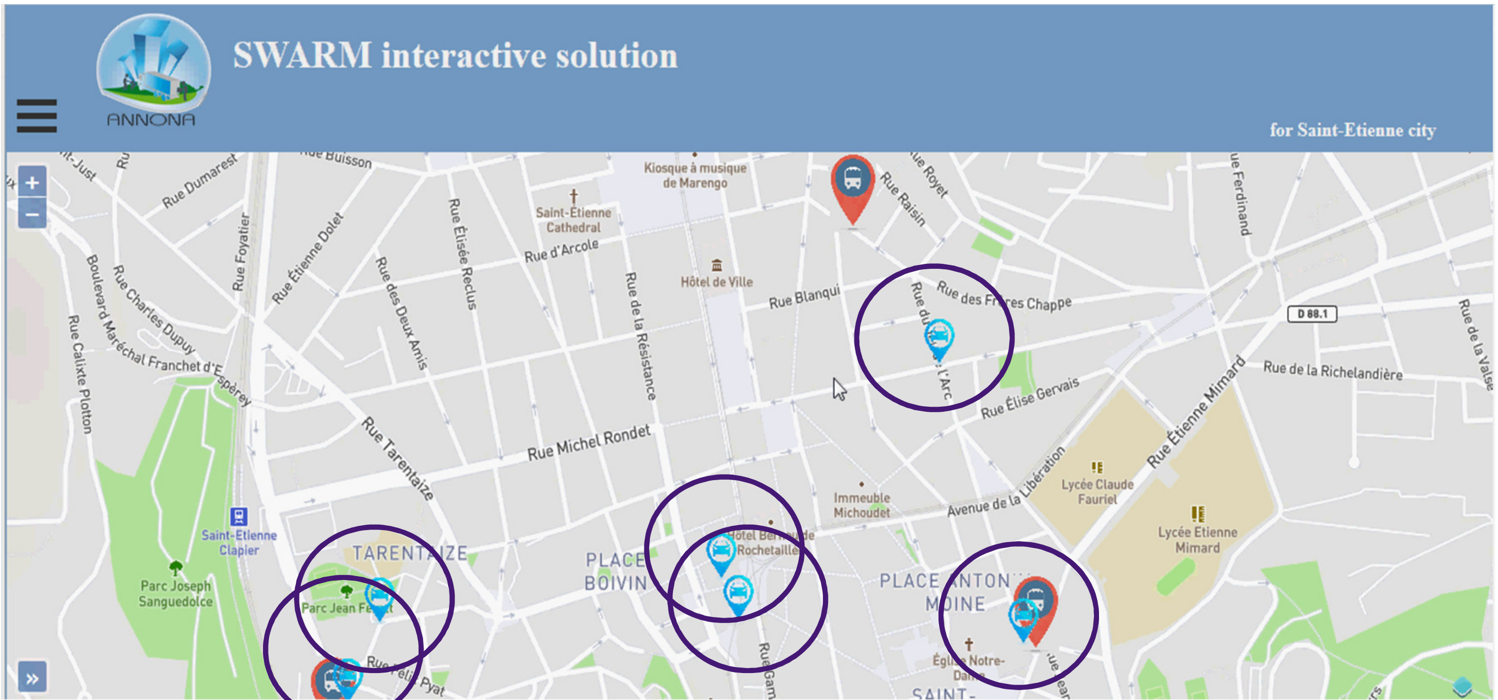


Compare allocation strategies to satisfy 90% of travel requests in a context of VANET communication and decentralized allocation process

Context

Assessment Criteria

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



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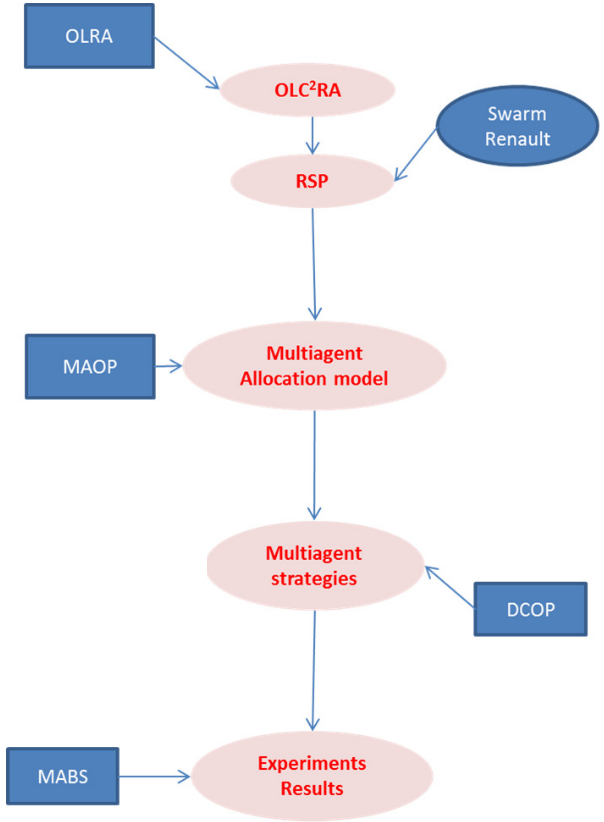
Context

