A multiagent approach for the dynamic VRPTW*

(*Vehicle Routing Problem with Time Windows)

By Mahdi Zargayouna *, **, Flavien Balbo *, and Gérard Scémama ****

* ***Lamsade*** Laboratory - Paris Dauphine University - http://www.lamsade.dauphine.fr

** ***Gretia*** Research Unit – Inrets Institute - http://www.inrets.fr/ur/gretia/gretia.e.html

Outline

1) Introduction

- DVRPTW problem
- Environment and Transport

2) Property Based Coordination

- PbC principle and objective
- Environment modeling

3) DVRTWs Modeling

- Multi-agent modeling of the DVRPTW problem
- The new measure of agents' perception fields

4) Conclusion

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The dynamic Vehicle Routing Problem with Time Windows

A multi-vehicle Traveler salesman problem where:

There is a fleet vehicles and each of them has a limited capacity
There is a dynamic set of customers to be visited, each specifying:

- A node of the network
- A quantity of desired goods
- A time window inside which she wants to be visited
- A service time during wich the vehicle has to halt before to proceed

Objectives:

11. Minimise the number of used vehicles
12. Minimise the total distance traveled by all the vehicles

Our Goals:

15. Provide a distributed model of the system
16. Propose a new heuristic focused on the possibility to take into account the future customers

MAS Environment and Transport

- The environment:
  - is a shared space:
    - A solution to give a space-time referential to the agents related to the resolution of the VRPTW problem.
  - has its own dynamic:
    - A solution to take into account the dynamic of the real environment. The objective is to simplify the design of the agents.
  - defines rules for the multi-agent system:
    - A solution to constraint perceptions and interactions of agents. The objective is to limit the number of messages.

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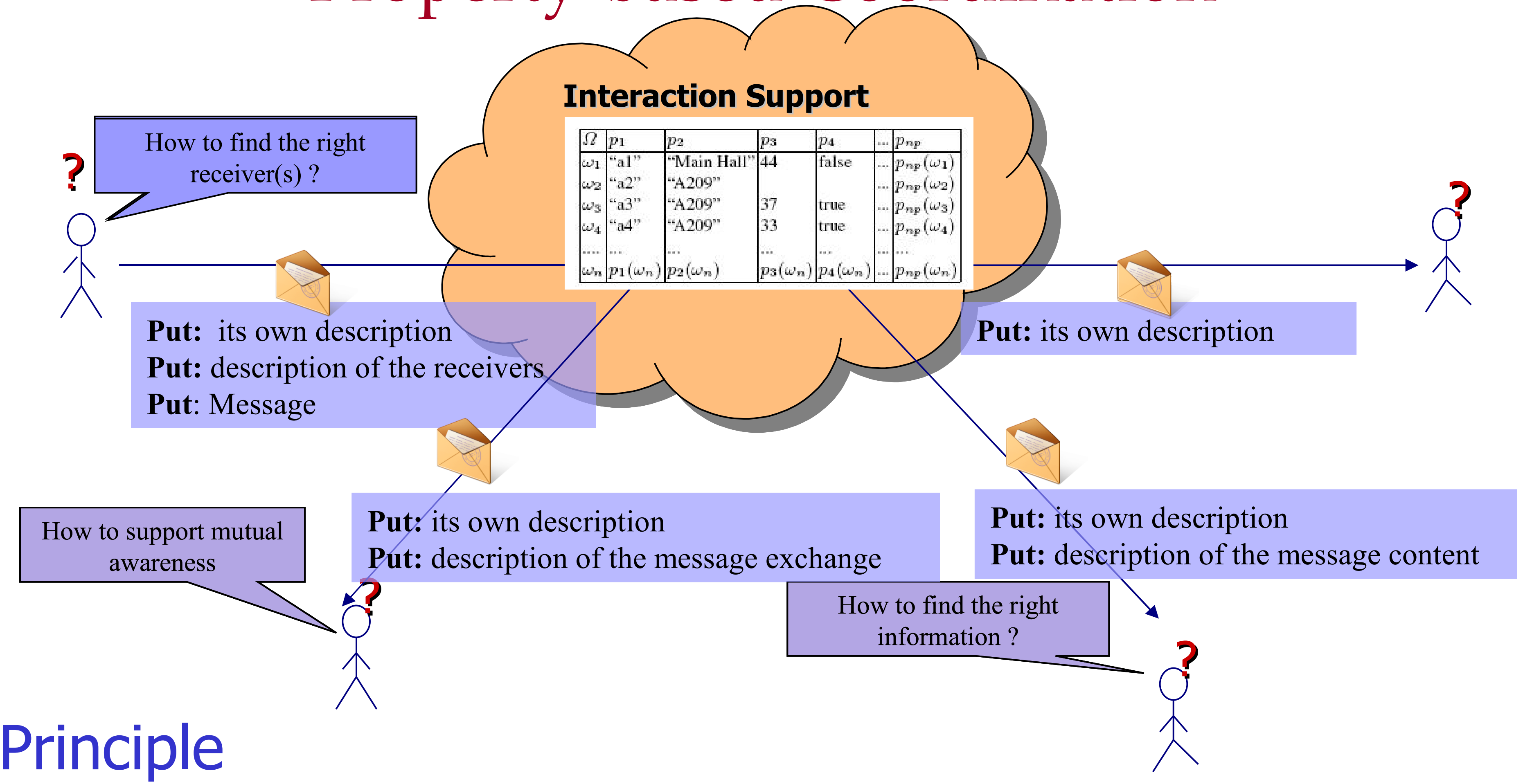
Property-based Coordination



