STATE MANAGEMENT IN DISTRIBUTED VIRTUAL ENVIRONMENTS: A VORONOI BASED APPROACH

Laura Ricci, Luca Genovali
Department of Computer Science
University of Pisa, Italy

PRESENTATION OUTLINE

- Voronoi Overlays: general features
- State Management in Voronoi-based Distributed Virtua Environments
  - Objects ownership
  - Persistency
  - Consistency
  - Optimizations: Forced Coordination Area
- Experimental Results

VORONOI BASED OVERLAYS

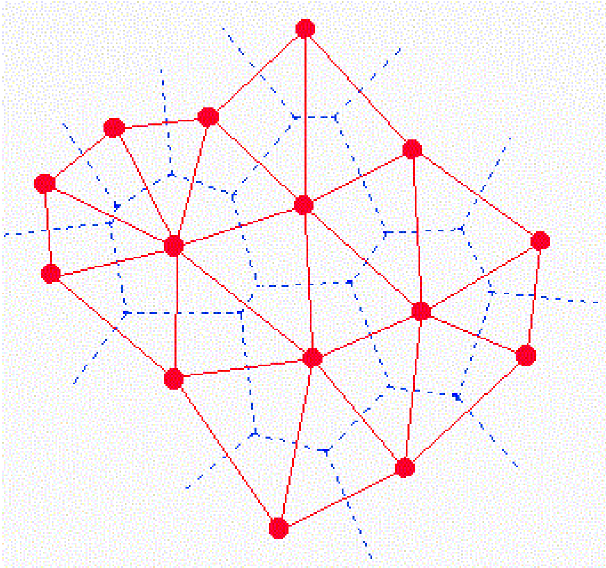
- Let $P = \{p_1, \ldots, p_n\}$ be a set of n distinct peers (sites) in a 2(3)-dimensional space S.
- Voronoi tessellation: partitions S into n regions $V(p_j)$, $j \in 1..n$, paired with each $p_i \in P$, where $V(p_j)$ includes all the points q such that:

  $$dist(q, p_j) \leq dist(q, p_i) \text{ for } i \neq j$$

- Delaunay Triangulation connects two Voronoi regions sharing a border (Voronoi neighbours)

  O(1) neighbours in 2-dimensional spaces

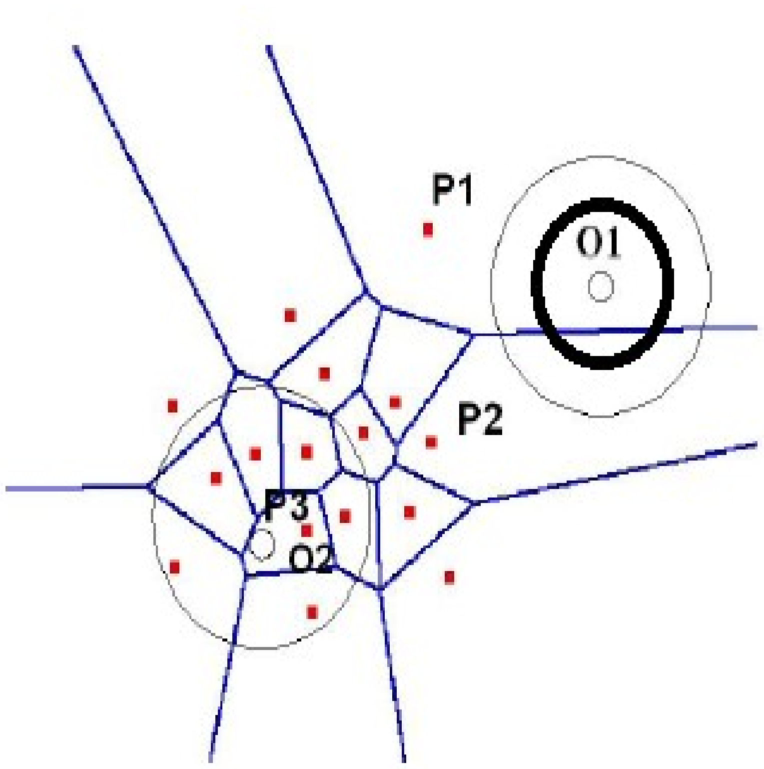
- Overlay Connections = Delaunay links
- Geometrical properties of Delaunay Triangulation may be exploited to define efficient routing strategies
  - Compass Routing
  - AOI-cast