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

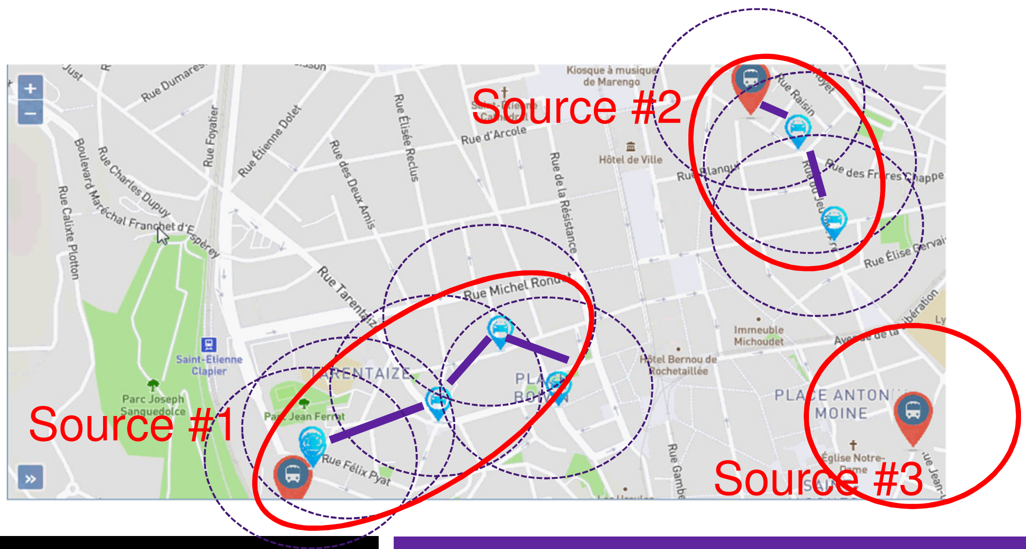
Problem components

- **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



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:*

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

$$\textbf{avec}$$

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

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

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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.

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

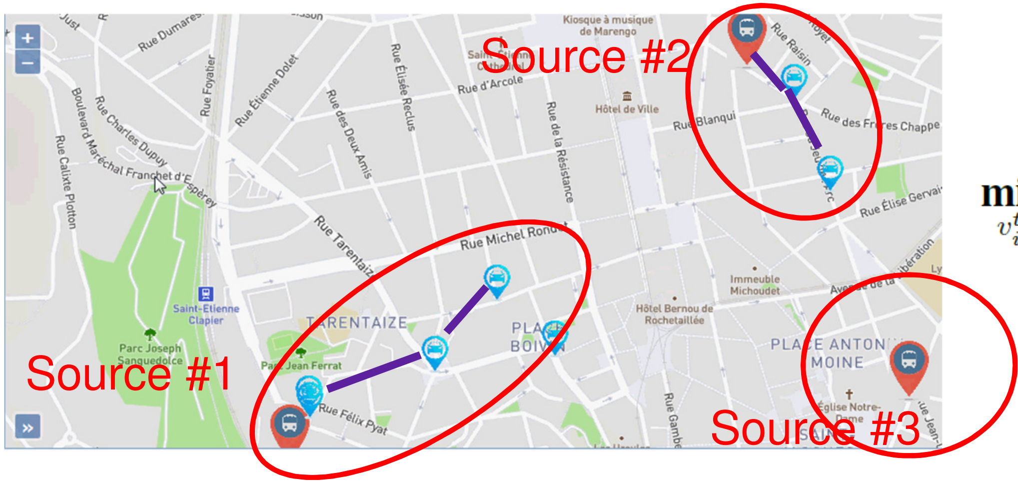
  - *the ratio of travelers who are waiting less than the traveler of the request r:* a taxi chooses the request which is the more penalized if it is not chosen by him.

