Programming Agent-Based Demographic Models with Cross-State and Message-Exchange Dependencies: A Study with Speculative PDES and Automatic Load-Sharing

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Context

- We study the interactions of ABM run on top of PDES Systems
- We concentrate on shared-memory multicore systems

- The average degree of interaction in ABM can be significantly higher than in other scenarios
- We want to be able to detect these interactions
- We want to exploit them to increase the overall performance

- Interactions can be explicit or implicit (thanks to ECS)

Event Cross-State Synchronization [PADS 2014]

- Event-Cross State Synchronization (ECS) allows multiple LPs to exchange information via in-place memory accesses

- LPs do not need to be disjoint entities anymore
- Exchange of large amount of data is faster
- Allows for a simpler programming model

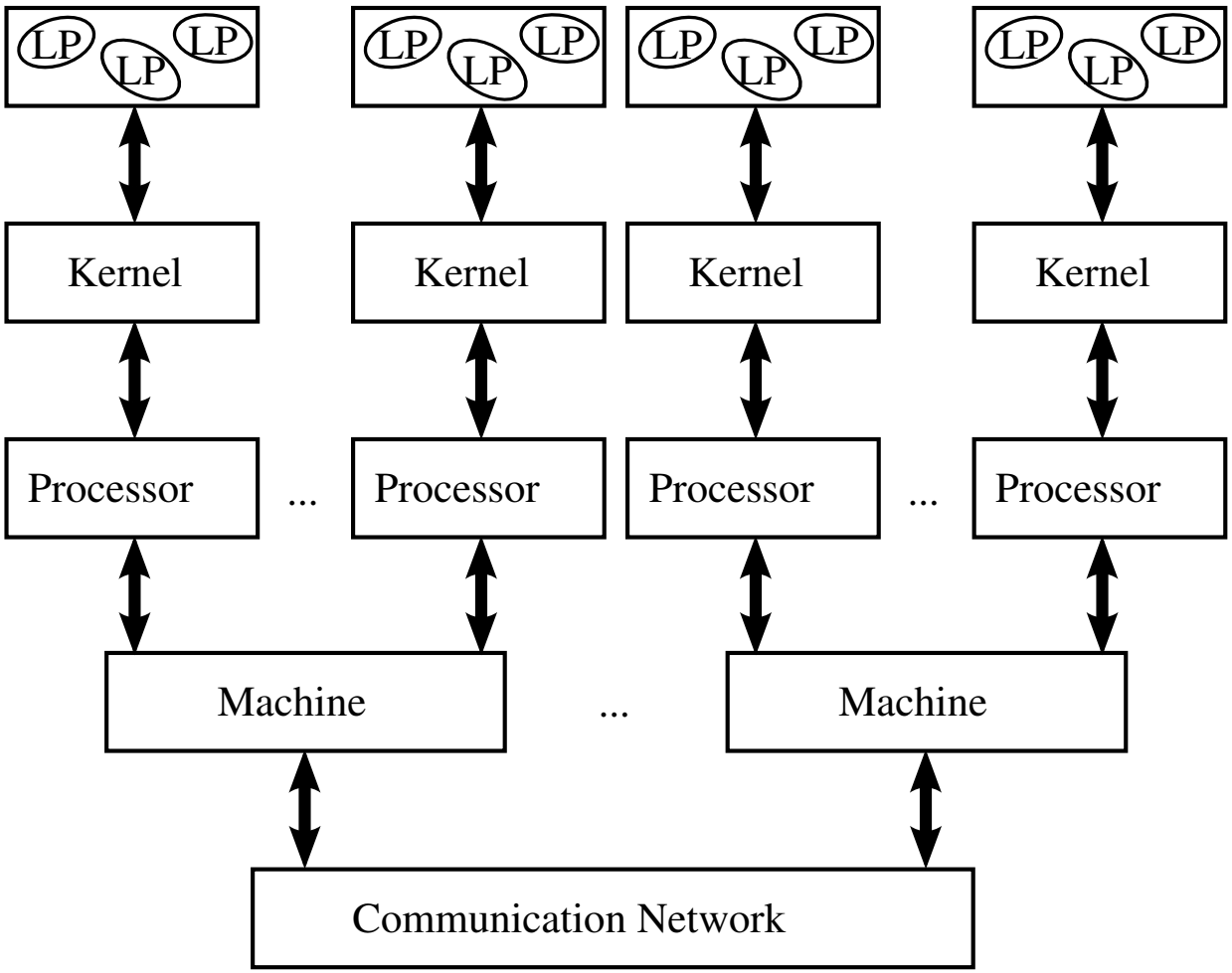
- Syncrhonization with ECS can be costly
- This is even more the case when LPs cross-synchronize a lot
- Load-Sharing can significantly reduce the cost

