Cooperation vs. Competition in vehicular networks

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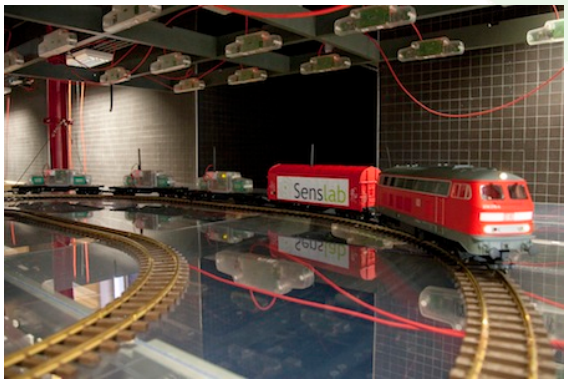
Mobile devices

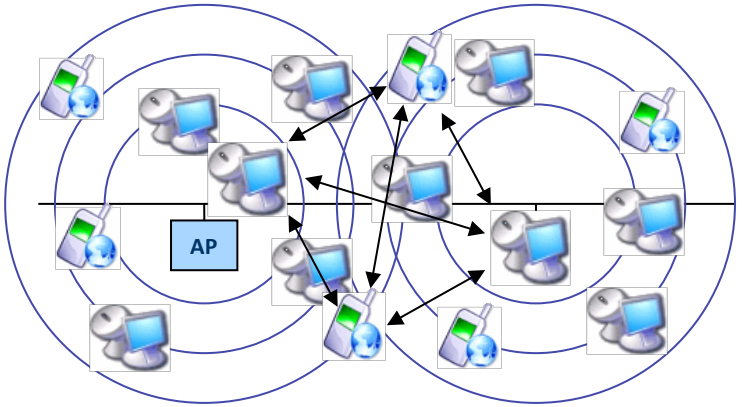
- Wide variety
  - Laptops, tablets, smartphones, sensors, etc.
- Mobile devices produce and/or store data!
  - « In 2014, the volume of mobile data sent and received every month by users around the world will exceed by a significant amount the total data traffic for all of 2008 » (ABI research)

SmartGrains



Wireless networks

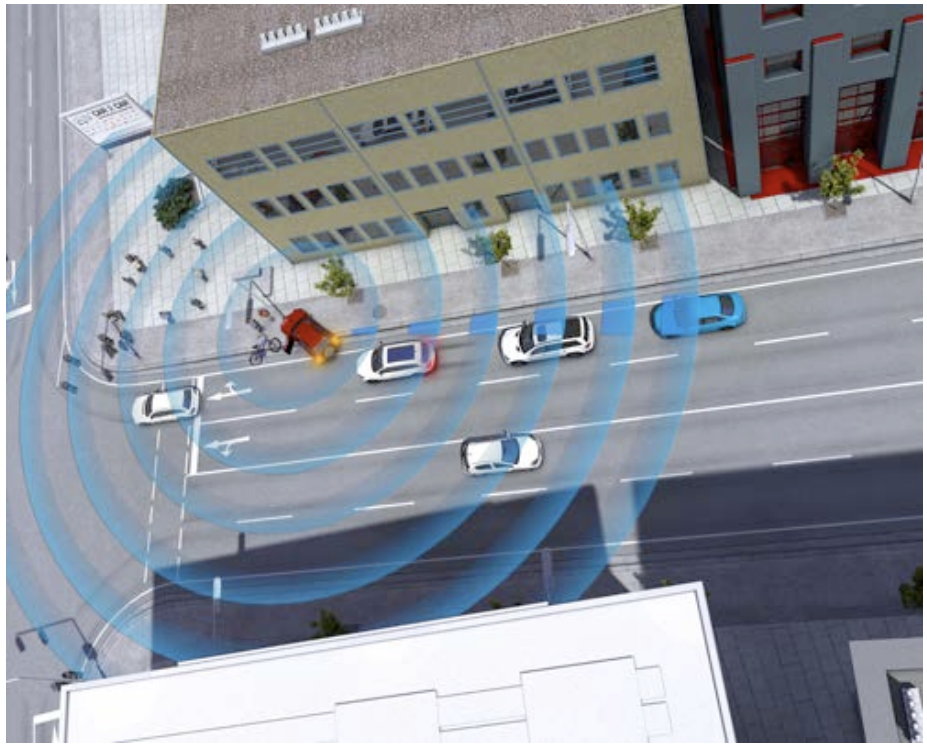
- Several solutions
  - Mobile telephony networks (LTE)
  - Short range communication networks
    - IEEE 802.11 (Wi-Fi), IEEE 802.15.4
    - Other arriving (e.g., IEEE 802.11p)
- Criteria to compare these solutions
  - Need of an infrastructure
  - Communication range
  - Support of mobility
  - Energy efficiency

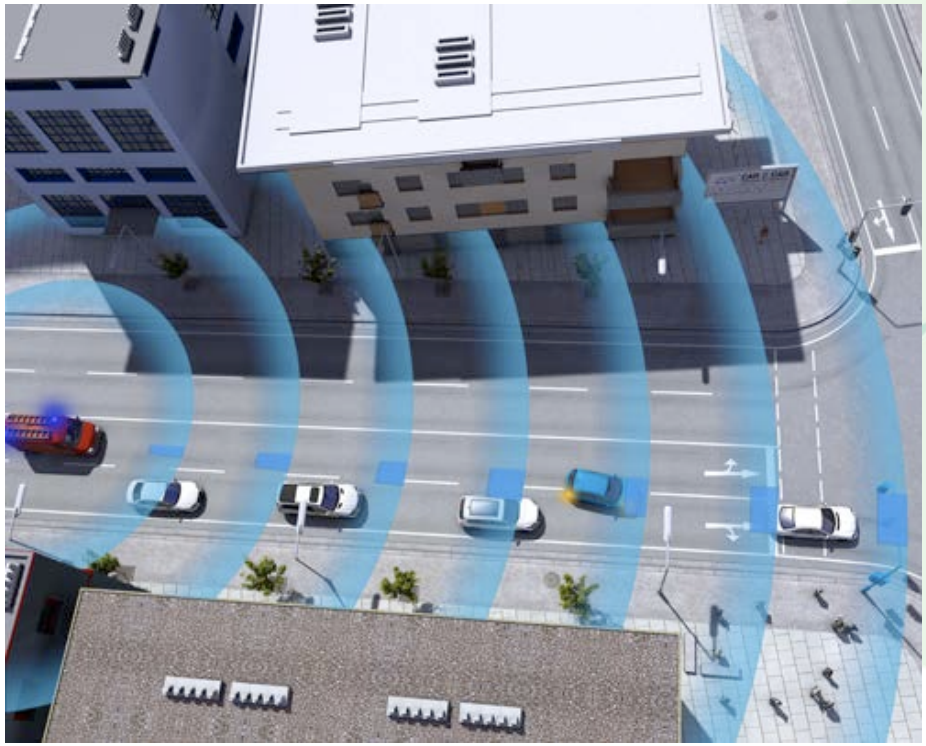


Positioning techniques

- Global Navigation Satellite Systems
  - GPS, GLONASS, EGNOS/GALILEO
- Many alternative solutions
  - Indoor/Outdoor
  - Exploit various technologies:
    - Repeaters, (wireless) signal strength, sensors, image recognition, etc.
  - Various characteristics:
    - cost, accuracy, reliability, coverage area, etc.