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

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



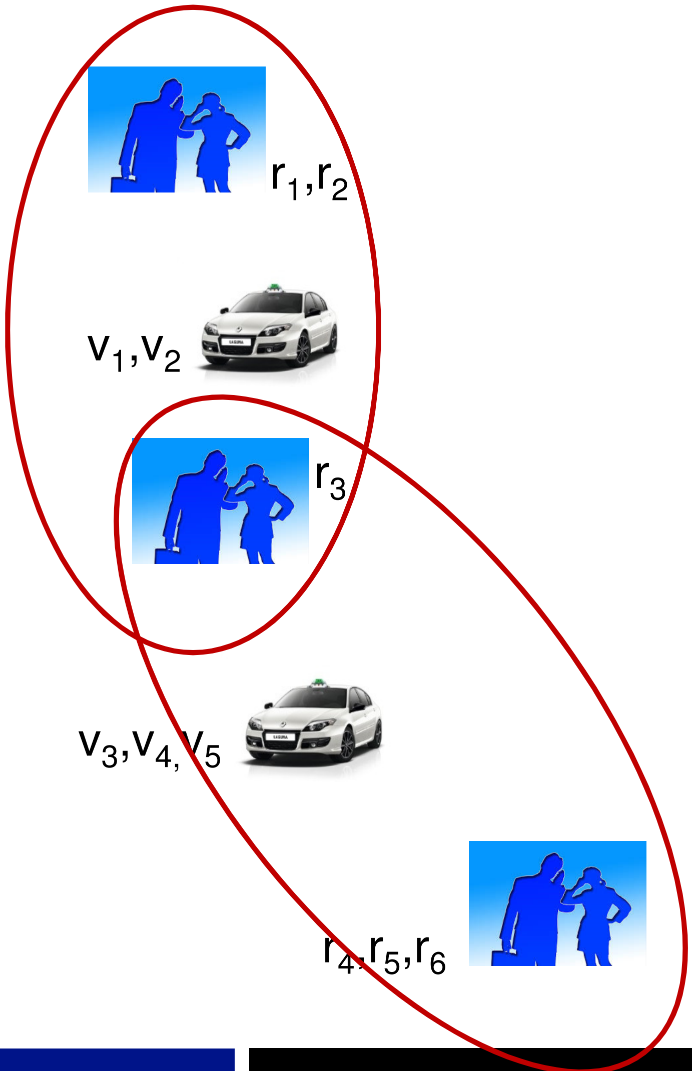
- **DCOP resolution**
  - Objective

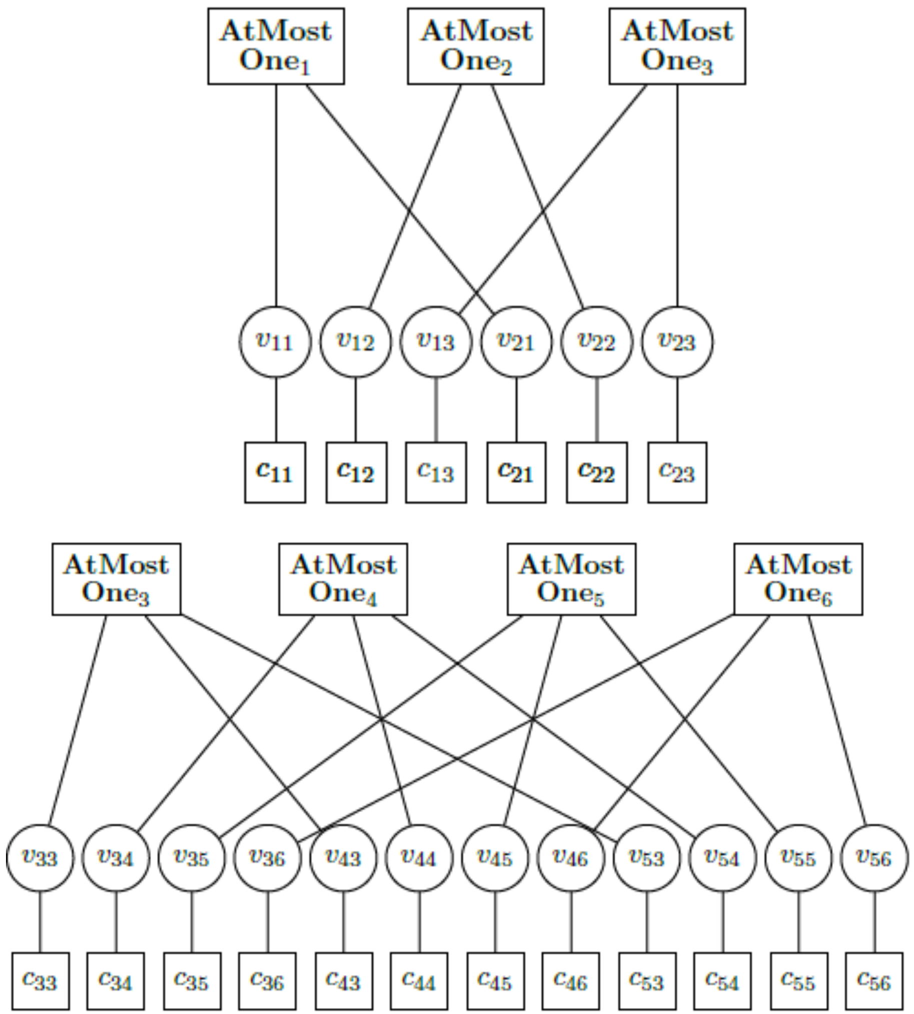
$$\min_{v_{ij}^t} \sum_{v_{ij}^t} c_{ij}^t(v_{ij}^t) + \sum_{\substack{C \in CSet_{\mathcal{A}}(t) \\ r_j \in KR(C,t)}} \mathrm{AMO}_j^t(v_{1j}^t, \ldots, v_{|C|j})$$