Contributions

1. We clearly specify agent-based programming guidelines for demographic simulations to be run on top of PDES
   - This is done by proposing a general skeleton model

2. We tackle the complex interaction pattern often exhibited by ABM, to enforce load sharing
   - Performance can be increased
   - All types of interactions should be captured

Reference Target Architecture



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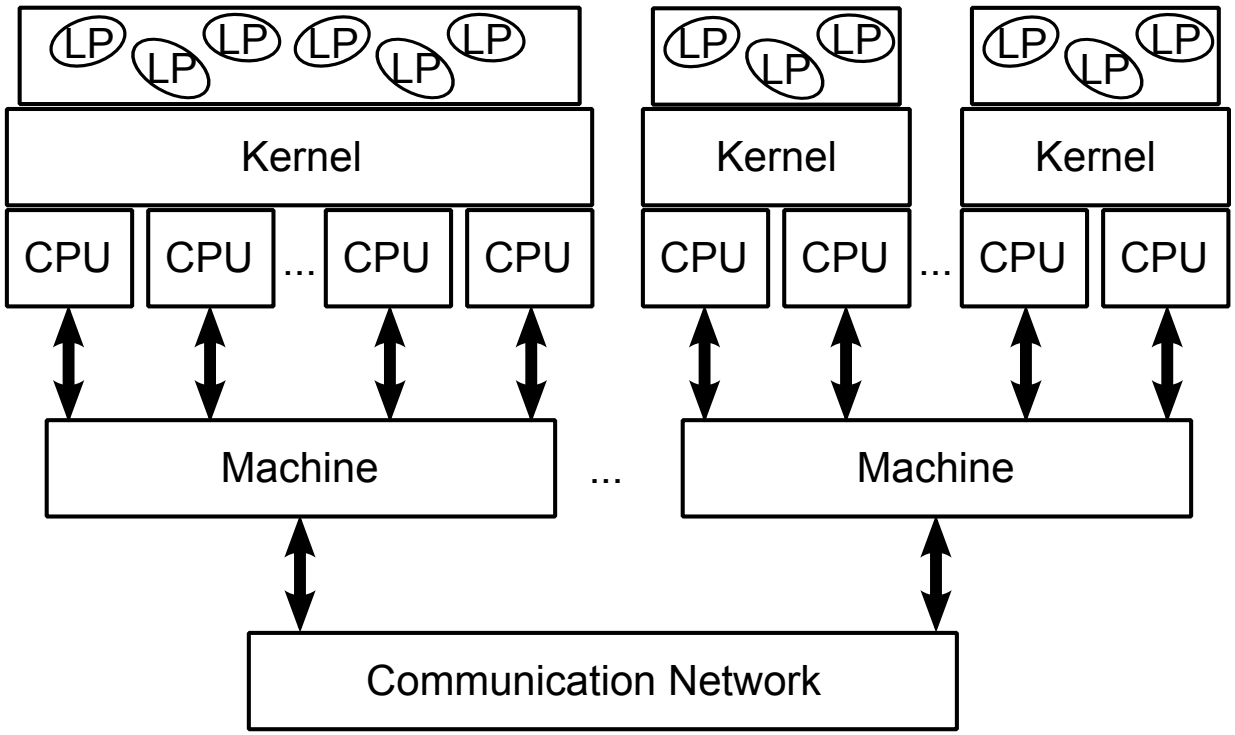
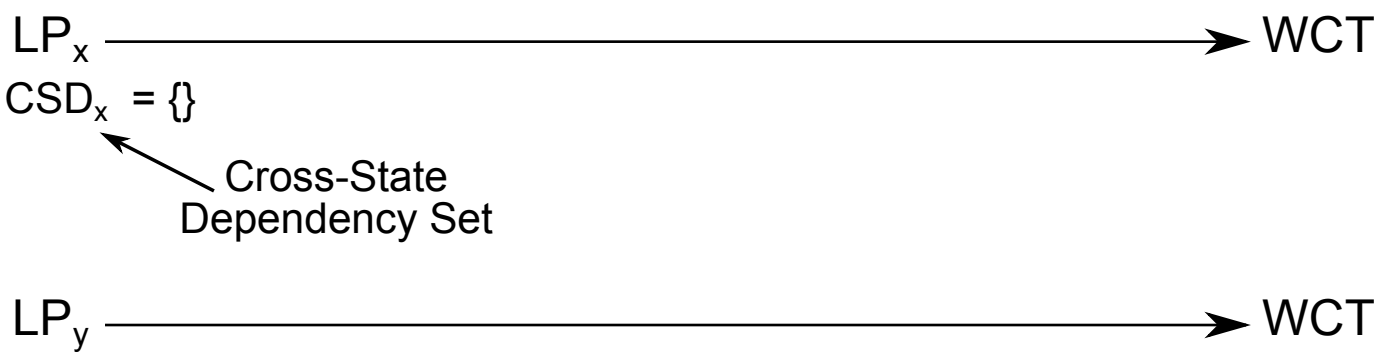