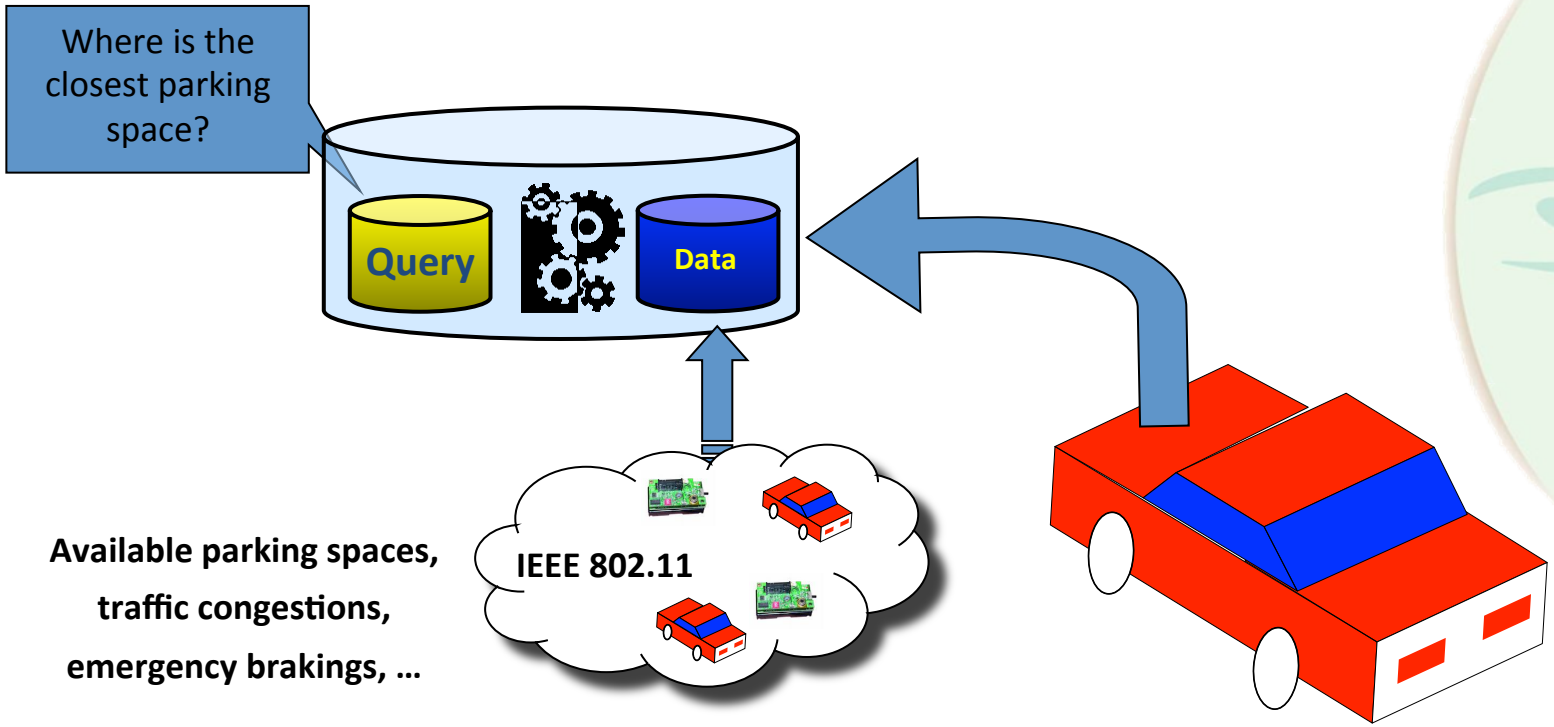
Use cases





Query processing in this context

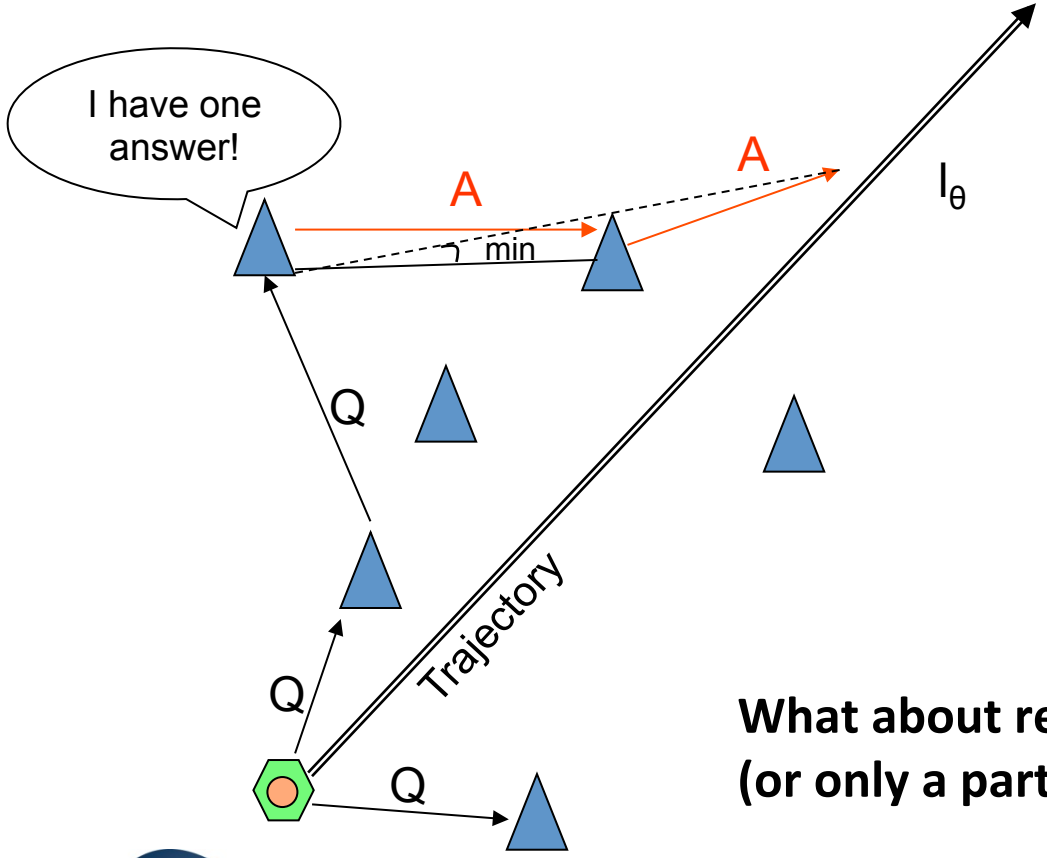
Use of a push model

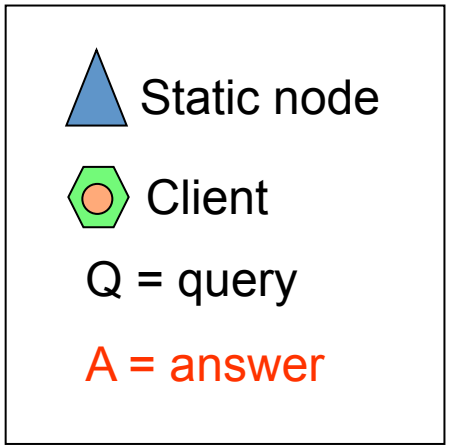


Such a scheme is used because routing results towards a moving object is a difficult task!

Why not prefer a pull approach?

- How to route partial results towards the mobile recipient?
- Decentralized architectures with some stationary nodes:

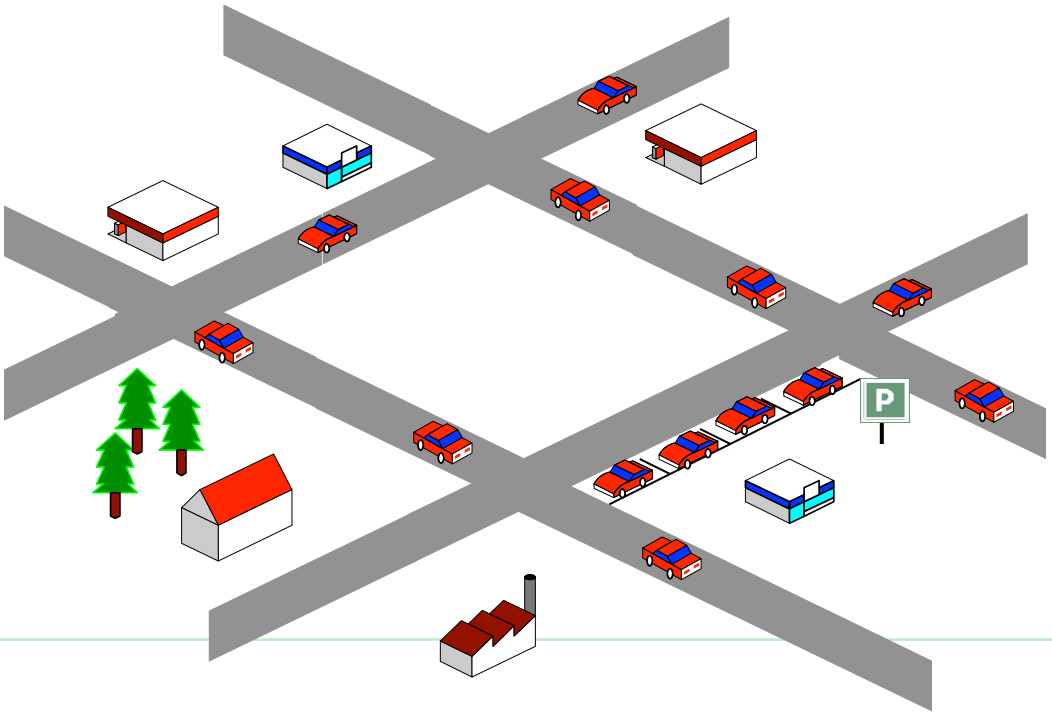




What about result routing if no infrastructure (or only a partial one) is available?

Data dissemination

- Objective:
  - Push data towards (potentially interested) mobile nodes
  - Exploit multi-hop relaying techniques



Data dissemination

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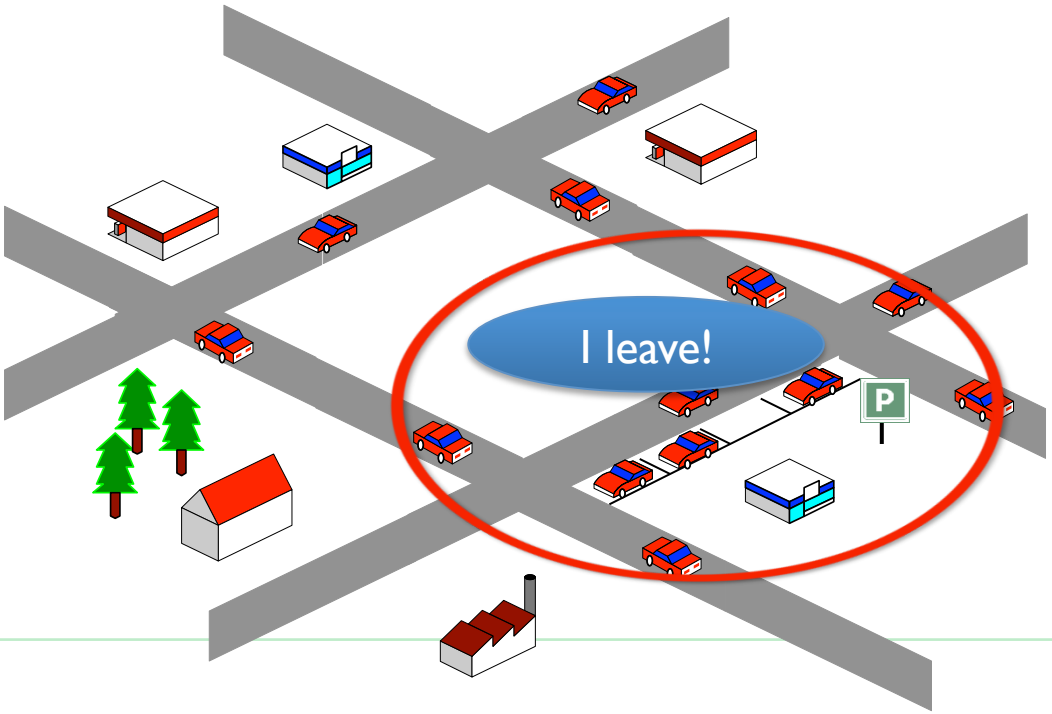
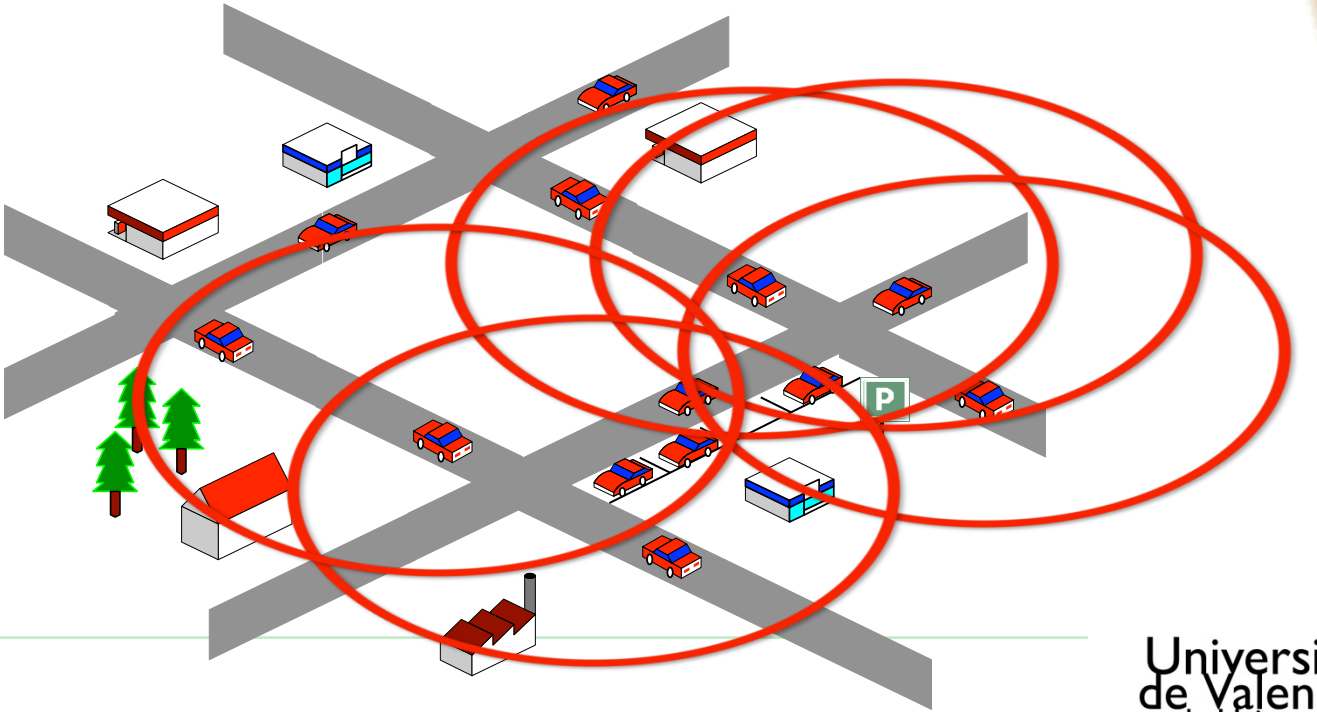