  - Protocol: Max-Sum

Multiagent solution modeling

Proposed allocation process solution

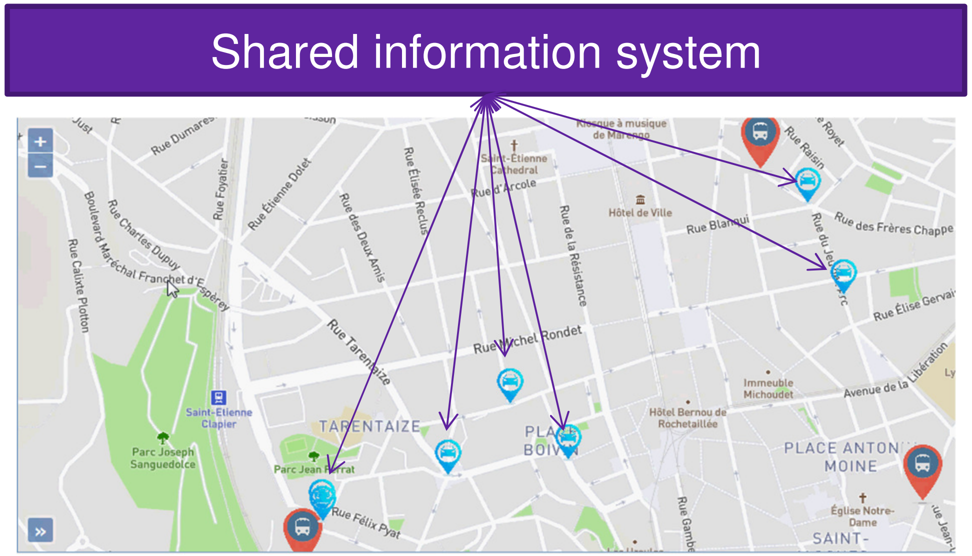




Multiagent solution modeling

Comparative allocation process solution

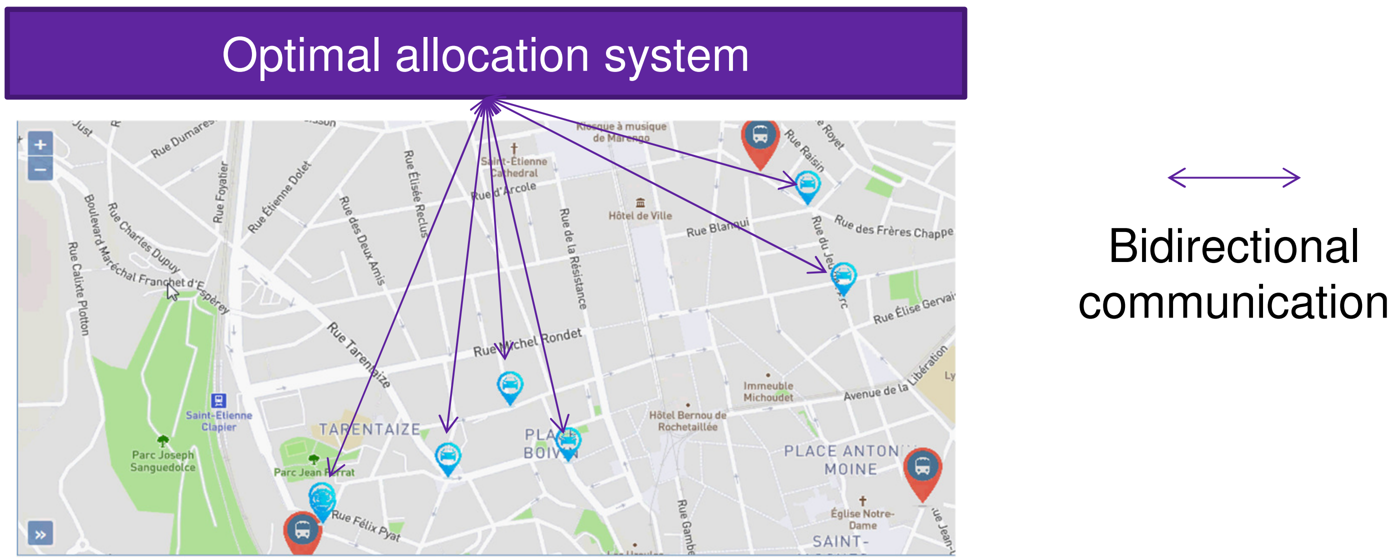
- ***p-alloc*** **Solution description**
  - A portal contains all active requests
  - Taxis pick their chosen request at portal
  - Allocation is never challenged