Ω	p_1	p_2	p_3	p_4	...	p_{np}
ω_1	"a1"	"Main Hall"	44	false	...	$p_{np}(\omega_1)$
ω_2	"a2"	"A209"			...	$p_{np}(\omega_2)$
ω_3	"a3"	"A209"	37	true	...	$p_{np}(\omega_3)$
ω_4	"a4"	"A209"	33	true	...	$p_{np}(\omega_4)$
....	...	...	...	...	...	...
ω_n	$p_1(\omega_n)$	$p_2(\omega_n)$	$p_3(\omega_n)$	$p_4(\omega_n)$	...	$p_{np}(\omega_n)$

Principle

- ➢ Every entity composing the system, including the agents, exhibits observable properties,
- ➢ Agents use the observable properties to manage the interactions, perceptions and actions inside the system.

Environment modeling

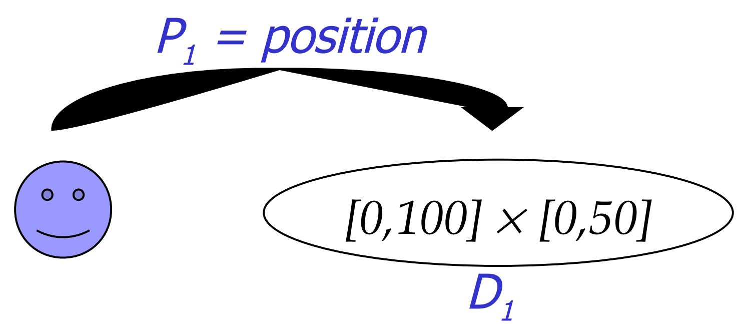
The environment contains:

- $\Omega = A \cup O$, *A is the set of agents, O is the set of objects*
    - $P = \{P_i \mid i \in I\}$,

      $P_i : \Omega \rightarrow d_i \cup \{null, unknown\}$, *$d_i$ is the domain of P_i*
    - $D = \prod_{i \in I} d_i$
- *F the set of filters*