PASSIVE OBJECTS MANGEMENT

- DVE Passive objects are characterized by a state
  - a door may be opened/closed
  - the level of a potion in a glass may change because an avatar drinks it
- In a pure P2P environment, peer should cooperatively manage the state of the objects
- Main idea: exploit the Voronoi tessellation to define a mapping of the passive objects to the peers
  - the coordinator, or owner of a passive object O, is the peer P whose Voronoi region includes O
  - the ownership of an object changes during the DVE evolution, because of the movement of the peers
  - Ownership is always delegated
- Optimization: define a set of strategies to reduce the number of ownershio changes in crowded regions

PASSIVE OBJECTS OWNERSHIP



- The owner of the object O1 is the peer P1 because it includes O1 in its Voronoi Area
  - P1 is the owner of O1 even if it cannot modify O1

Each object O is paired with

- Visibility Area of Interest ViAoI: (larger circle) portion of the DVE where O may be perceived

- Interaction Area of Interest IAoI (smaller circle) portion of the DVE where a peer must be located to interact with O

OBJECT PERSISTENCE

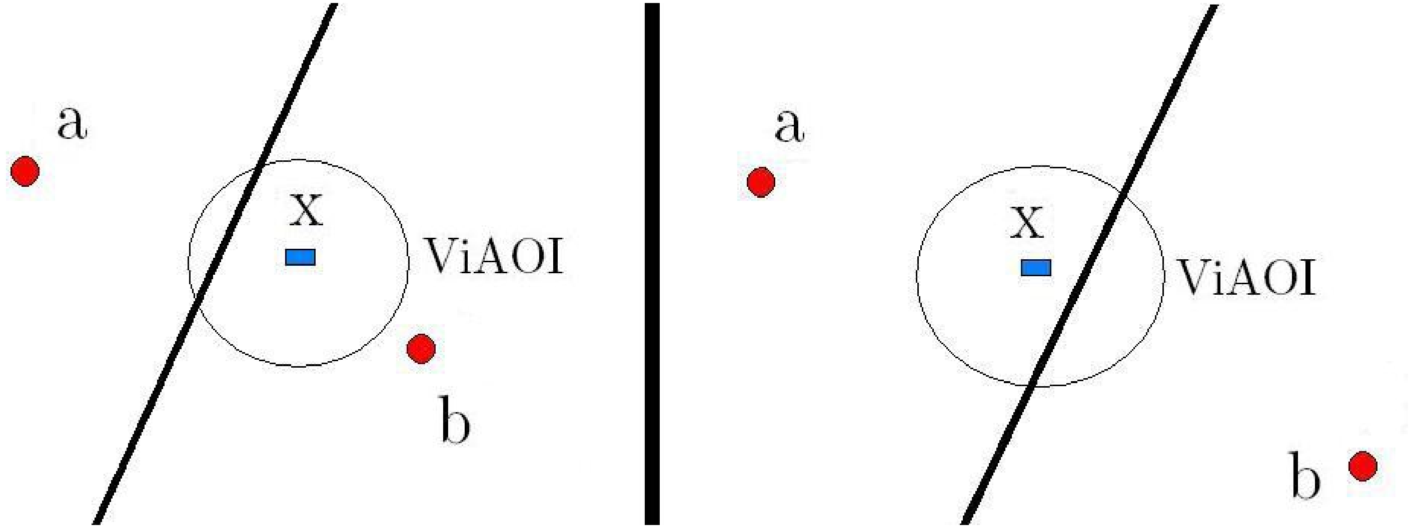
- The owner of an object may crash or voluntarily leave the overlay
  - churn problem

- The state of an object must be replicated onto a set of peers

- Replication is required by the game semantics
  - on object must be replicated onto any peer in its ViAoI, but....
  - the ViAoI of an object does not include any peer if the DVE is scarcely populated
  - further mechanisms are required to guarantee object persistence

- OwnerShip forecast: Voronoi Diagrams are exploited to detect the peers where the object should be replicated

OWNERSHIP FORECAST (1)