Bidirectional communication

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



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Results

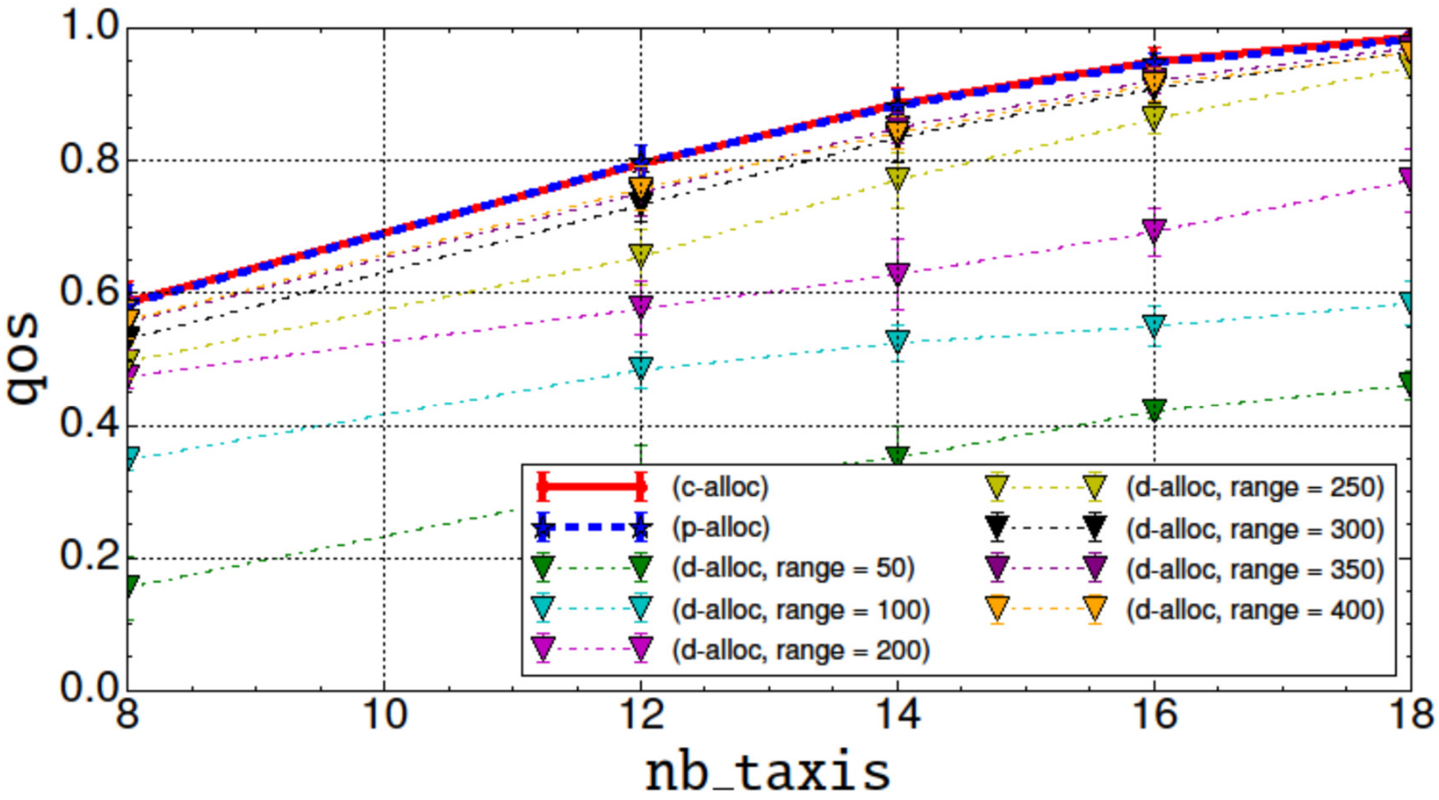
Experimental Conditions

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)