P_i (w) = null $\Leftrightarrow$ P_i is not defined for w

P_i (w) = unknown $\Leftrightarrow$ the value of P_i is hidden for w



Example: *Position (a1)=(5,10), position(a2)=unknown*

Environment modeling

Definition 1 (Filter). *Let* $A \subset \Omega$ *be the subset of agents, let* $O \subset \Omega$ *be the subset of objects, the filter* f *is defined as follows,* $f : A \times O \times \mathcal{P}(\Omega) \rightarrow \{true, false\}$
$f(a, o, C) = f_{ag}(a) \wedge f_{pe}(o) \wedge f_{co}(C)$ *where:*
-$f_{ag}(a) = \wedge_{P_i \in P_{f_{ag}}} [P_i(a) R_{P_i}^{f_{ag}} d_{P_i}^{f_{ag}}]$
-$f_{pe}(o) = \wedge_{P_i \in P_{f_{pe}}} [P_i(o) R_{P_i}^{f_{pe}} d_{P_i}^{f_{pe}}]$
-$f_{co}(C) = \wedge_{c \in C}\, g_{co}(c)$, *with*
$g_{co}(c) = \wedge_{P_i \in P_c} [P_i(c)\ R_{P_i}^{c}\ d_{P_i}^{c}]$.

Example:

$$f(a_1, m, \{a_2\}) = [P_{identifier}(a_1) = 12] \wedge [P_{receiver}(m) = P_{identifier}(a_2)] \wedge [P_{state}(a_2) = \text{"}busy\text{"}]$$