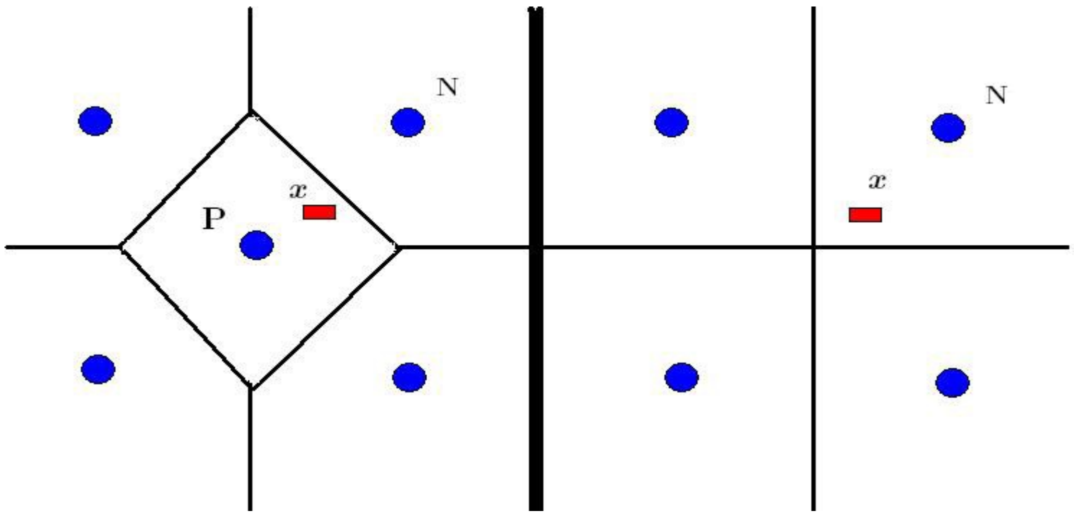


A peer replicates an object O onto its Voronoi neighbours, even if they are not in the ViAoI of O

Peer b sends the state of X to a, even if the ViAoI of X does not include neither b nor a

a may recover the state of X in case of a sudden crashes of b

OWNERSHIP FORECAST (2)



The owner of an object x:

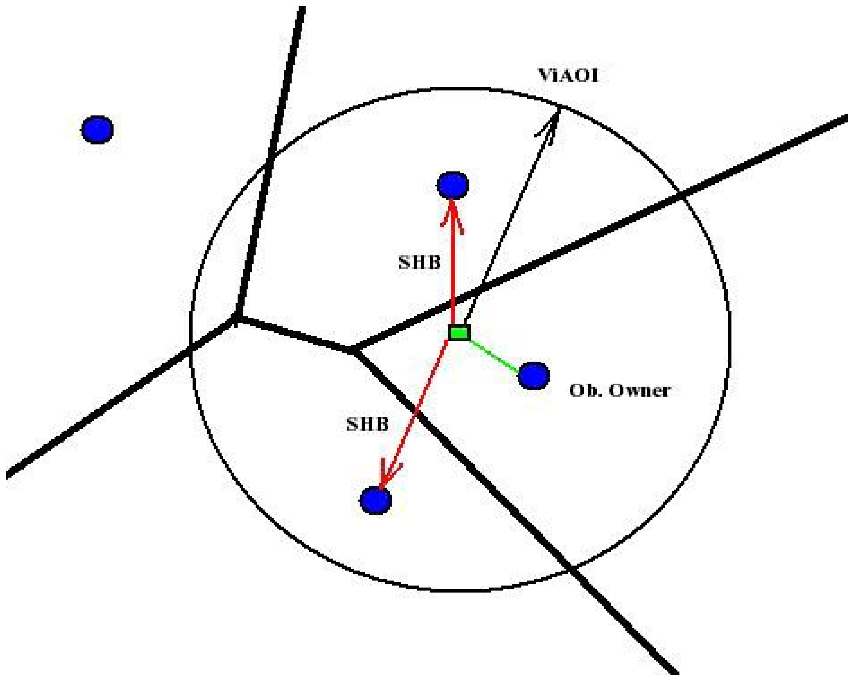
- computes a Voronoi Diagram including all its neighbours, but not itself
- detects which would be the owner of the object in the case of its crash
- replicates the object on this peer

A sequence of Voronoi diagrams corresponding to different levels of replications may be computed

OBJECT CONSISTENCY

- the owner P of an object O acts as a temporary server for O
- the owner P of an object O
  - receives the updates performed on O by the peers in the IAoI(O)
  - modifies the state of O
  - broadcasts the updates to each peer belonging to ViAoI(O)
- updates are notified through static heartbeats
  - are generated when an object is modified/created
  - differ from dynamic heartbeats which are generated periodically to notify the movement of the peers
  - are propagated through the Delaunay overlay
  - AOI-cast defined by exploiting reverse compass routing