Data dissemination

- Challenges:
  - Avoid network flooding
  - Reach potentially interested vehicles
  - Several dissemination protocols (Ouksel et al. 2004, Szczurek et al. 2011)



The VESPA example

- Objective: share any type of event between vehicles using vehicular ad hoc networks
  - Numerous events to share!!!
    - Available parking spaces
    - Available charging stations for EV
    - Emergency braking
    - Obstacles on the road
    - Real-time traffic information
    - Emergency vehicles
    - Driver in state of hypovigilance / doing strange maneuvers
    - …
- Observation: The type of event considered has an incidence on its relevance (and so on its dissemination)

Representation of events

- Messages are exchanged between vehicles to describe physical events
- Different attributes, at least:
  - Identifier
  - Priority
  - Position (and reference positions)
    - GPS coordinates
  - Time
    - GPS time
  - Event type
    - e.g., available parking space, accident, etc.
  - Version
    - No invalidation message is considered!

Is this enough?

Content-based Dissemination

- Objectives:
  - Support different types of events
  - Inform all the potentially interested vehicles
  - Support a high number of vehicles and events
- Challenges:
  - Avoid network flooding
    - Limit the number of vehicles relaying
      - Only the *k*-farthest vehicle will relay the message
  - Adapt the dissemination area to the type of information carried
    - A vehicle will not further broadcast a message received if this message is not relevant anymore

Probability to encounter

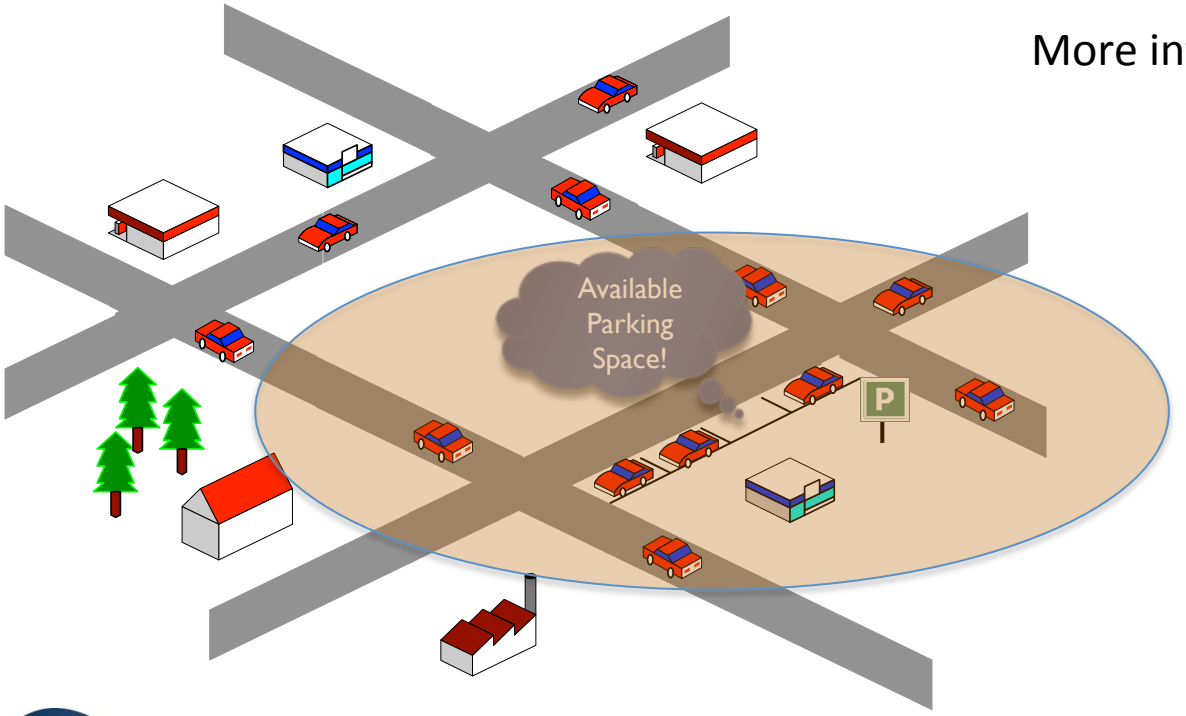
- Objective: estimate whether a vehicle is likely to encounter an event or not
  - First level of selection before integrating drivers' interests
- Observation: not trivial when the final destination of the driver cannot be assumed

Probability to encounter

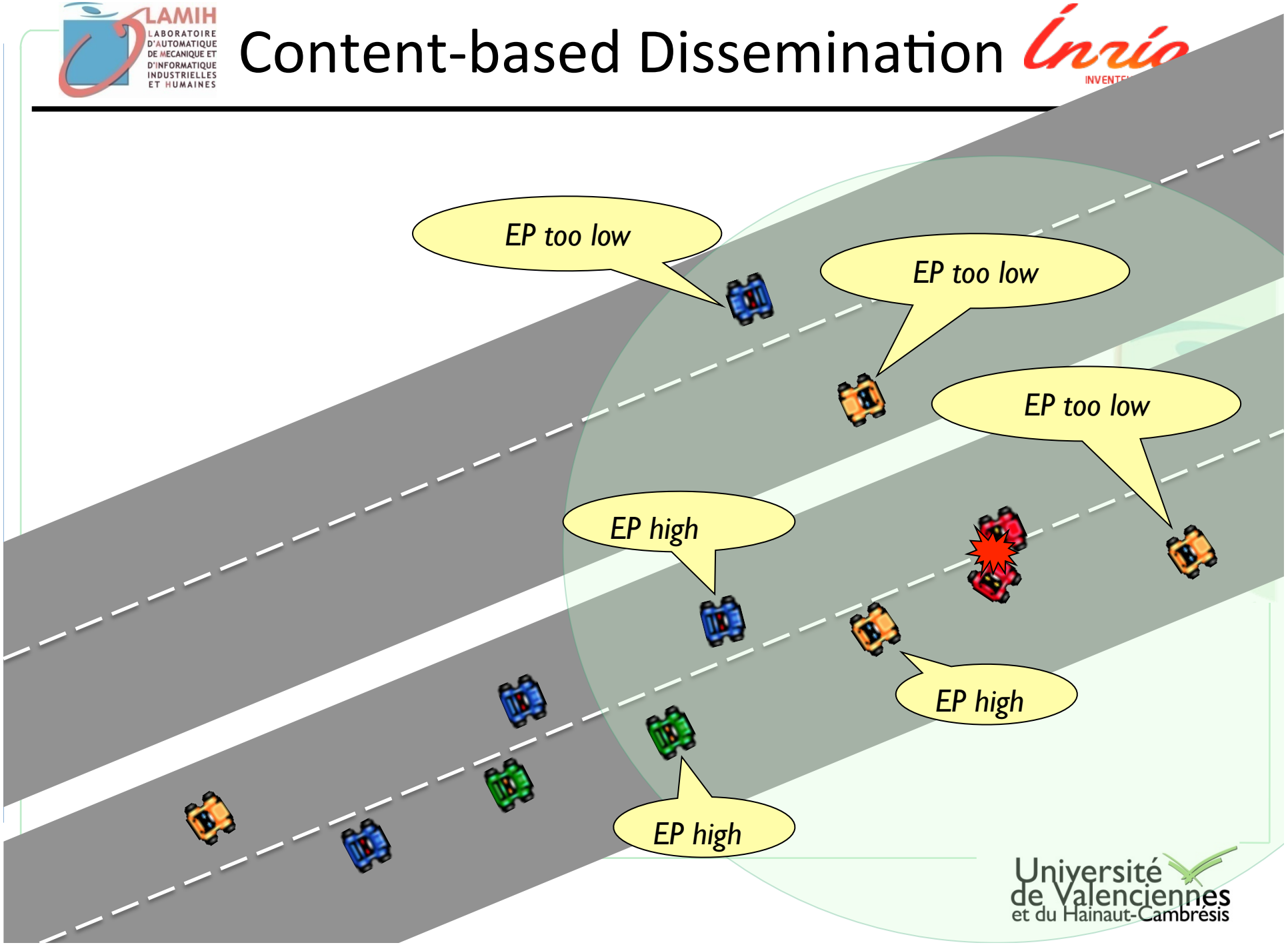
- Example of computation:
  (with maps, with geographic vectors)

$$EP = \begin{cases} 1 \text{ if } TTR < TTL \\ 0 \text{ otherwise} \end{cases}$$