➡ *a_1 will receive m if a_2 is the initial receiver and a_2 is busy*

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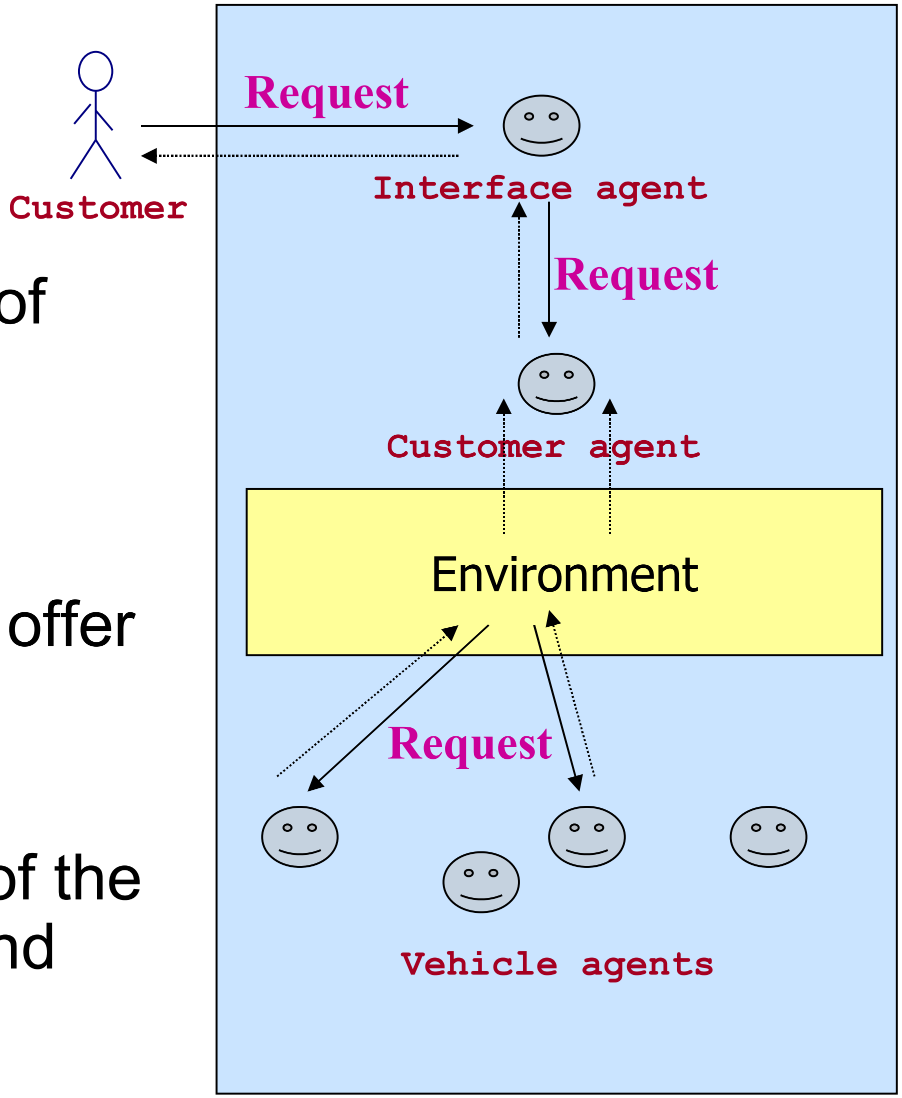
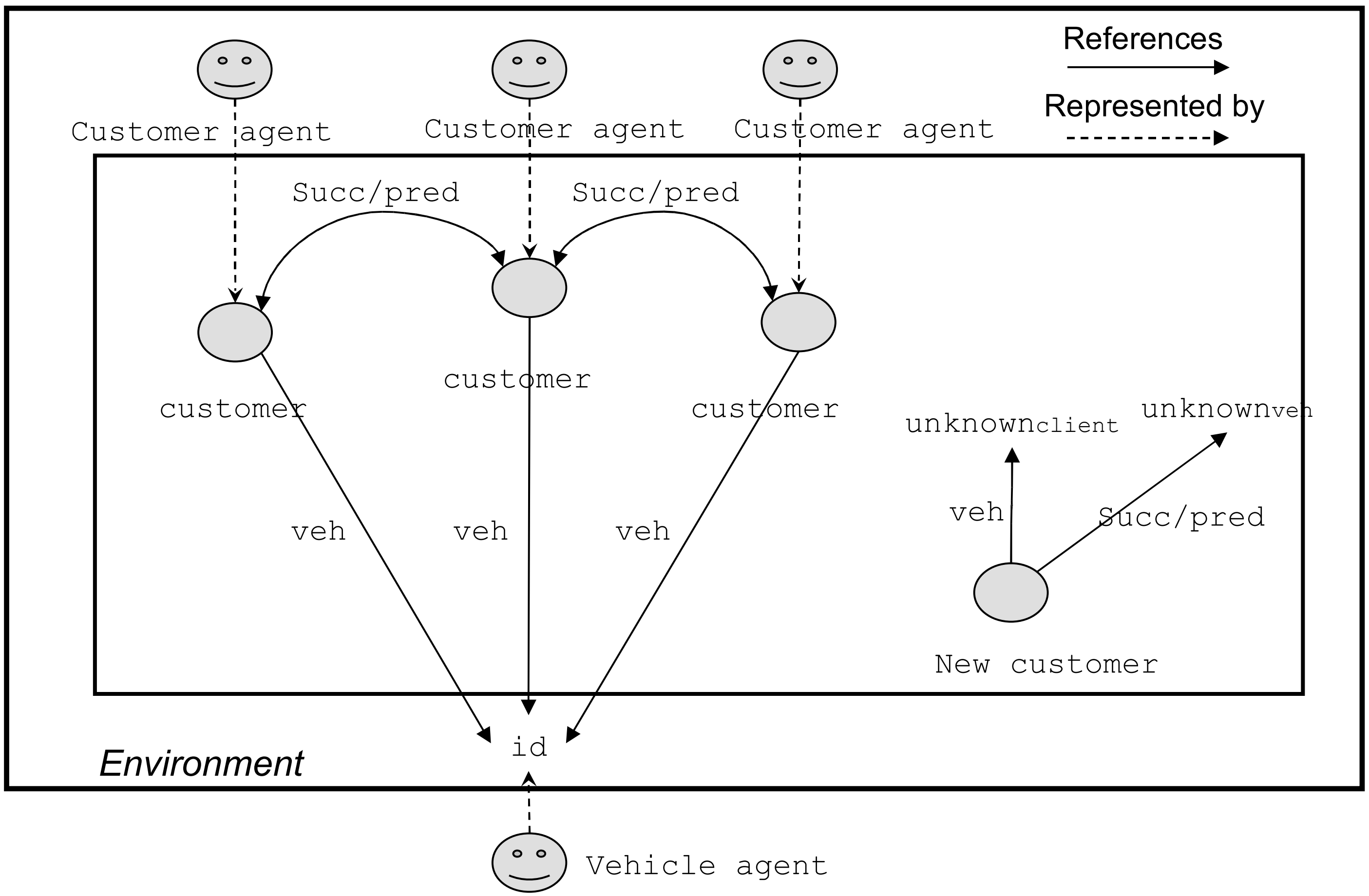
DVRPTW multi-agent modeling