STATIC HEARTBEAT PROPAGATION



The owner of the object sends the state of the object O to the other peers in the ViAoI of O through a static heartbeat

OBJECT CONSISTENCY

- Each peer in the IAoI of an object may modify it
- A set of strategies must be defined to resolve conflicts due to concurrent updates
- Strong consistency models vs. optimistic consistency models
- Different models may be exploited according to the object semantics
- Different types of objects
  - the big walls of a fortified city must be consistent to avoid that the player enter the city through a closed door
  - the state of the non player characters may be temporary inconsistent during the battle

OBJECT CONSISTENCY

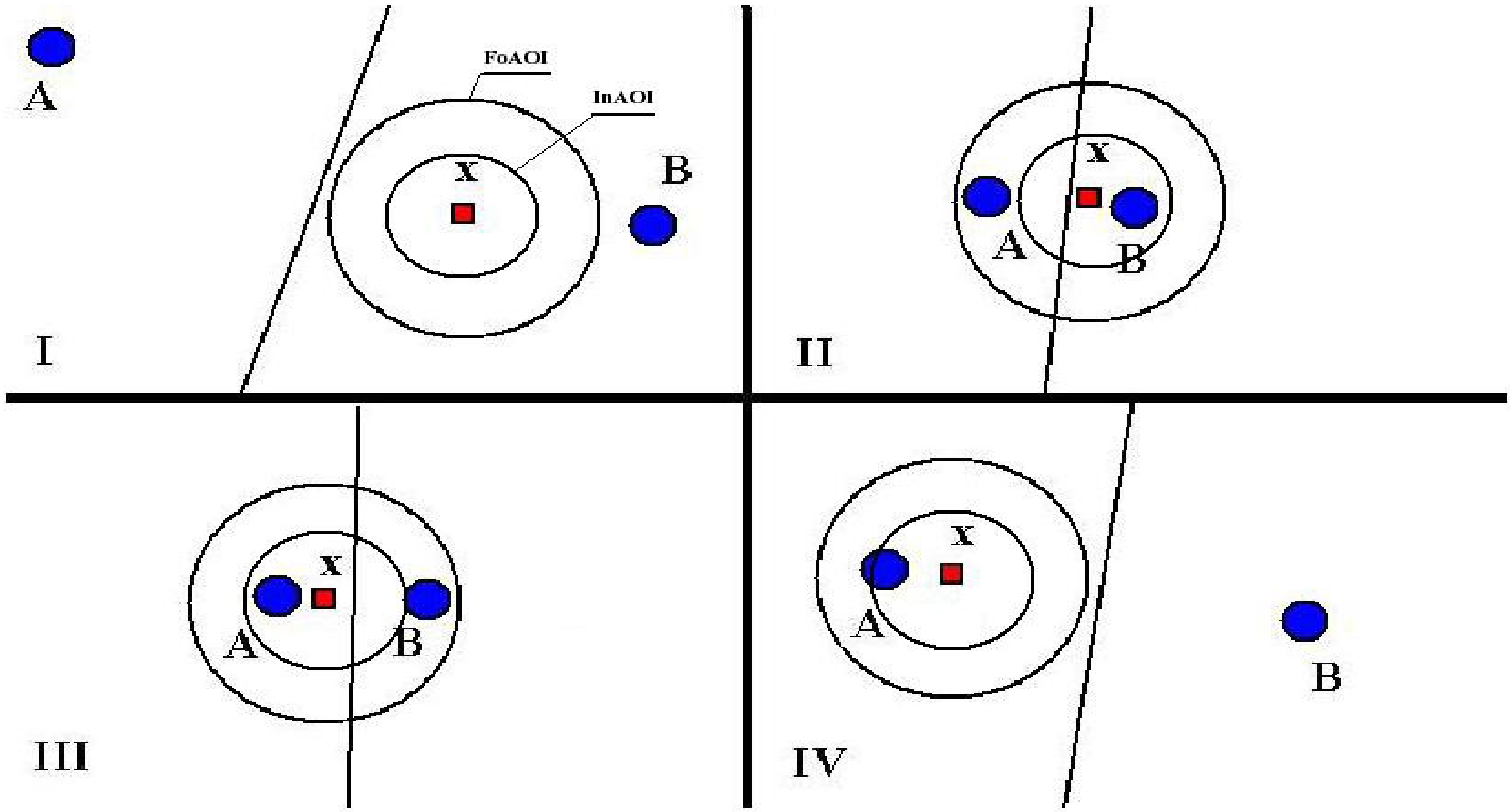
An optimistic approach for the maintainance of the consistency:

- the state of an object O is replicated at each peer in the ViAoI of O
- each peer P modifies its local copy of the object
- the update must be committed by the owner of the object
- if the update is committed, a positive acknowledgment is sent to P which renders the object on the user interface
- otherwise a negative update is sent to the owner of the object and the update is retried

FORCED OWNERSHIP

- ownership is always delegated
- a ping pong effect may occur, expecially in crowded areas
- a pair of Voronoi neighbours may continuosly exchange an object O, due to their movement, because their common Voronoi edge steps over the object
- introduction of the Forced Coordination Area of Interest (FCAoI)
  - an area centered at the object
  - the owner does not delegate the ownership of an object if it belongs to the FCAoI, even if the object is not located in its Voronoi Area

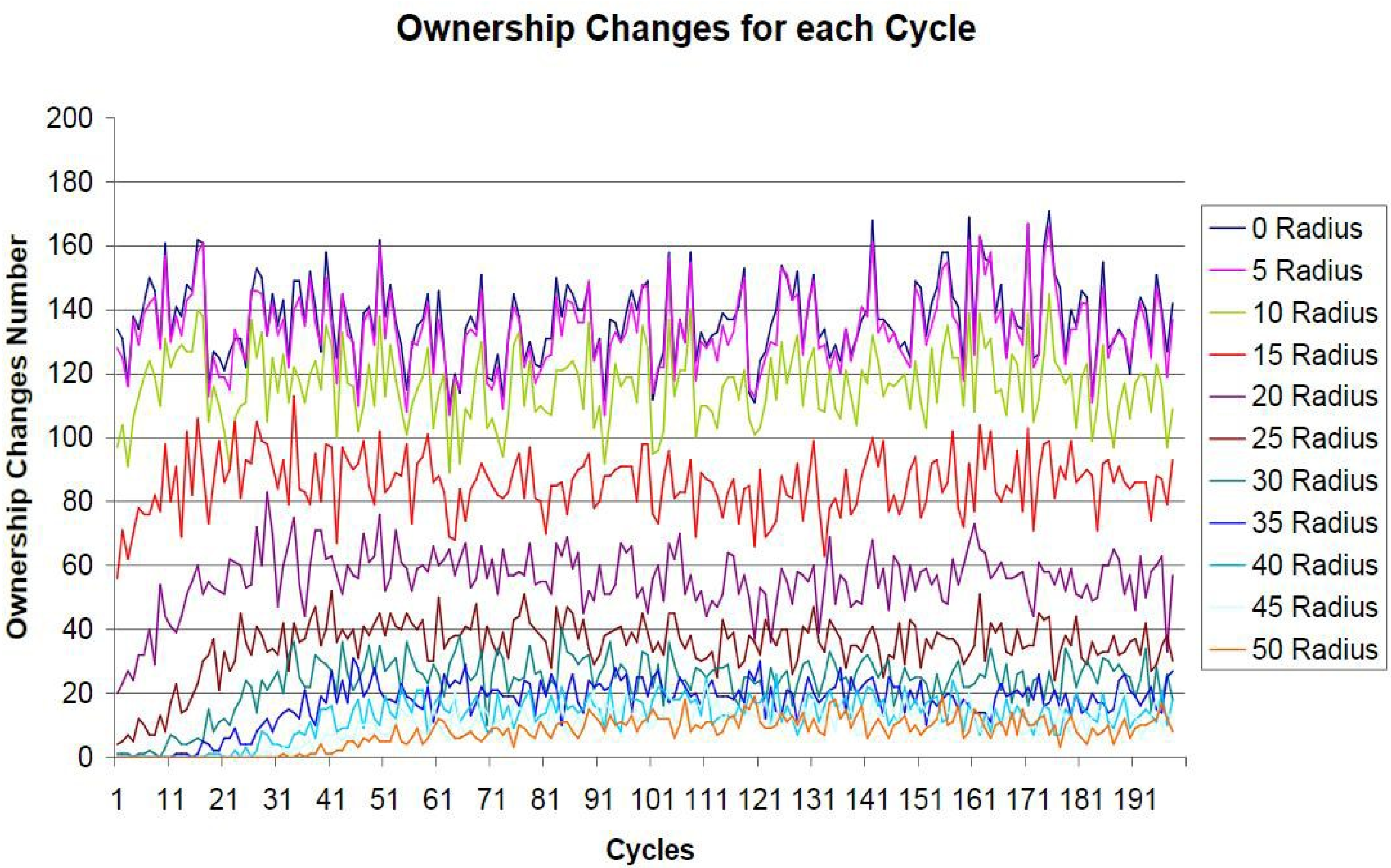
FORCED OWNERSHIP



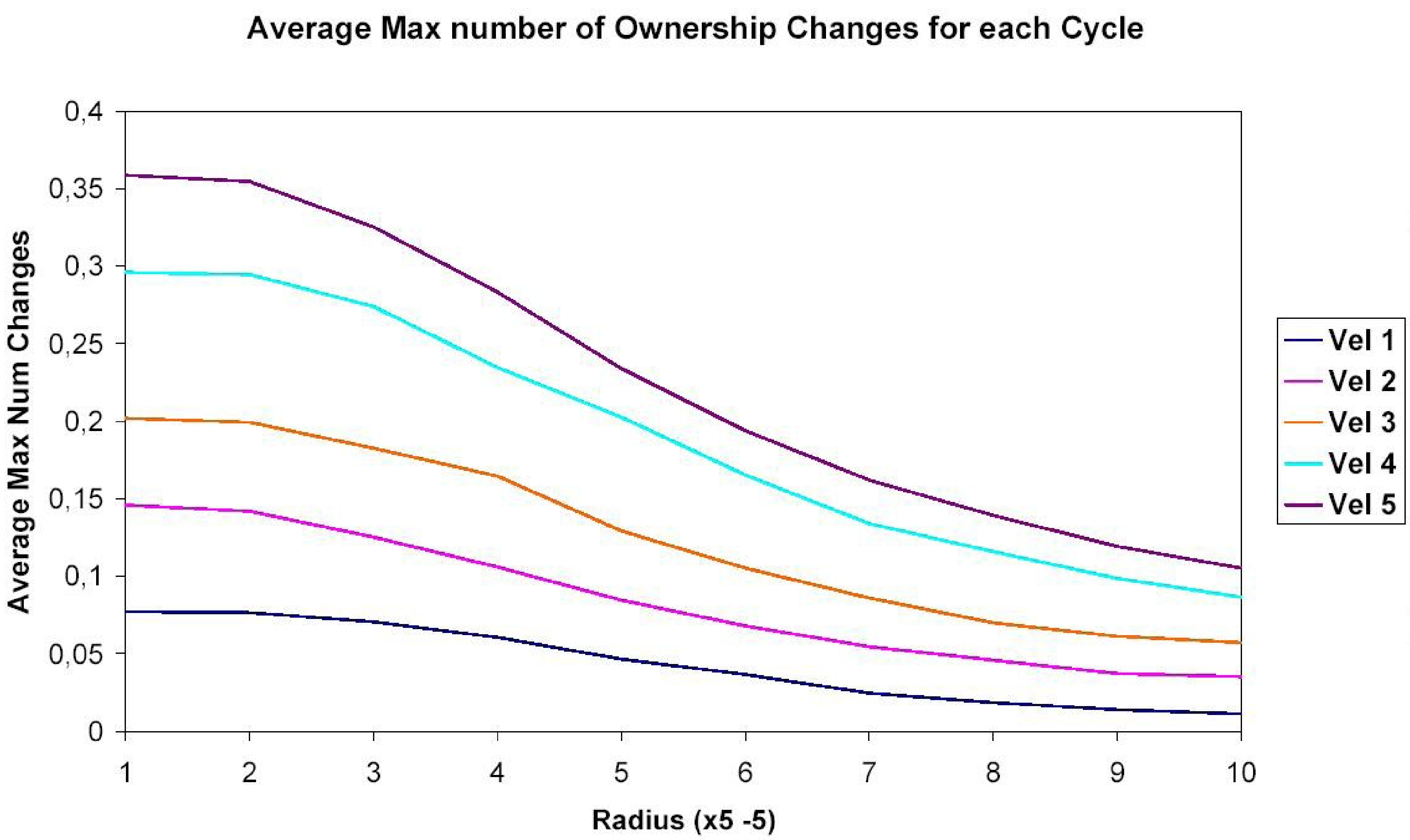
EXPERIMENTAL RESULTS

- a set of simulation developed through Peersim, a scalable simulator for testing P2P overlays
- 1000 peers, 3000 objects
- random movement of the peer within the Dve
- our goal: evaluate ownership changes as a function of
  - Peer speed
  - Radius of the Forced Coordination Area