More info: [MIS'11a]



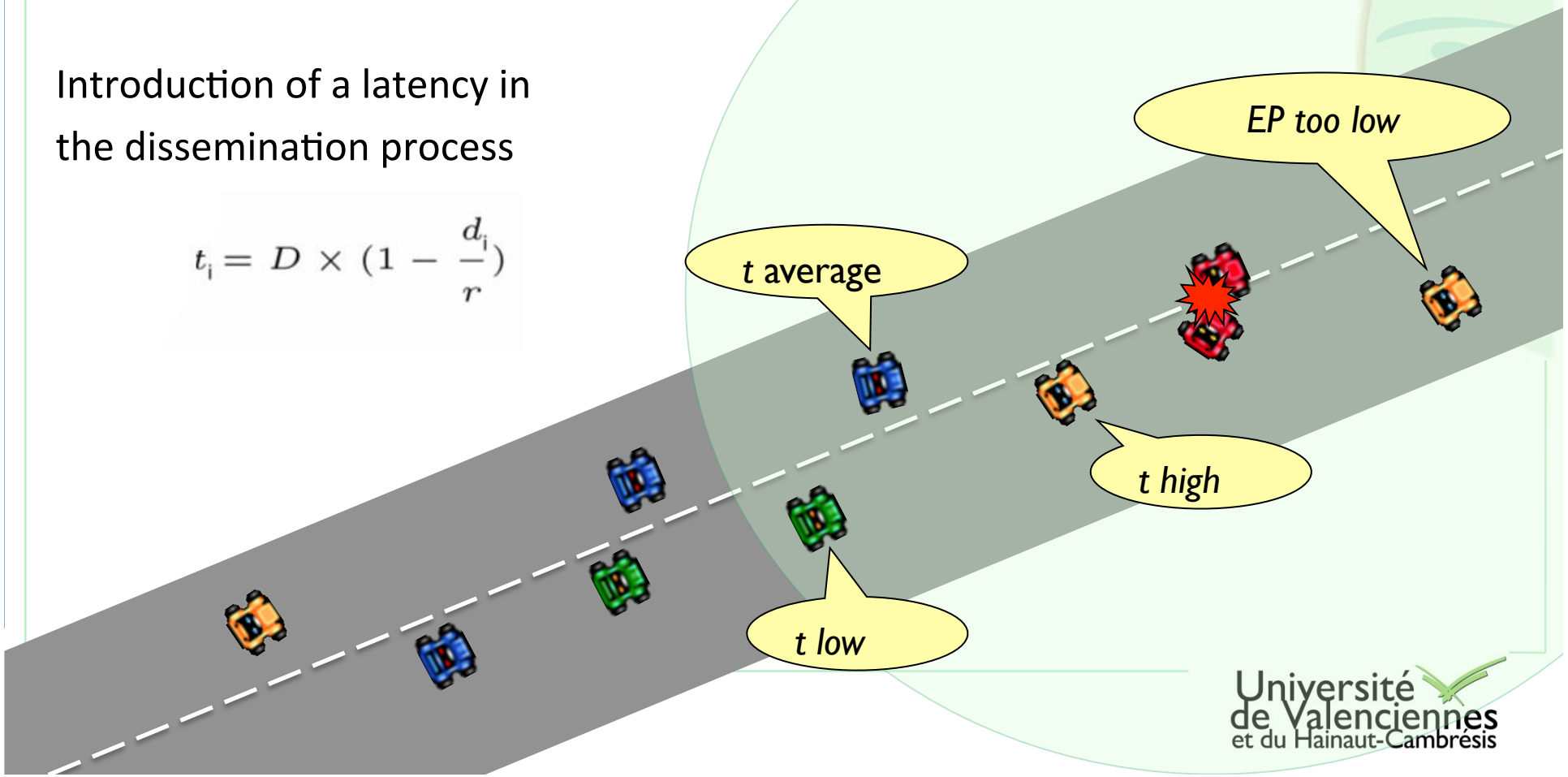
Content-based Dissemination



Content-based Dissemination

Introduction of a latency in the dissemination process

$$t_i = D \times (1 - \frac{d_i}{r})$$



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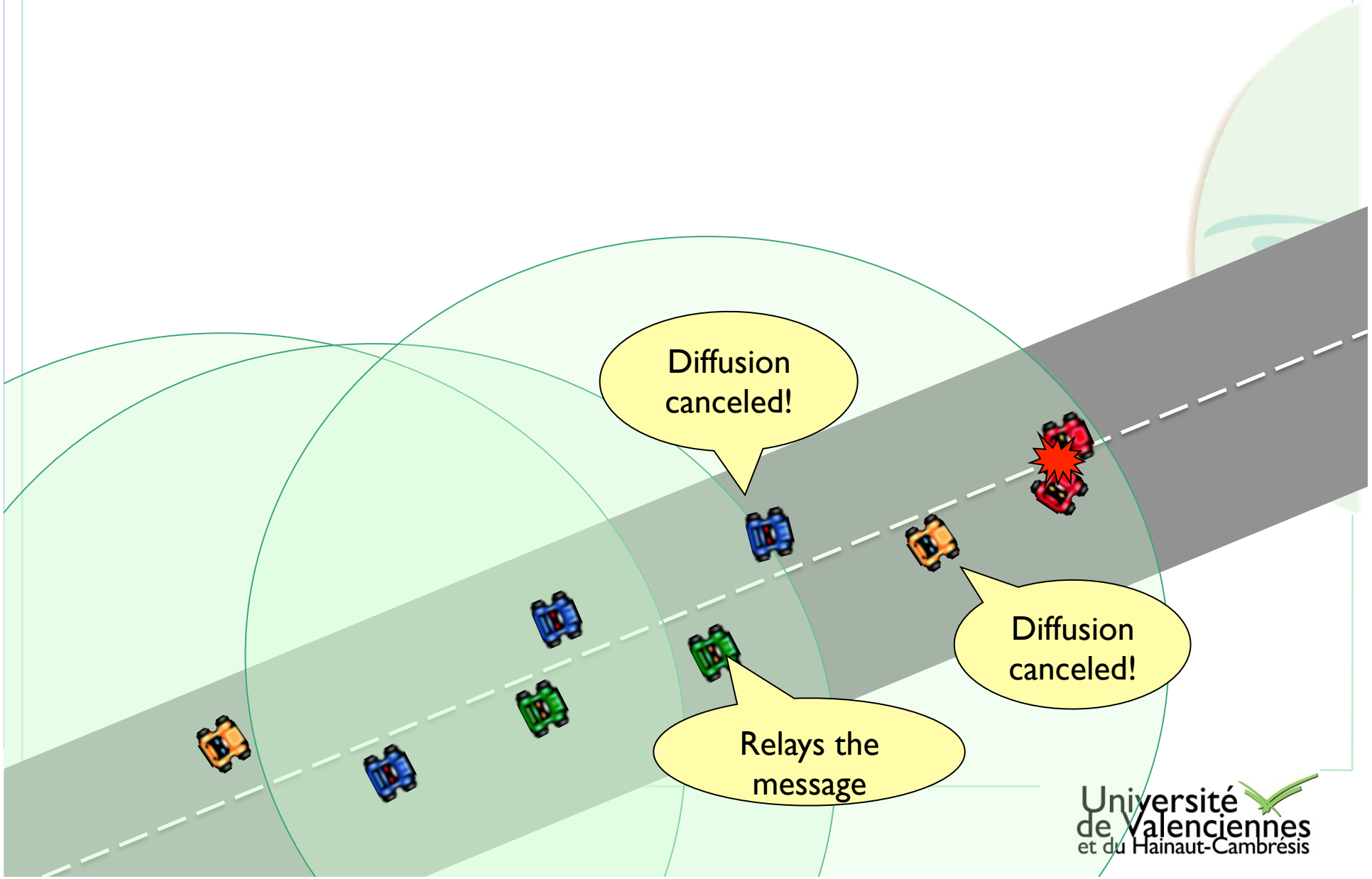
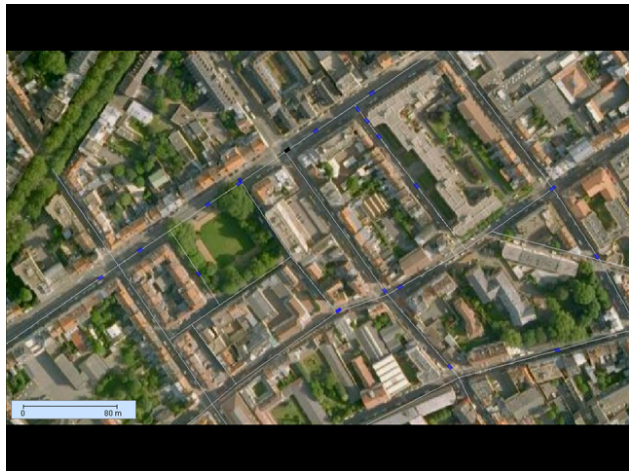
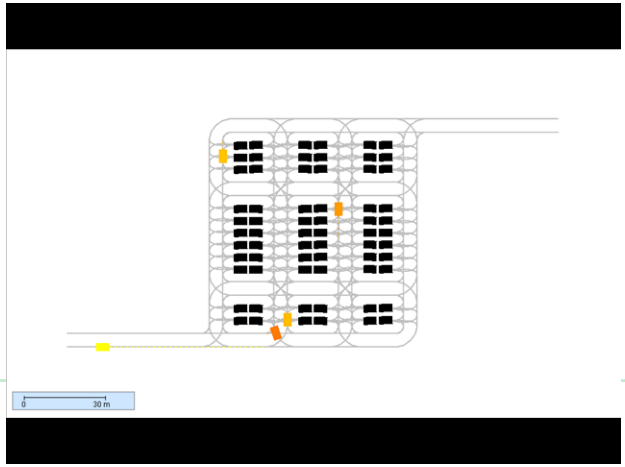


Experimental evaluation

- Prototype
- Simulator
  - With and without maps (roads and parking lots)
- More info:

  [TR-C'10, IEEE Trans. on ITS'11]





Dealing with competition

How to deal with resources?