- Agents:
  - Interface Agent (IA):
    - An IA checks the validity of the human request and creates a CA agent.
  - Customer Agent (CA):
    - *A* CA has to find the best offer for the human request.
  - Vehicle Agent (VA):
    - A VA computes the cost of the insertion of the request and makes offer.



Use of the environment for the DVRPTW



- Principle : publish the routing plans of the vehicles in the form of a chained list of customer objects
- Objective: restrain the vehicles' perception to the only customers they are able to visit (with filters)

Use of the environment for the DVRPTW

- There is an interaction between a CA (*c**) and a VA (*v**) if the request (*r**) of the CA can be inserted in the plan of the VA:
  - There is a capacity ($f_{capacity}$) and a space-time (f_{space_time}) condition and

$$f = f_{capacity} \wedge f_{space\_time}$$

  - $f_{capacity}$: The quantity associated to the request of *c** does not exceed the current capacity of *v**.

$$f_{capacity}(v^*, r^*, \emptyset) = [q(r^*) \leq cap(v^*)]$$

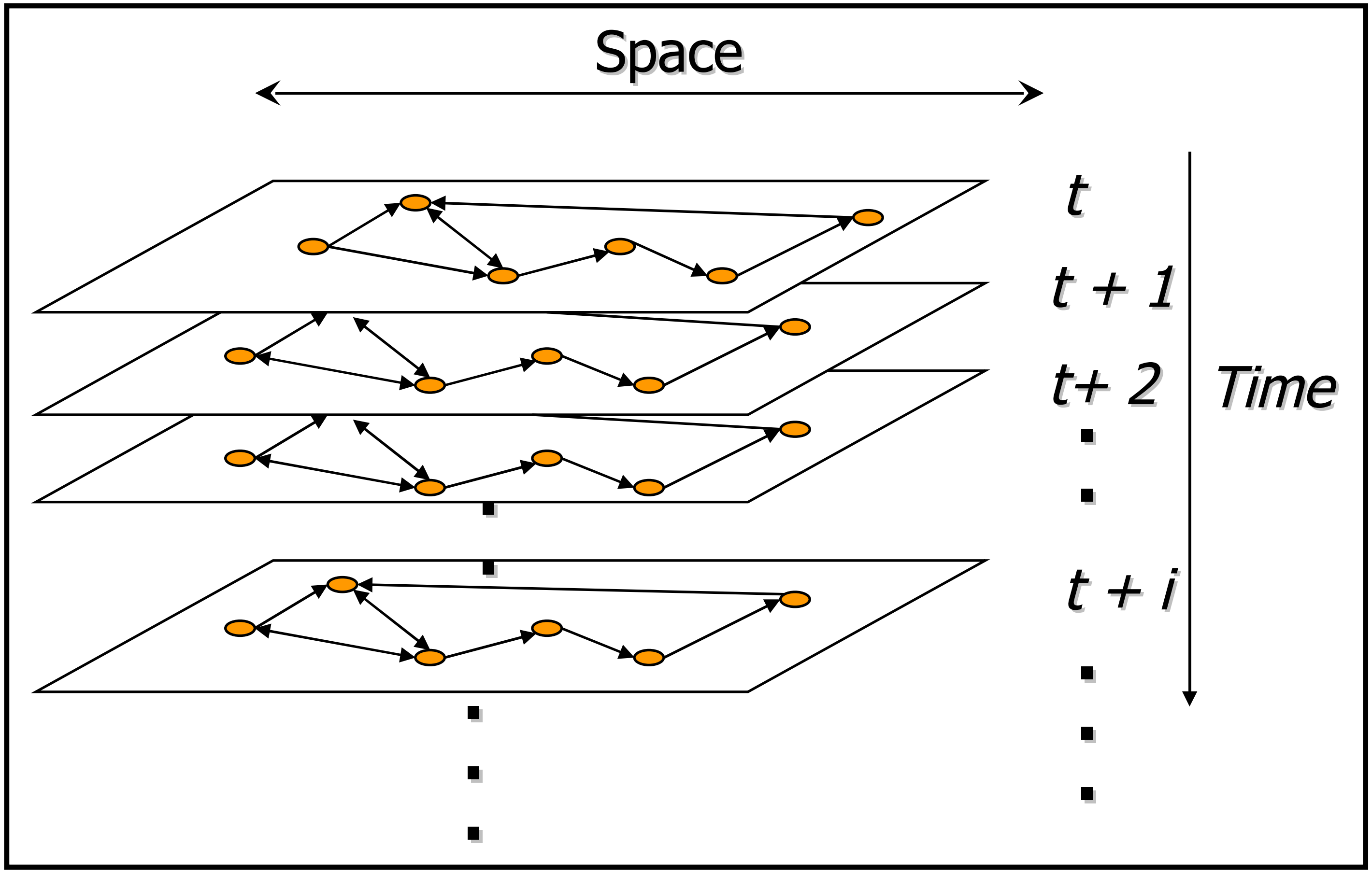
Use of the environment for the DVRPTW

- f_{space_time} : There exist a position in the plan of v* between two adjacent customers, say *c1* and *c2*, so that *v** can visit *c1*, then *c* and finally *c2* without violating any time window of the three customers

$$f_{space-time}(v^*, r^*, \{c_1, c_2, a_1, a_2\}) =$$

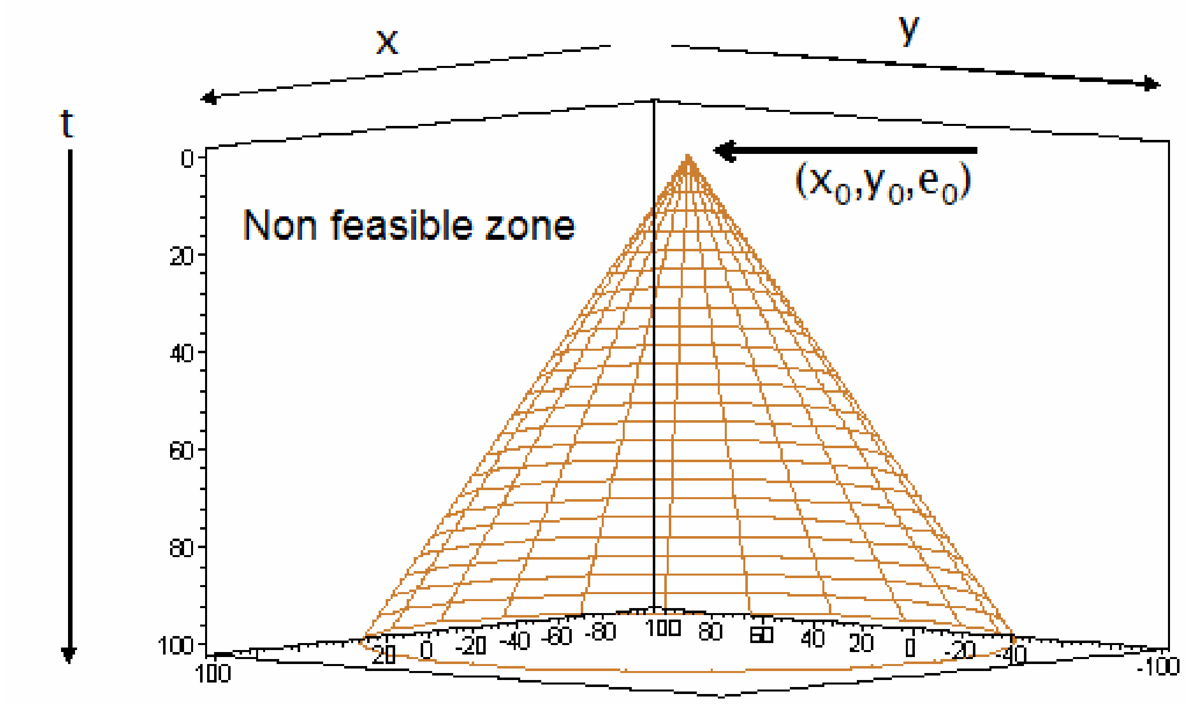
$$[succ(c_1) = id(c_2)] \wedge [veh(c_1) = id(v^*)] \wedge$$
$$[n(c_1) = on(a_1)] \wedge [n(r^*) = dn(a_1)] \wedge$$
$$[e(c_1) + cost(a_1) + s(c_1) \leq l(r^*)] \wedge$$
$$[n(r^*) = on(a_2)] \wedge [n(c_2) = dn(a_2)] \wedge$$
$$[Max(e(r^*), e(c_1) + cost(a_1) + s(c_1)) +$$
$$s(r^*) + cost(a_2) \leq l(c_2)]$$