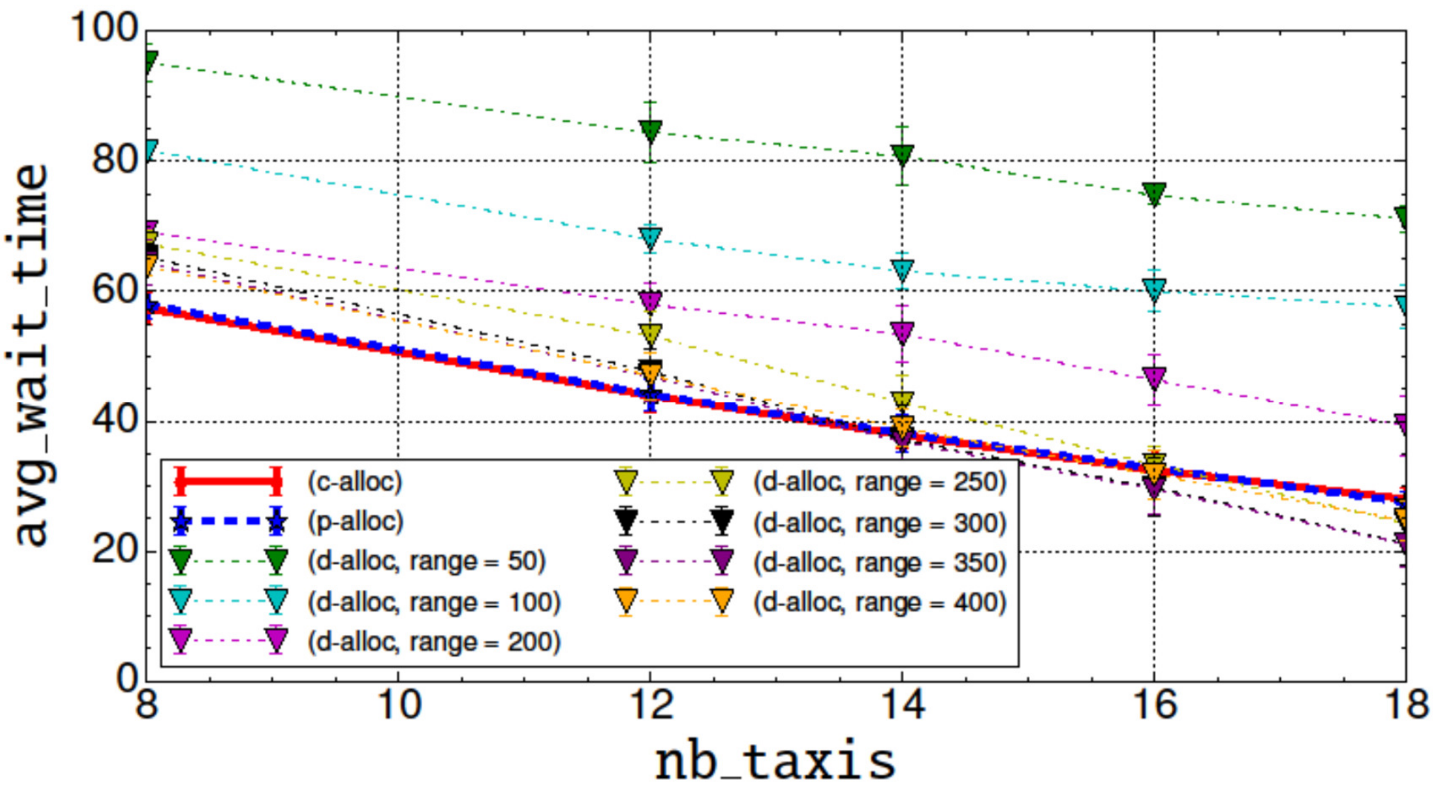
Evaluation

Quality



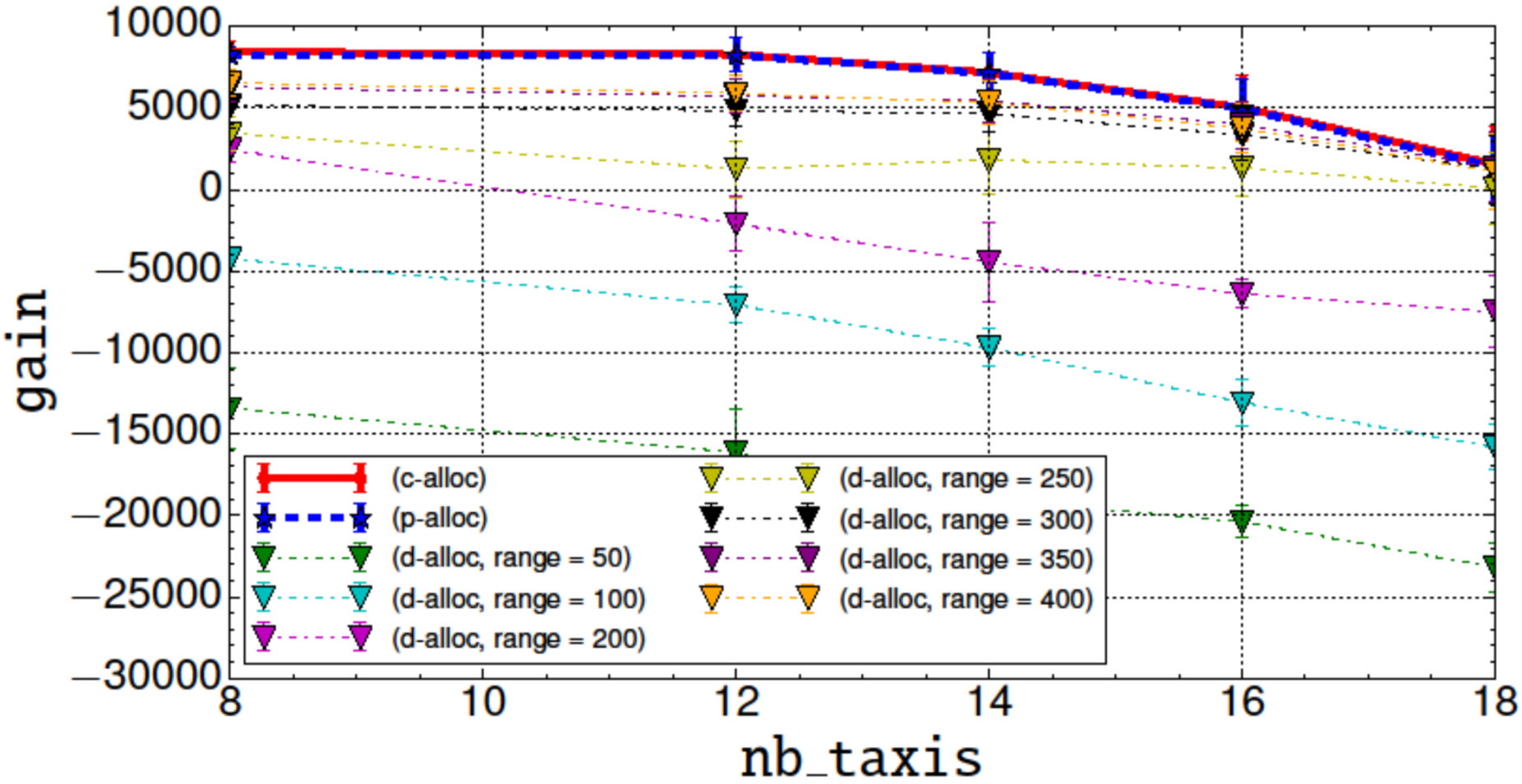
Evaluation

Quality



Evaluation

Quality