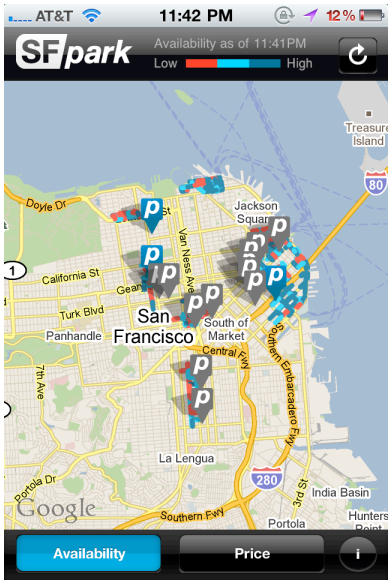
- Some of the elements exchanged are rather resources than events
  - e.g., an available parking space
- Competition among the drivers
  - First arrived, only served…

Resource allocation

- Importance of the problem!
  - Sustainability issues
  - Time lost
  - (Increasing) number of vehicles/drivers concerned
- How to estimate the relevance of a resource?
  - Age
  - Distance (w.r.t. the current position? the final destination?)
  - Probability that other vehicles are driving towards it

Existing approaches

- SFPark



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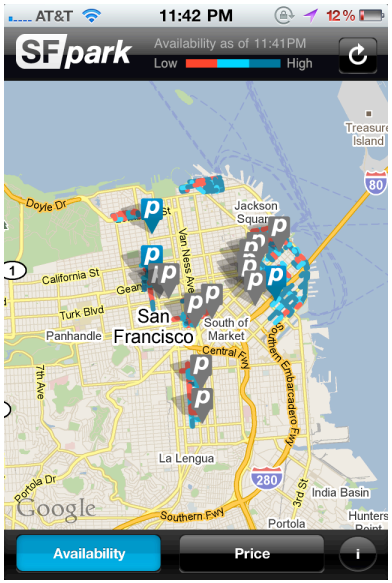
Existing approaches

- SFPark



- Other approaches: Apila, PlaceLib/ShareMySpot

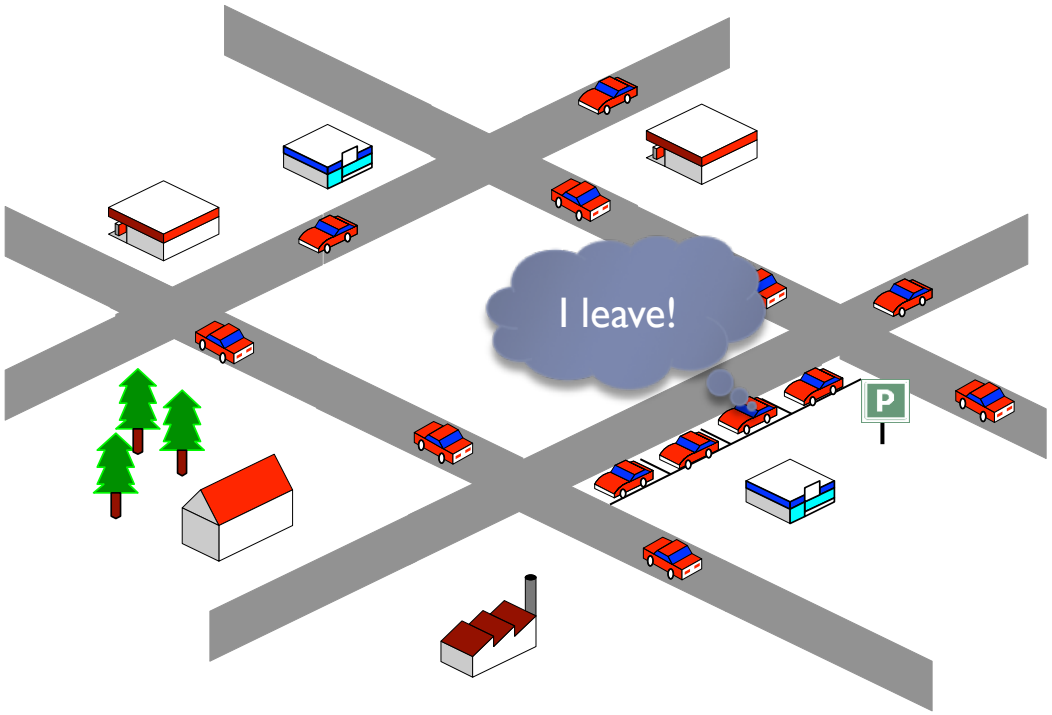
Existing approaches

- Operational Research / Path computation
  - Verroios et al. 2011
  - Do not consider the shortest path to the closest available parking space
  - Determine the best way to visit the parking spots reported to be free
  - Time varying traveling salesman approach
- Centralized approach
  - Ayala et al. 2011 - Parking Slot Assignment Game
  - Centralized solution / optimal cost
  - Game theory / Nash Equilibrium
- Locality-based approach

Our approach

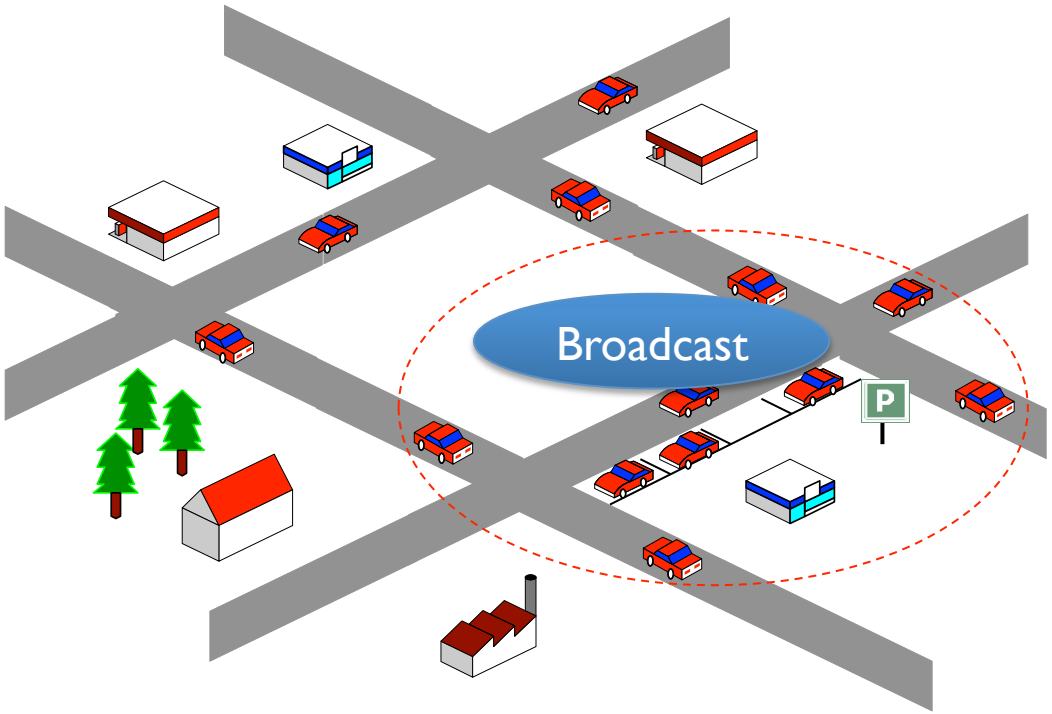
- Objective:
  - "Allocate" a resource to only one driver
- Principle of a reservation protocol:
  - Rely on a coordinator
    - In charge of the allocation of the resource
    - e.g., the vehicle leaving or the sensor monitoring the parking space