New Heuristic : space-time representation of the network



A time dimension is added to the network in order to take into account future positions of the vehicles

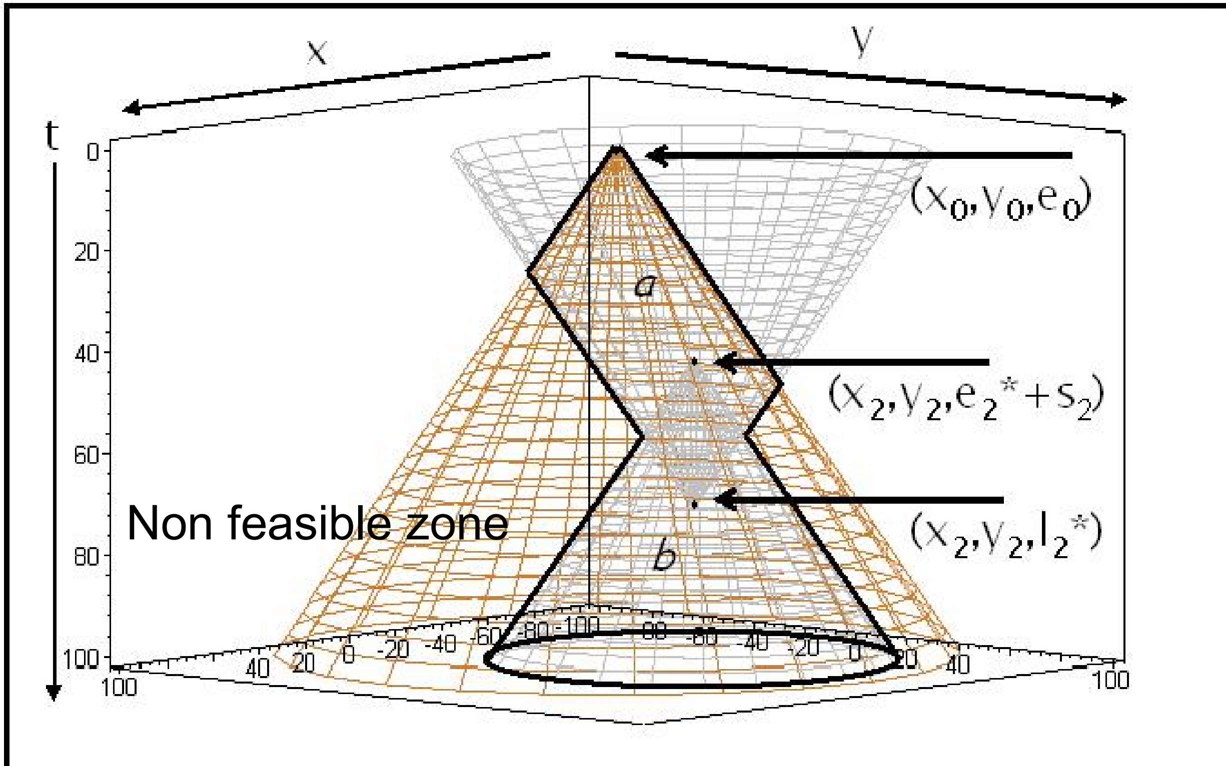
Agents' perception fields (euclidean case)