Event Cross-State Synchronization [PADS 2014]



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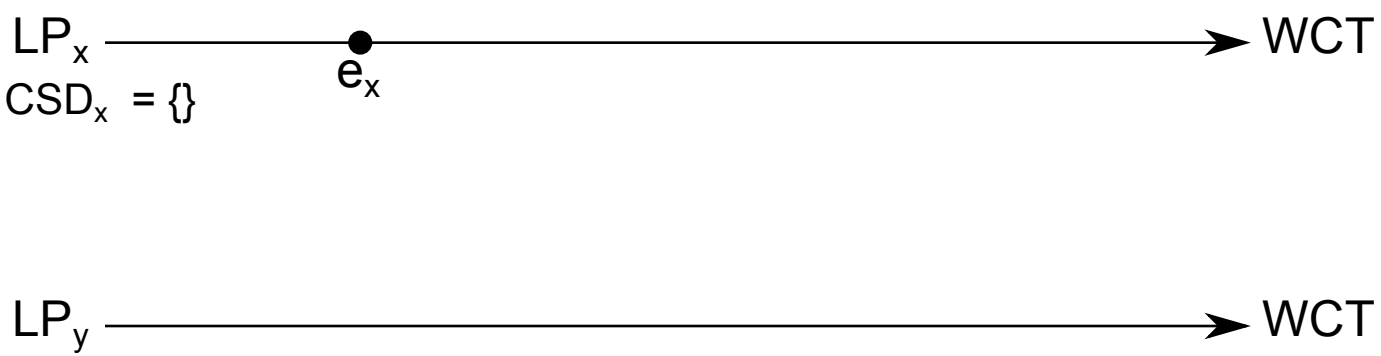

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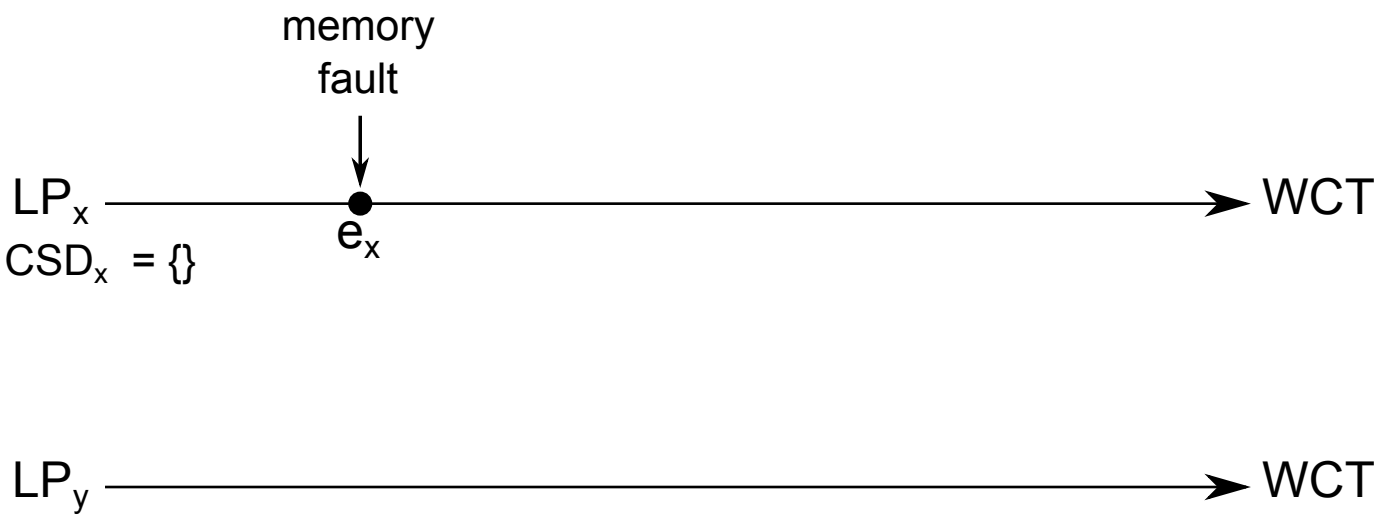