Main steps…

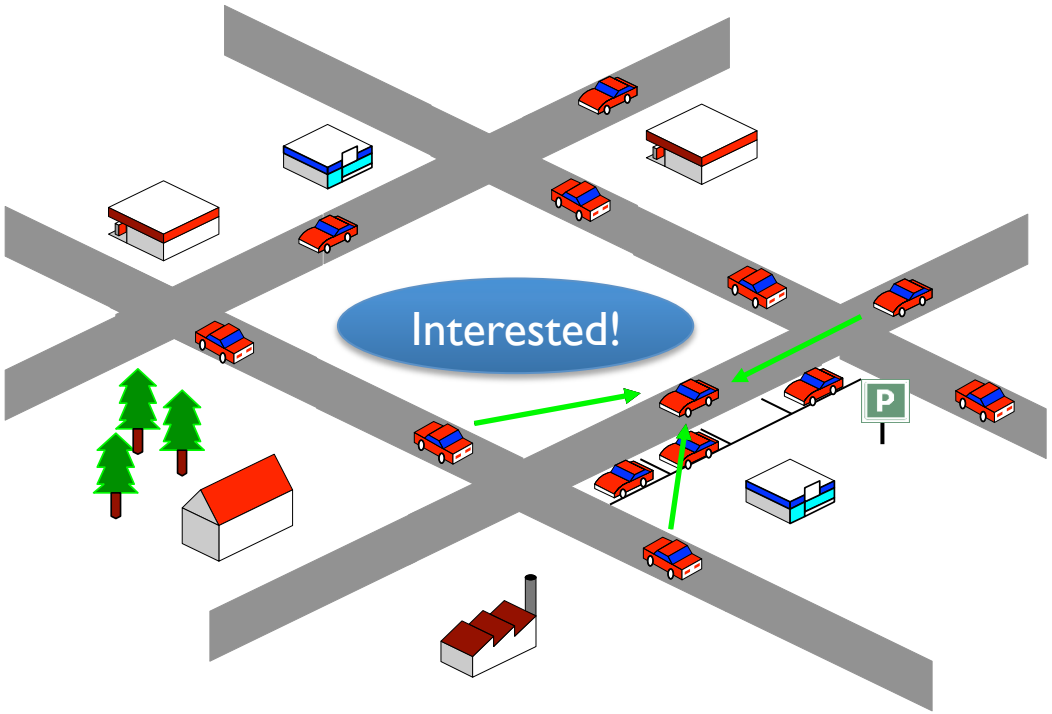


A vehicle leaves a parking space and becomes coordinator for this resource

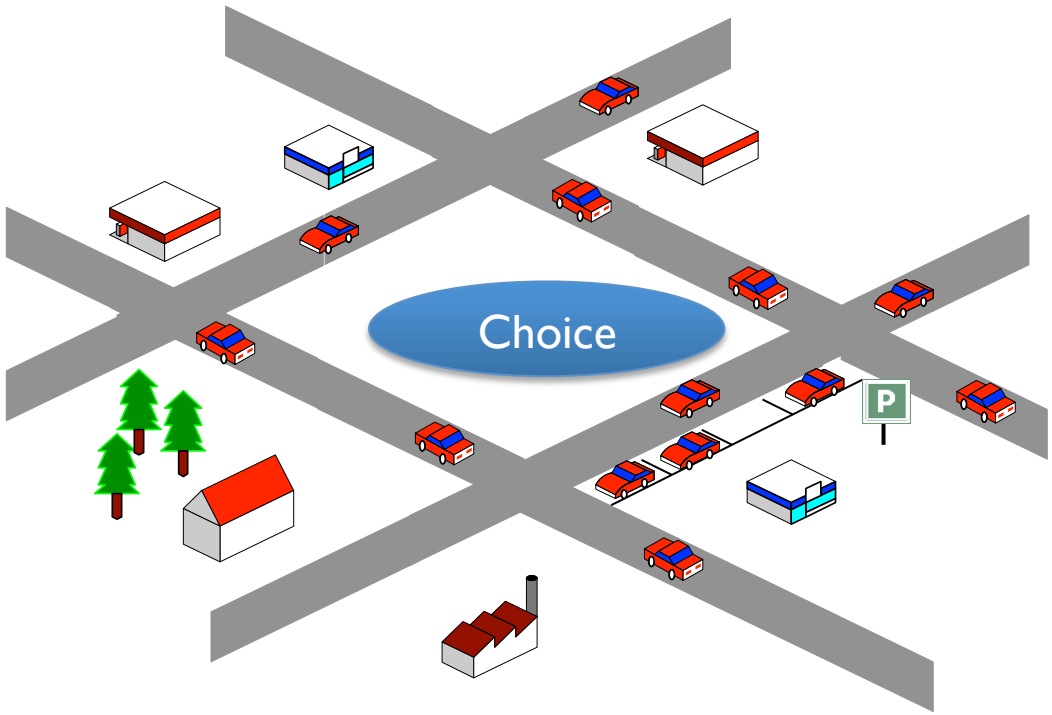
Main steps…



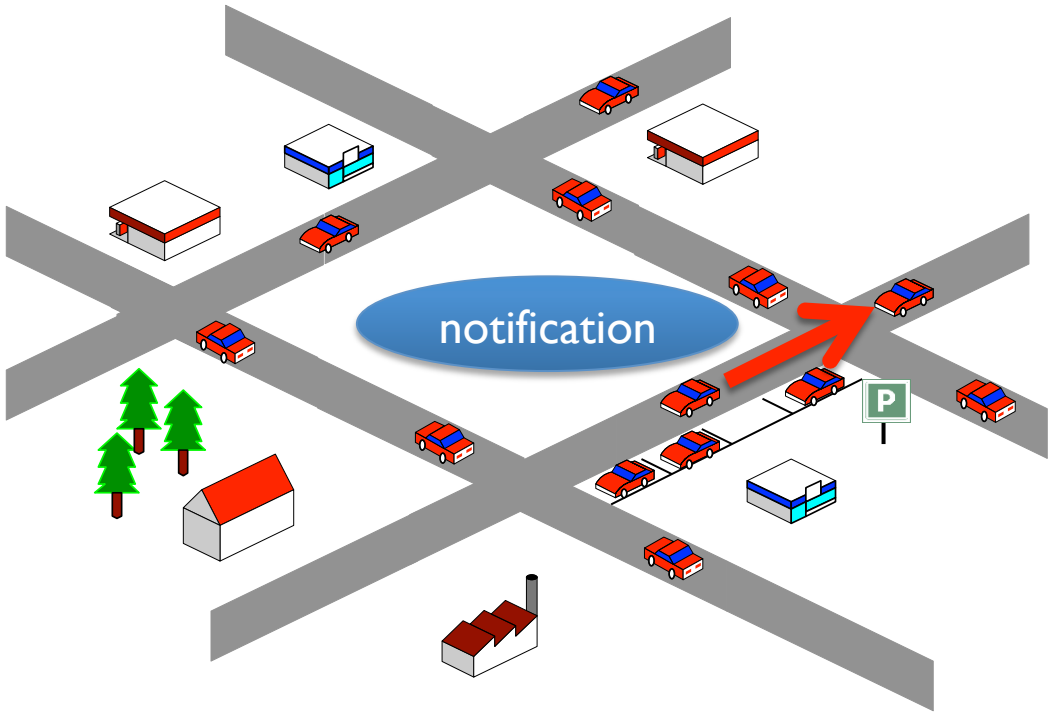
Main steps…



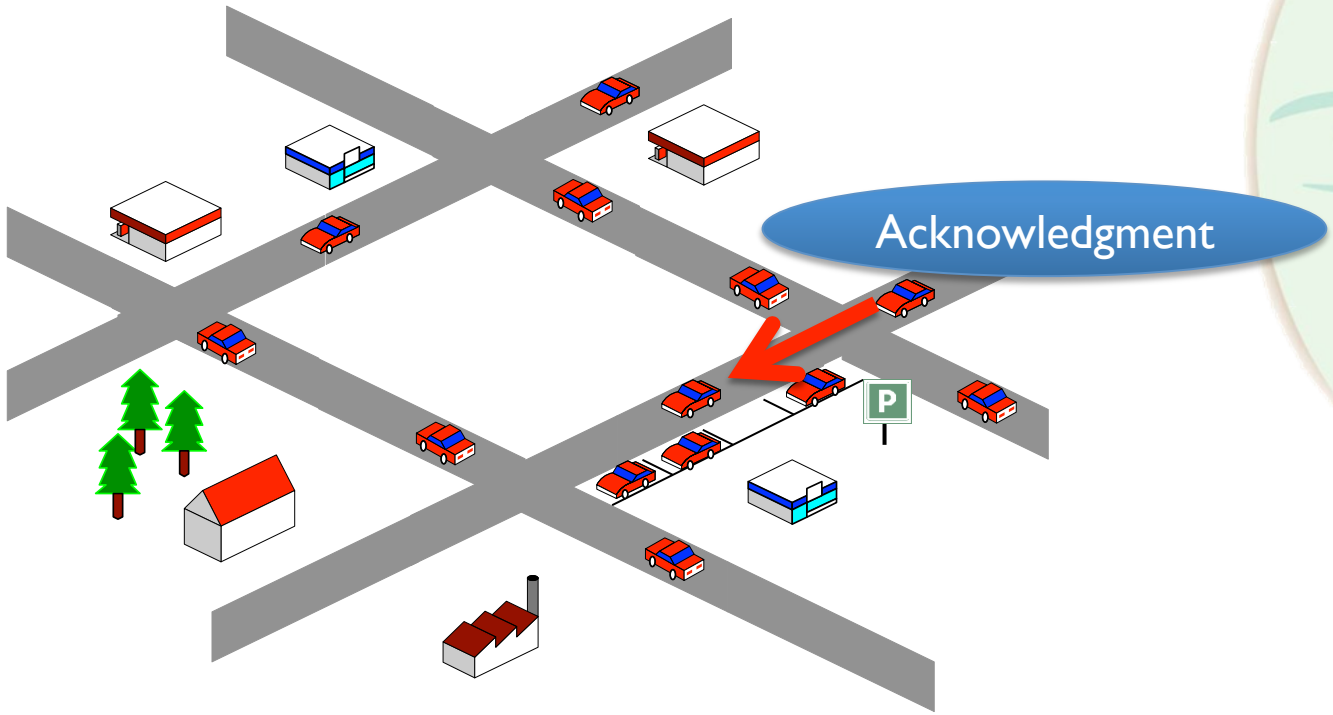
Main steps…



Main steps…



Main steps…



Extending the notification range

- What if there is no interested vehicle in the communication range of the coordinator?
  - Need to communicate the information farther from the resource
    - Use the (possible) mobility of the coordinator
    - Change of coordinator
    - Difference with the usual dissemination in VESPA