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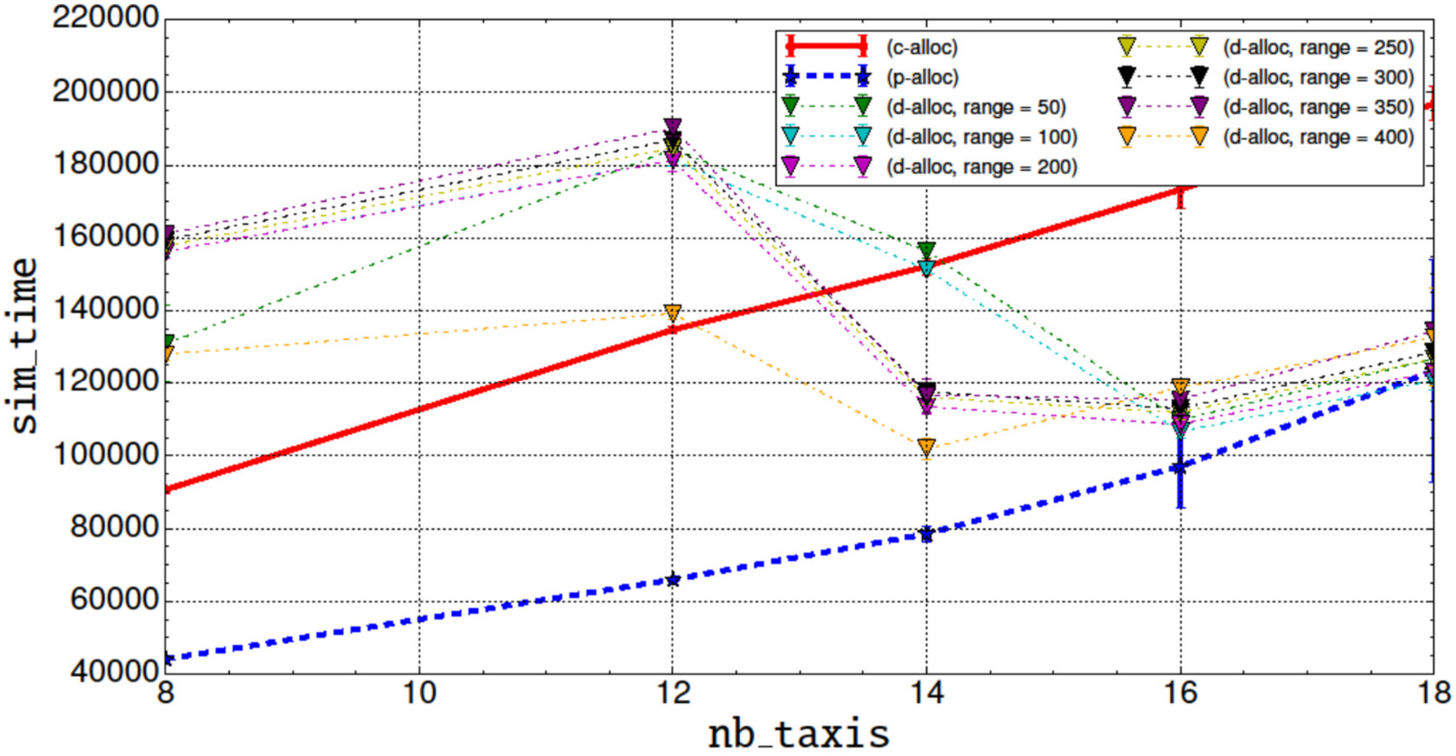
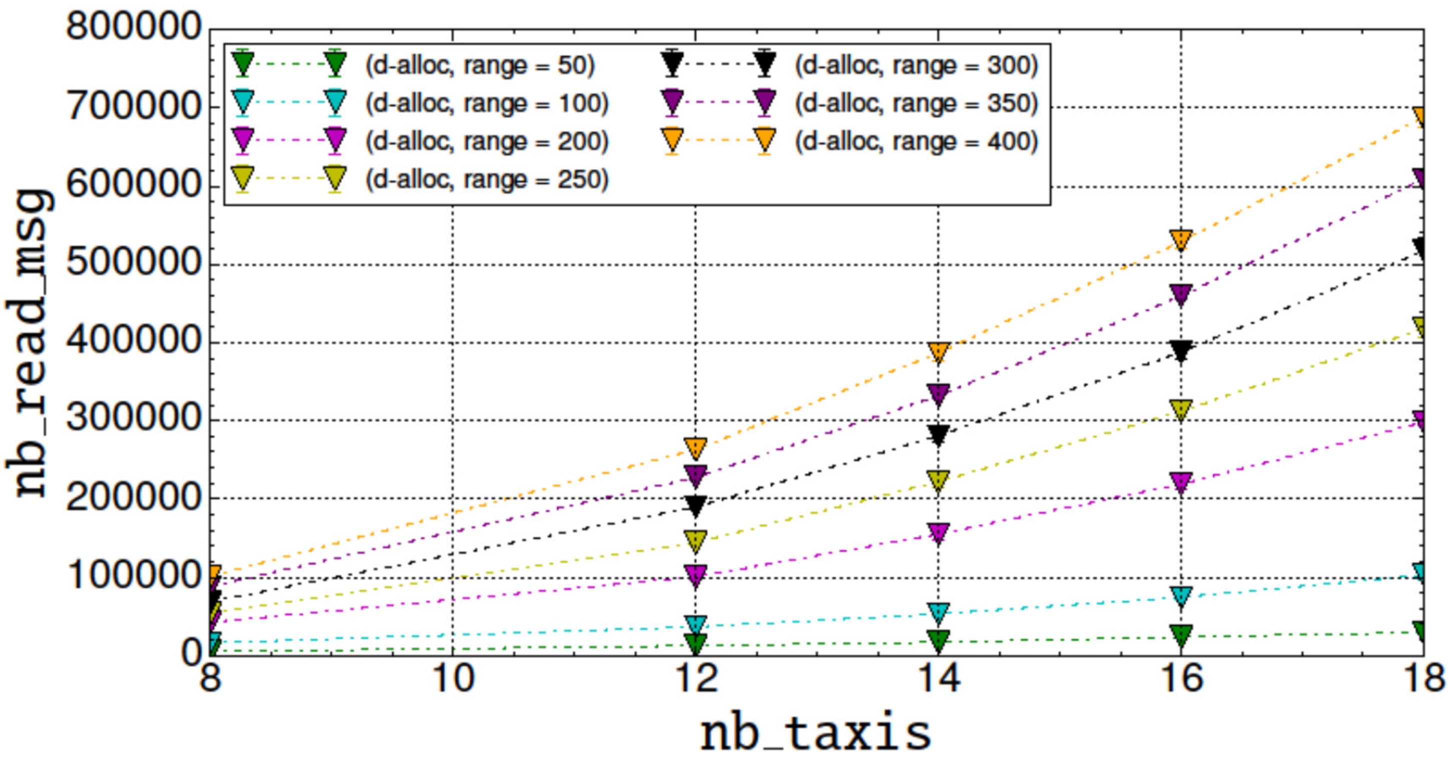
Evaluation