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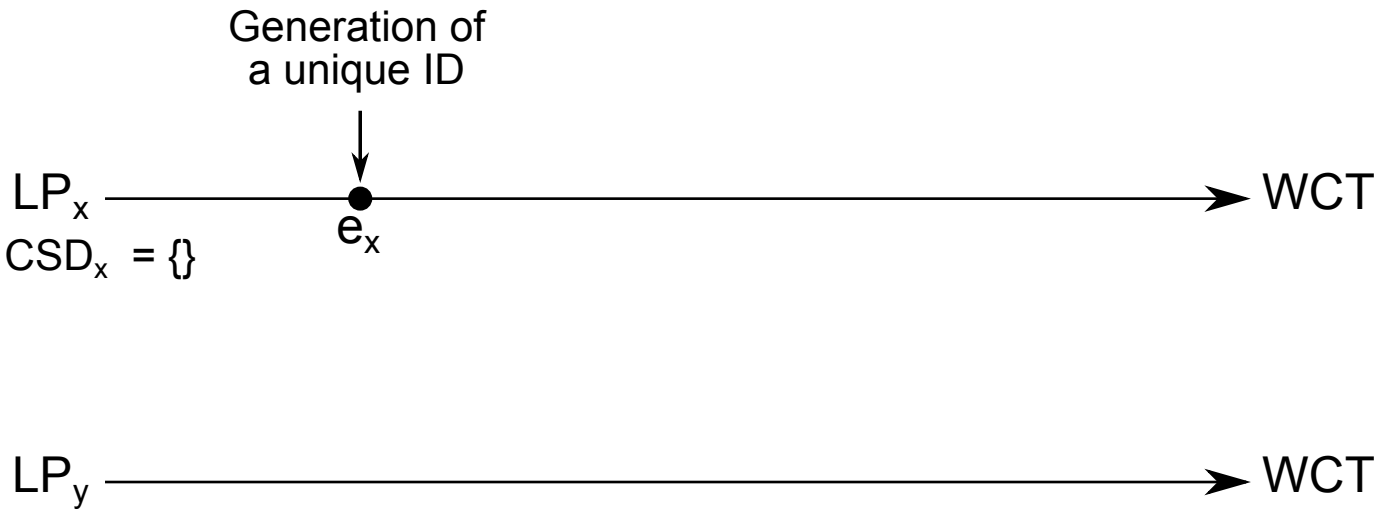

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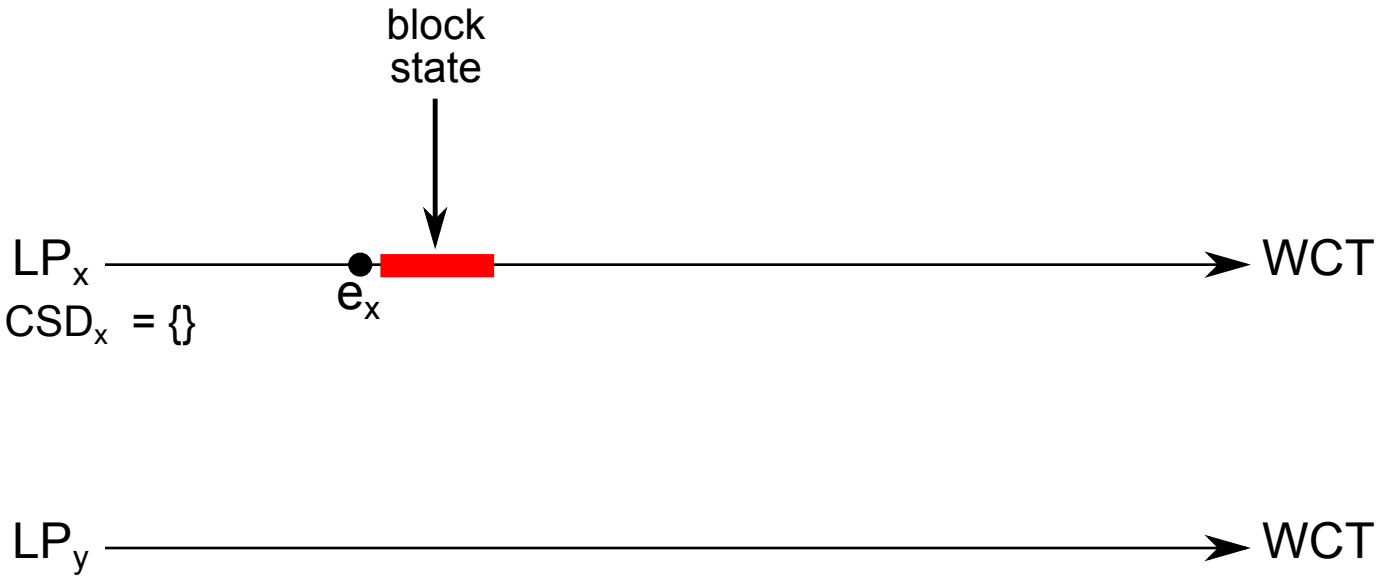