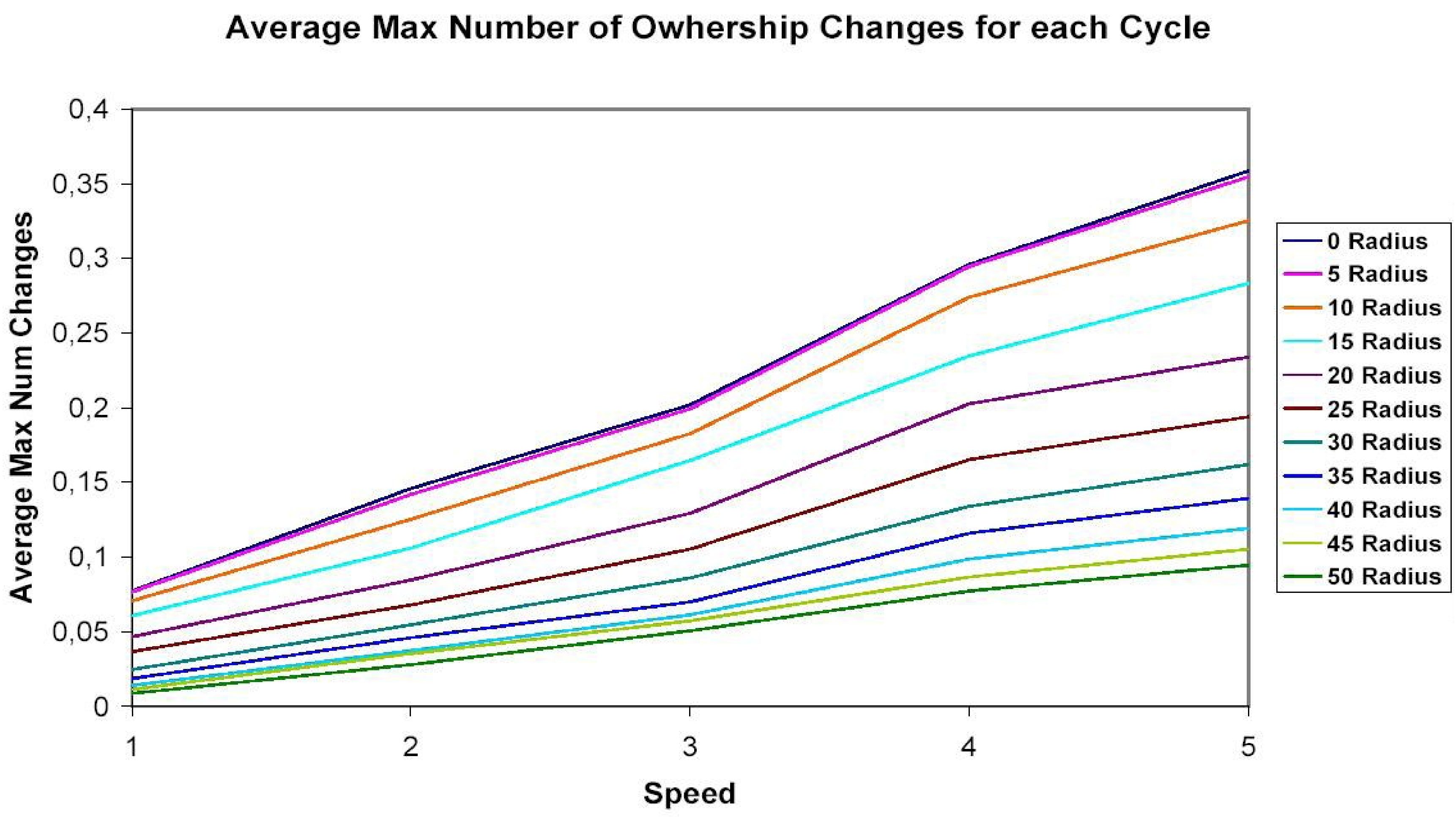
EXPERIMENTAL RESULTS



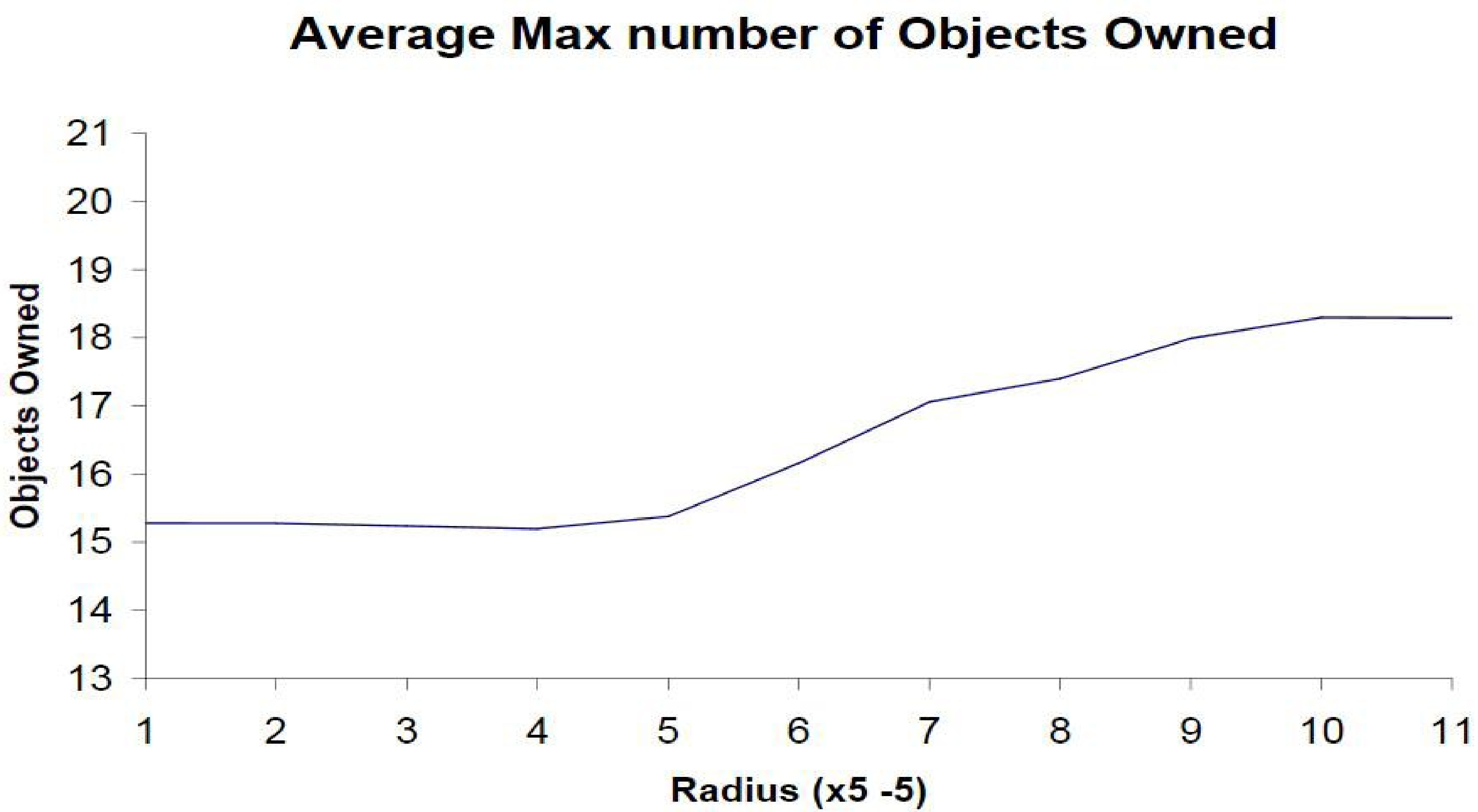
EXPERIMENTAL RESULTS



EXPERIMENTAL RESULTS



EXPERIMENTAL RESULTS



CONCLUSIONS

- A Voronoi based approach for the management of passive objects
- Voronoi diagrams are exploited for defining
  - objects ownership
  - object persistence
- Optimizations for reducing ownership changes
- Optimistic consistency strategies
- Future work
  - investigate further optimistic consistency models
  - implementation on a real platform