Allocation issues…

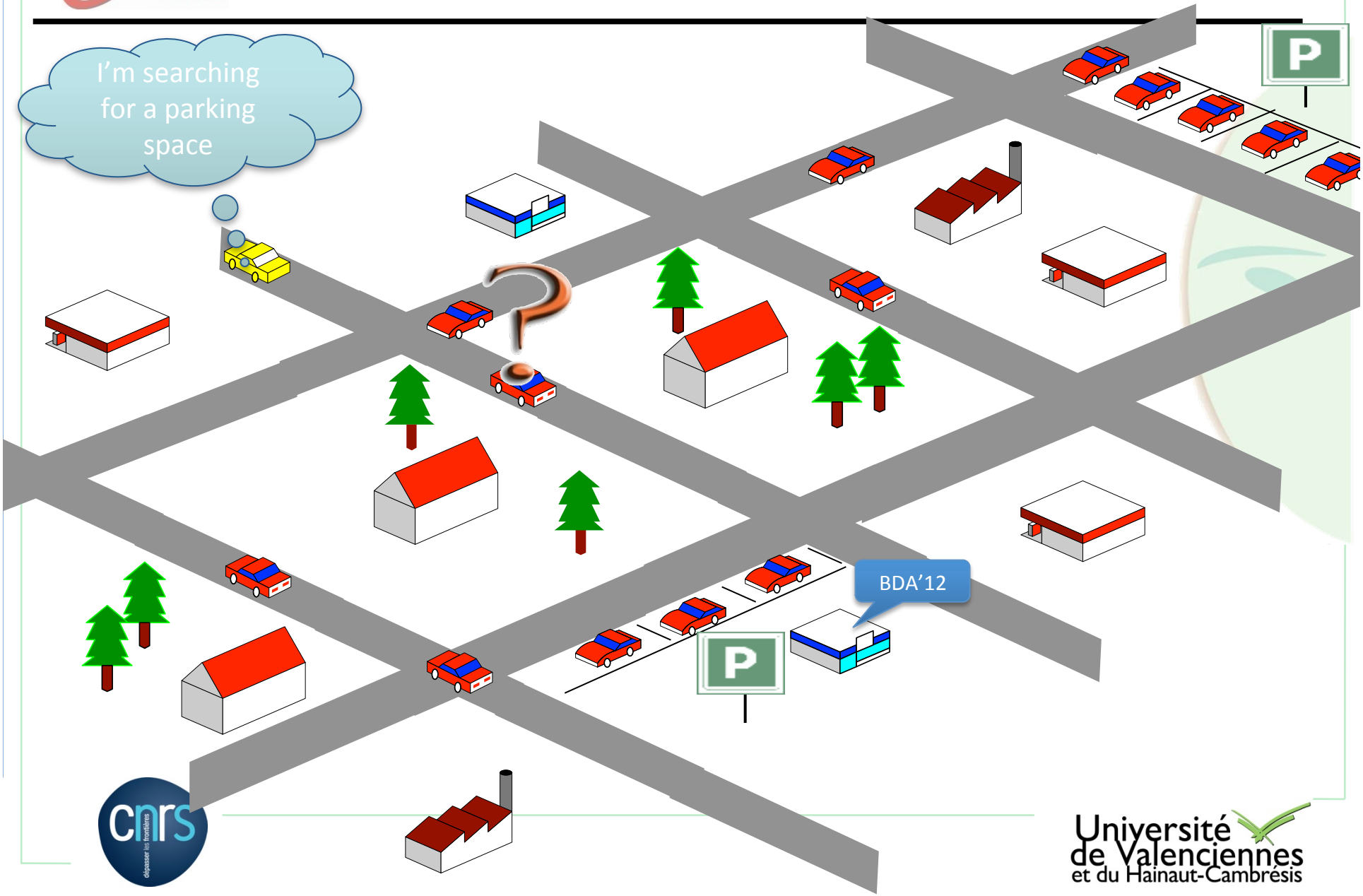
- How to choose:
  - The winning vehicle to which the resource is allocated?
    - Time elapsed since the vehicle started searching for a space
    - Distance to the resource
    - Highest Encounter Probability
    - etc.
  - A new coordinator?

Limitations

- Reliability
  - What if an acknowledgement is lost?
  - No transactional behavior
- Human behavior:
  - No actual reservation: no way to prevent drivers from taking an available parking space they see, even if it was allocated to another one…

Prediction & query processing

What if no information is provided?



Our Approach

- Store and aggregate (summarize) data
  - Do not destroy them once used to warn the driver
  - Major difference with other works on data aggregation for vehicular networks
- Use the summaries generated to extract additional knowledge usable by drivers
  - Estimate the probability that an event occurs in a spatio-temporal area

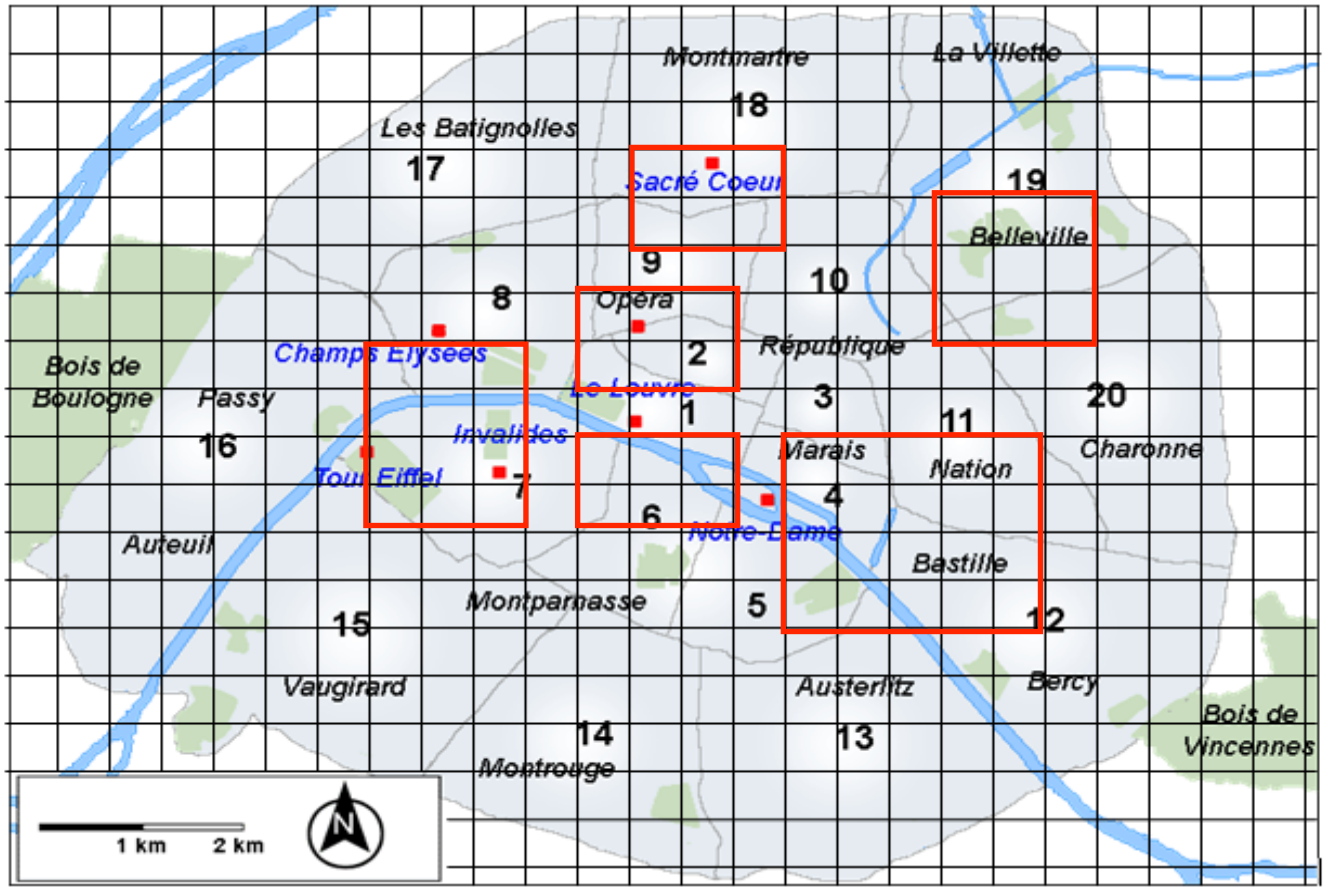
Use cases

- Parking
  - Detect areas where the probability of finding a parking spot is the highest (depending on the day and time)
- Warning
  - Detect dangerous areas by correlation of messages received about accidents and emergency brakings

Properties

- Promote fundamental dimensions that are the location and time;
- Be incrementally constructible and inexpensive in computing time and storage space;
- Allow each driver to choose which types of events is interested in and the spatial and temporal dimensions s/he wants;
- Allow an exchange of summaries between vehicles to enrich their knowledge.

Two levels space model



Spatial Model

Spatio-temporel Model

- *Spatial Model:*
  - ***Physical level:*** cutting the space into squares of fixed size which form a complete partition (exchange level)
  - ***Logic level :*** a set of rectangles which consist of a set of squares of the physical level (driver level)
- *Temporal Model:*
  - Time is divided into segments that form a full partition