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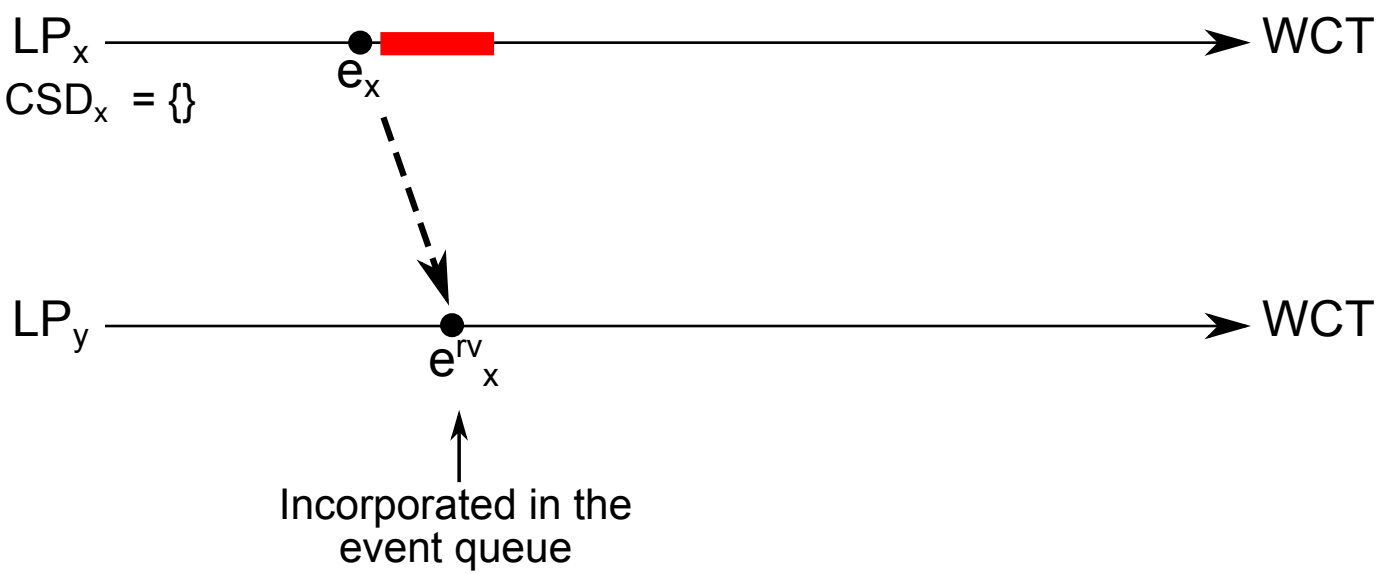

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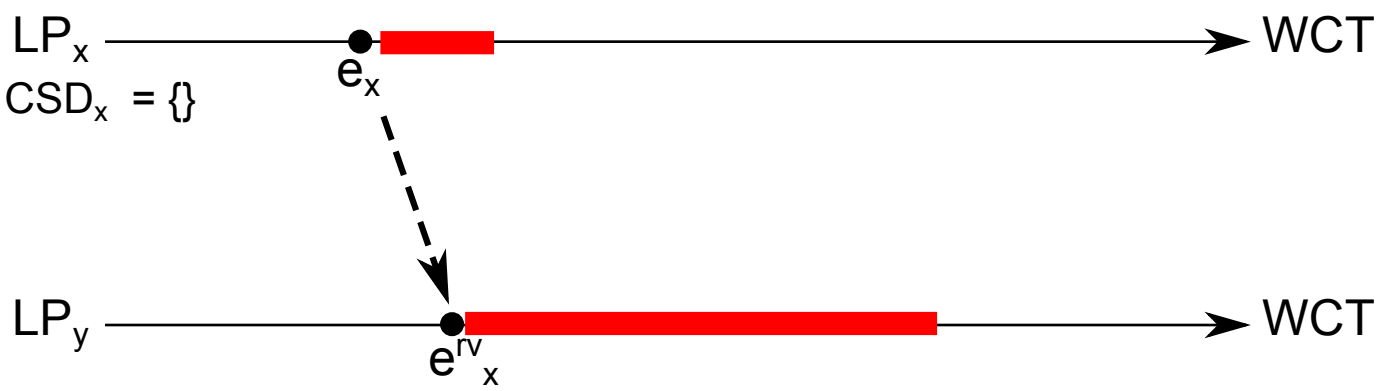