Scalability



Evaluation

Scalability



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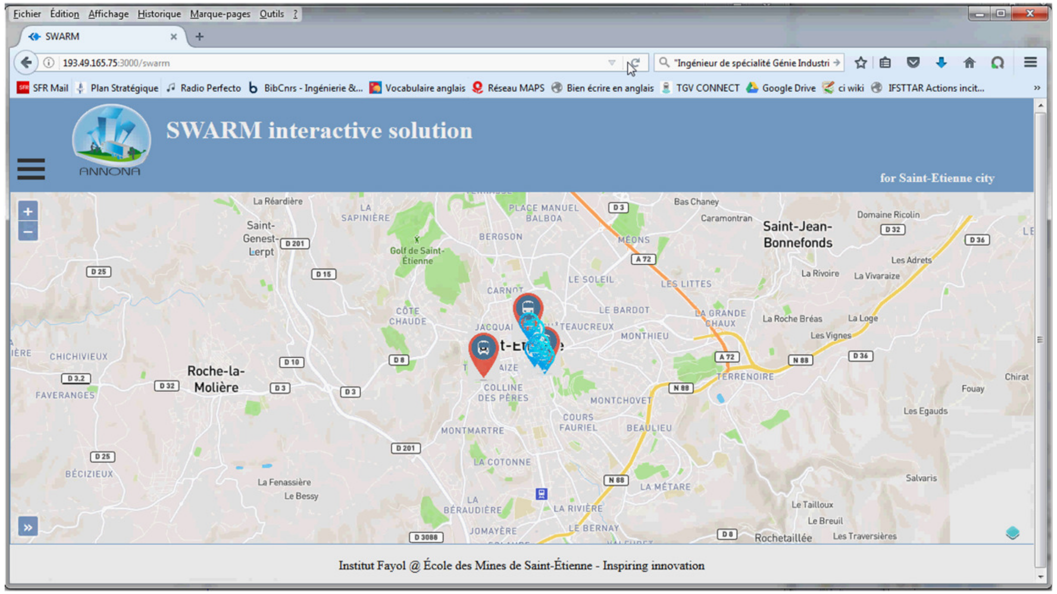
Conclusion



- 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