Inside the cone : the (x,y,t) positions where an empty vehicle can be
Outside the cone : the non-feasible positions

- The vehicle agents perceives the only customers it can serve
- The volume of the cone is the initial perception field width of the vehicle agent

Dynamics of the perception fields (euclidean case)



With every new perceived customer, the vehicle agent calculates its new perception field
The vehicle loosing the minimum perception field is selected to serve the new customer

- The future availability of vehicles is privileged in the insertion choice

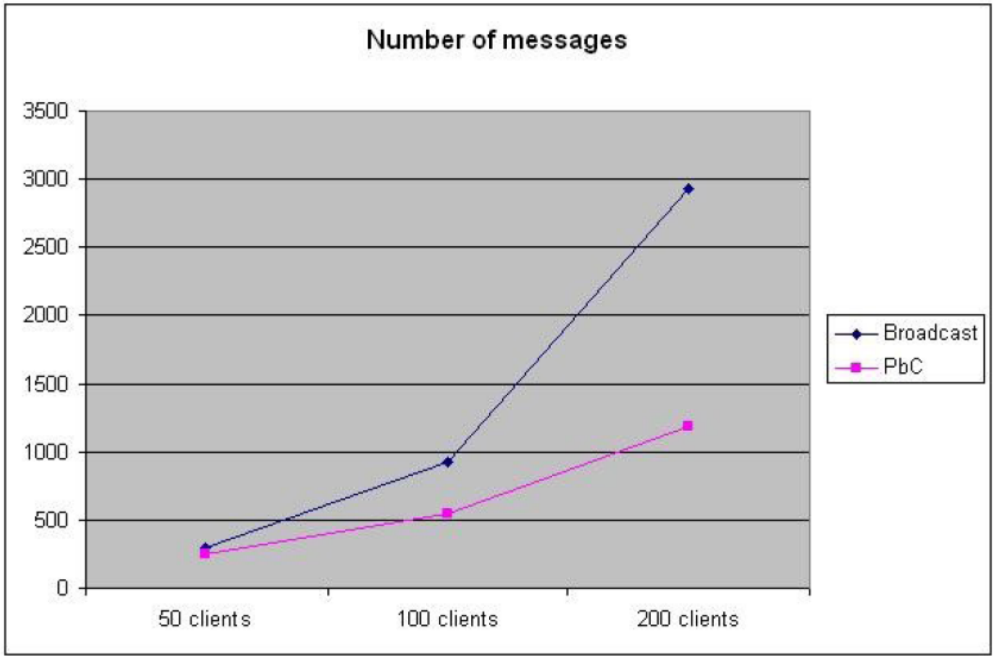
First Experimental results

Δ Distance		
Nb customers	Nb vehicles	Distance
25	3.4	316
50	6	671
100	12.1	1601
200	21.6	6315

The new measure dominates the traditional measure [solomon, 87] w.r.t the number of used vehicles

Δ Perception field		
Nb customers	Nb vehicles	Distance
25	3.3	347
50	5.9	731
100	11.9	1774
200	21.4	6979

The traditional measure dominates new measure the w.r.t the number of used vehicles



The cost of the CNP is reduced.

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Summary

An environment design based on the Property-based Coordination (PbC) principle

Suitable for open systems where agents don't know each others *a priori*

An application: Dynamic Vehicle Routing Problem with Time Windows

A new choice measure (perception fields) focusing on future (unknown) customers

Perspectives

Consider other dynamic data : dynamic travel times, delays, breakdowns etc.

Generalization of the perception fields measure to other problems