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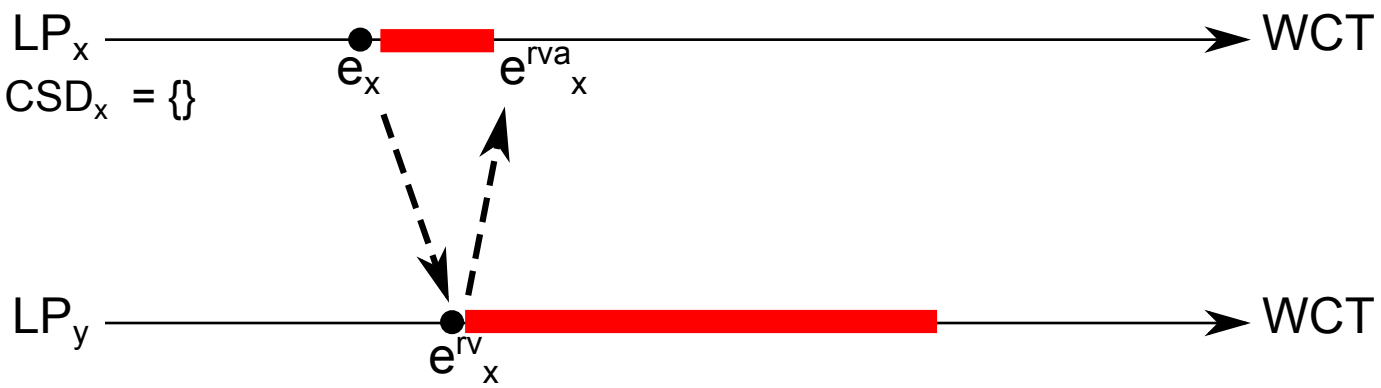

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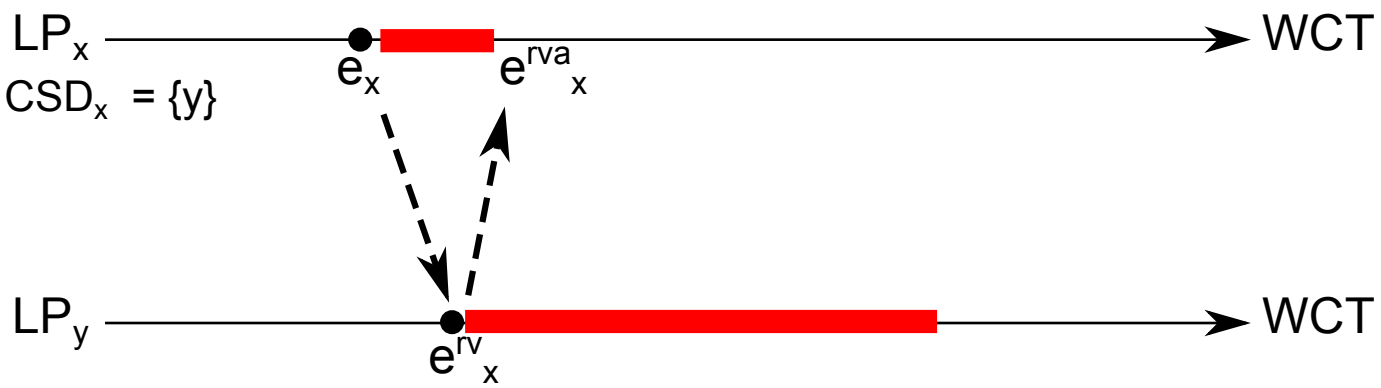