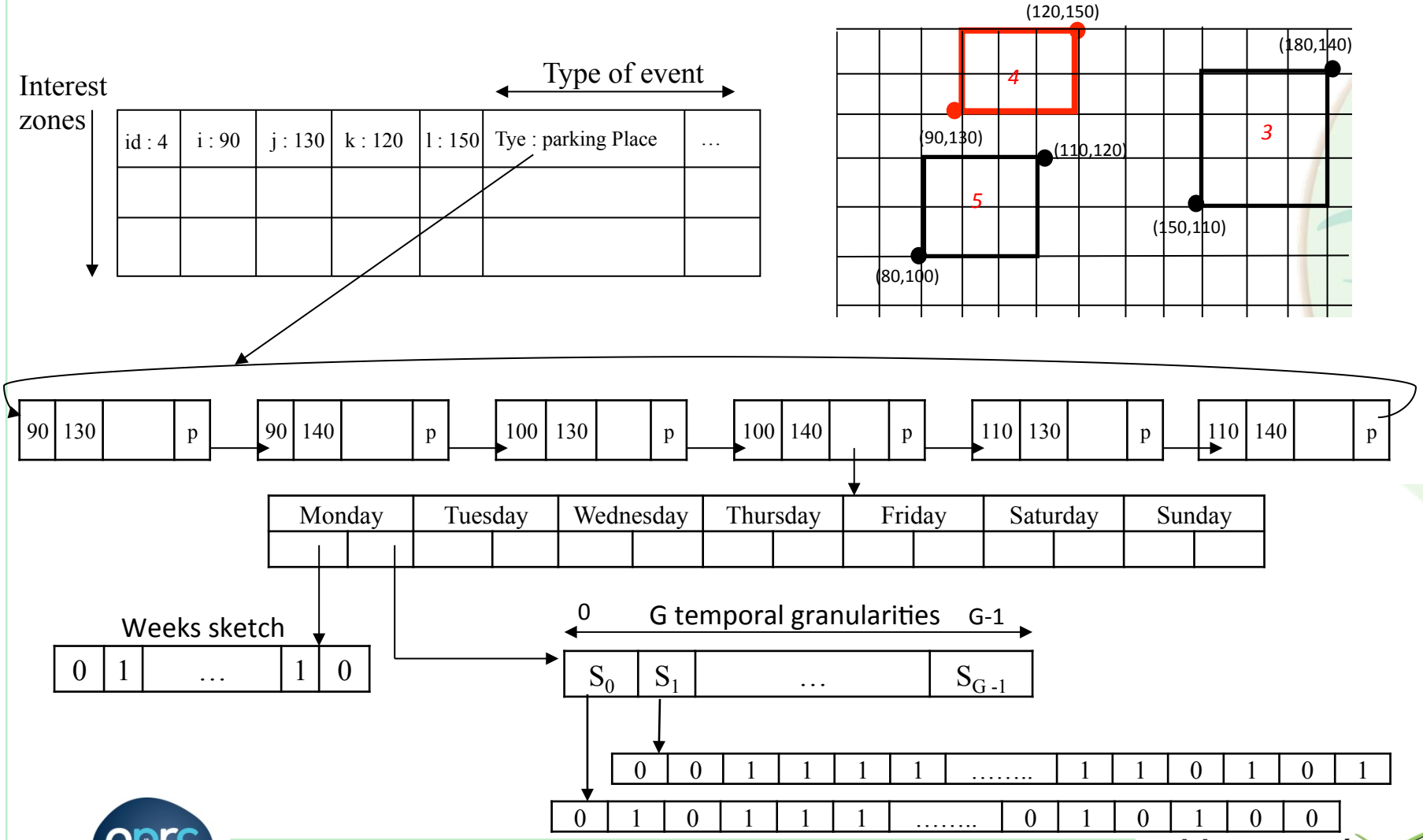
Flajolet-Martin sketches

- Used instead of simple counters

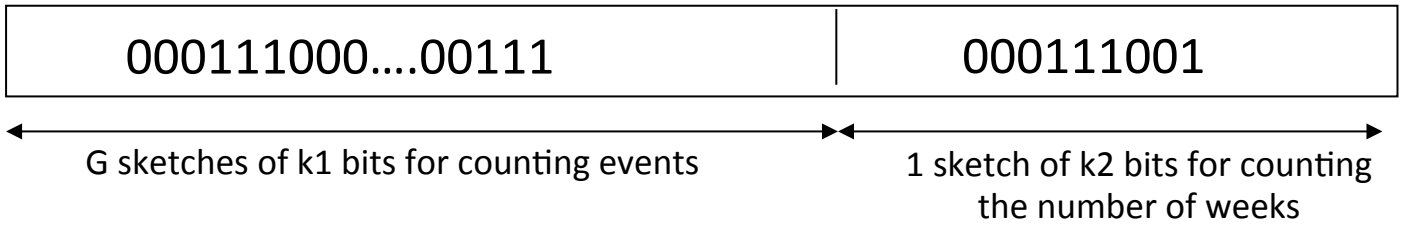
Initial sketch	00111001
h(X) where X is the element to insert into the sketch	01010010
Sketch after insertion	00111011

- Provide a quick but accurate estimation of the number of observations

Data structure



Data structure (2)



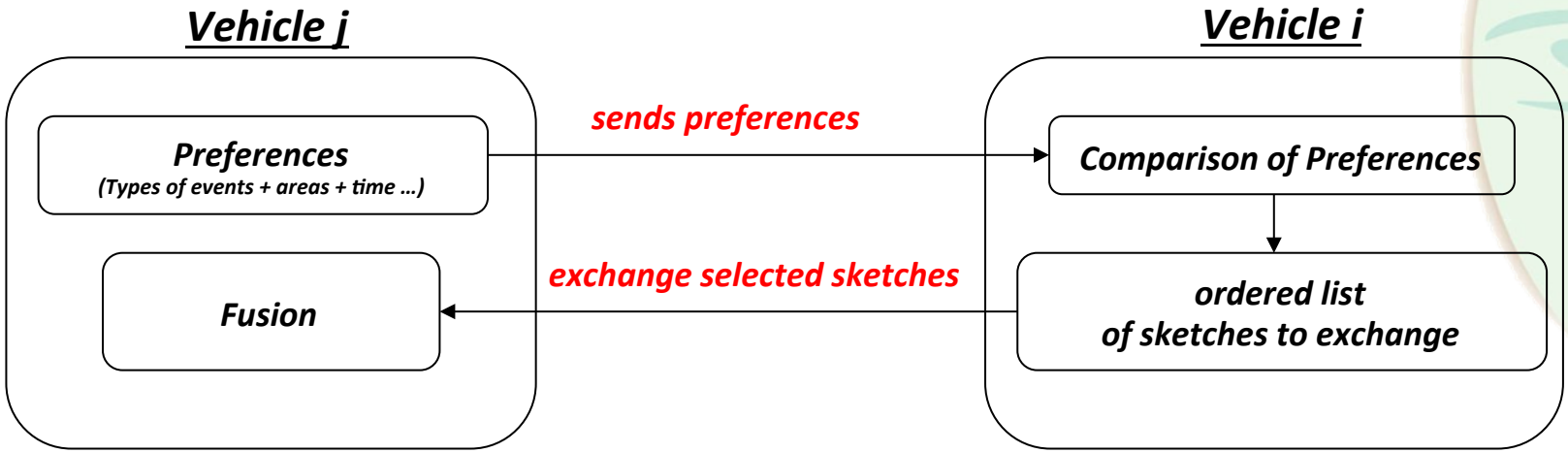
Frequency = number of events / number of weeks

- Temporal + spatial organization
- Detects duplicates
- Compact

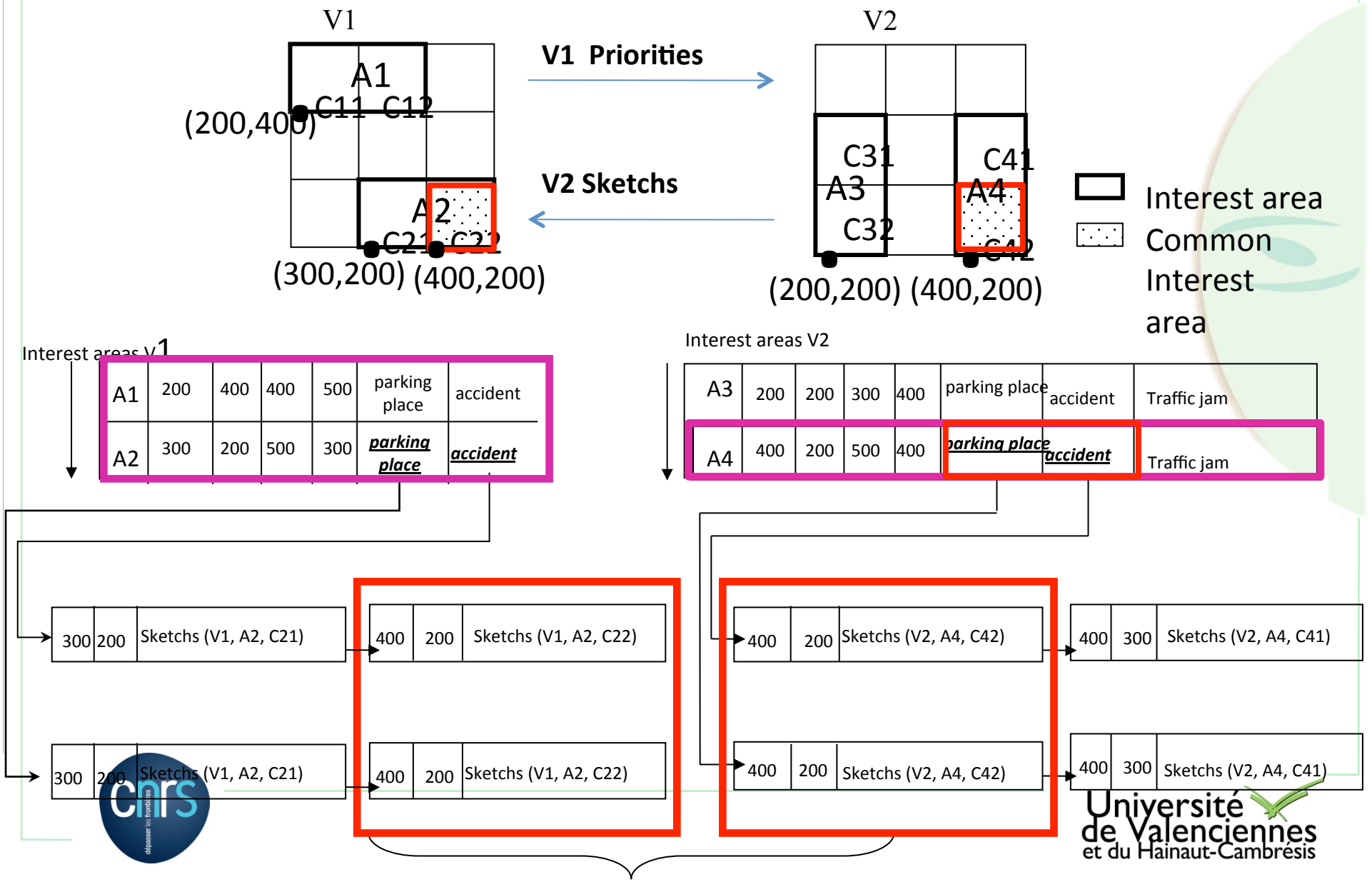
Inter-vehicle exchanges

- Centralized vs. Decentralized use of the summaries
- Each car/driver decides what to exchange and his/her preferences
  - Preferences with priorities
- Duplicate detection is important (I might observe the same events as my neighbor!) → sketch
- Need to know the vehicles with which exchanges have taken place recently (list of identifiers)

General principle



Exchange process


V1
A1
C11 C12
(200,400)
A2
C21 C22
(300,200) (400,200)
V1 Priorities
V2 Sketchs
V2
C31
C41
A3
A4
C32
C42
(200,200) (400,200)
Interest area
Common Interest area
Interest areas V1
A1 200 400 400 500 parking place accident
A2 300 200 500 300 parking place accident
Interest areas V2
A3 200 200 300 400 parking place accident Traffic jam
A4 400 200 500 400 parking place accident Traffic jam
300 200 Sketchs (V1, A2, C21)
400 200 Sketchs (V1, A2, C22)
400 200 Sketchs (V2, A4, C42)
400 300 Sketchs (V2, A4, C41)
300 200 Sketchs (V1, A2, C21)
400 200 Sketchs (V1, A2, C22)
400 200 Sketchs (V2, A4, C42)
400 300 Sketchs (V2, A4, C41)

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INVENTEURS DU MONDE NUMÉRIQUE

Thank you for your attention!

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Université de Valenciennes et du Hainaut-Cambrésis

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