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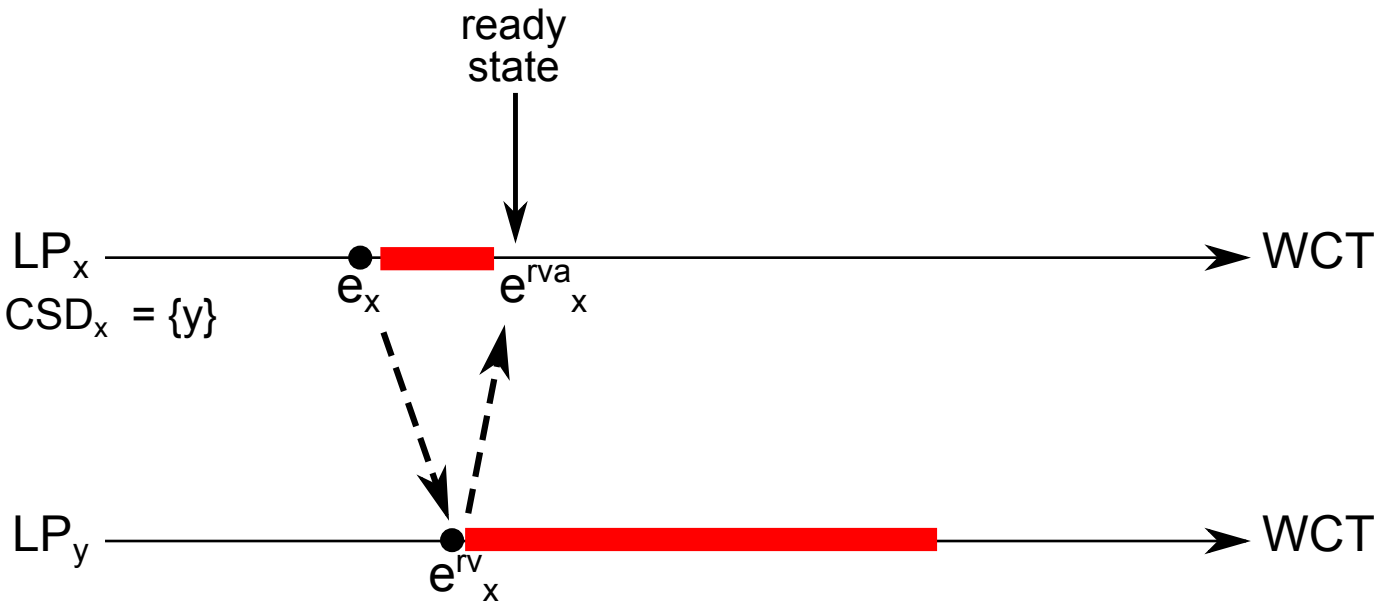

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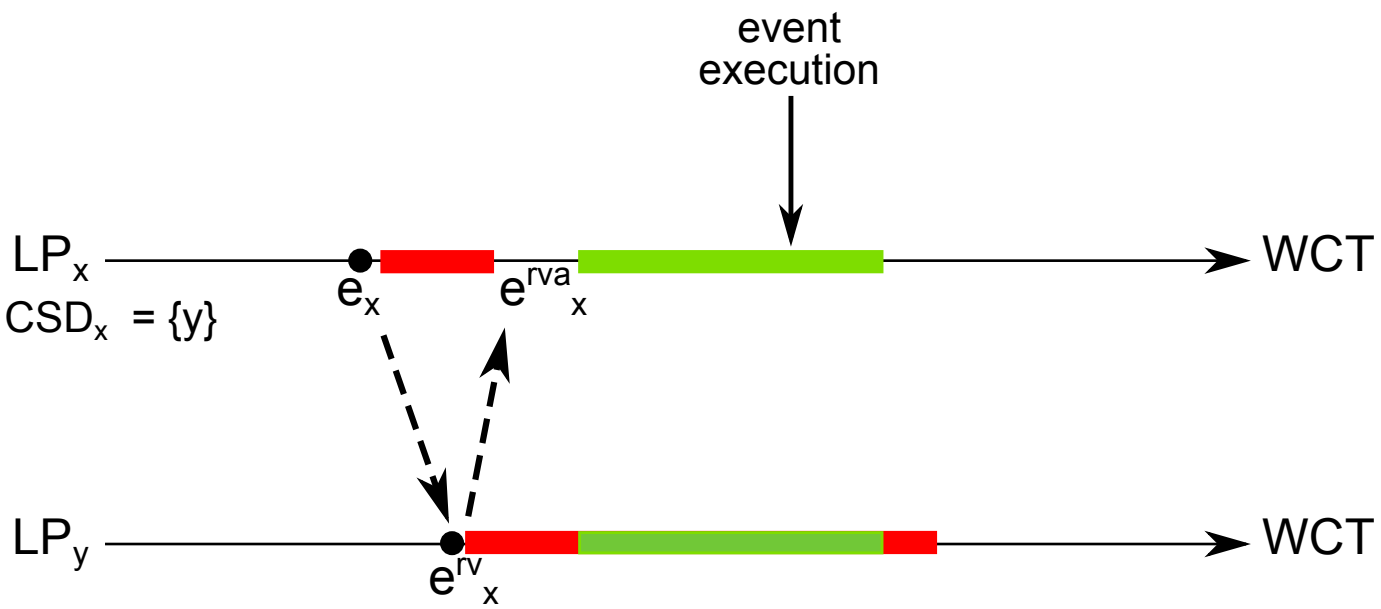

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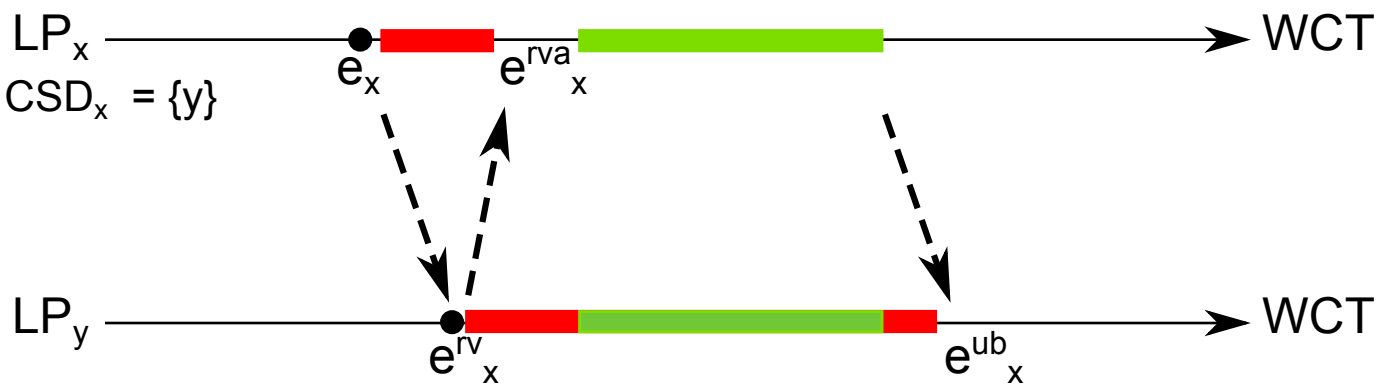

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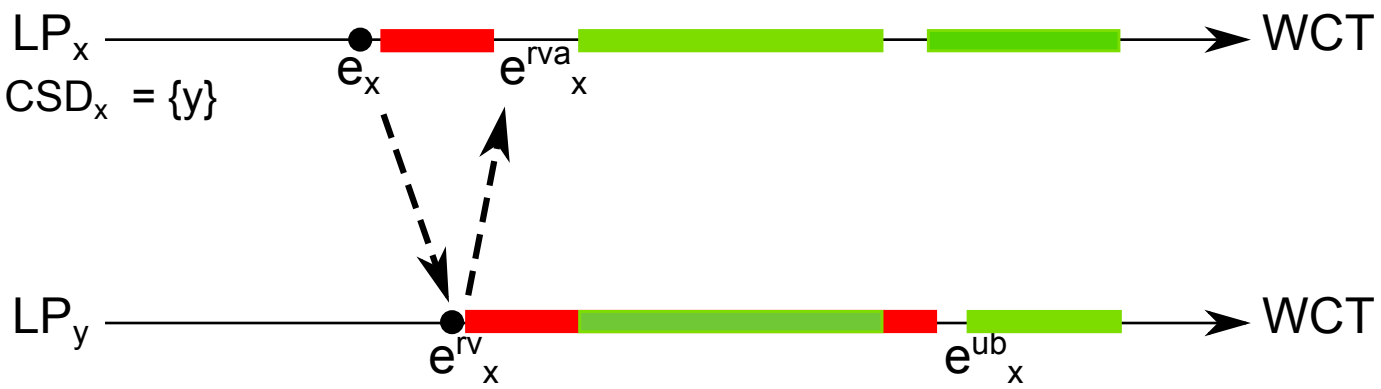
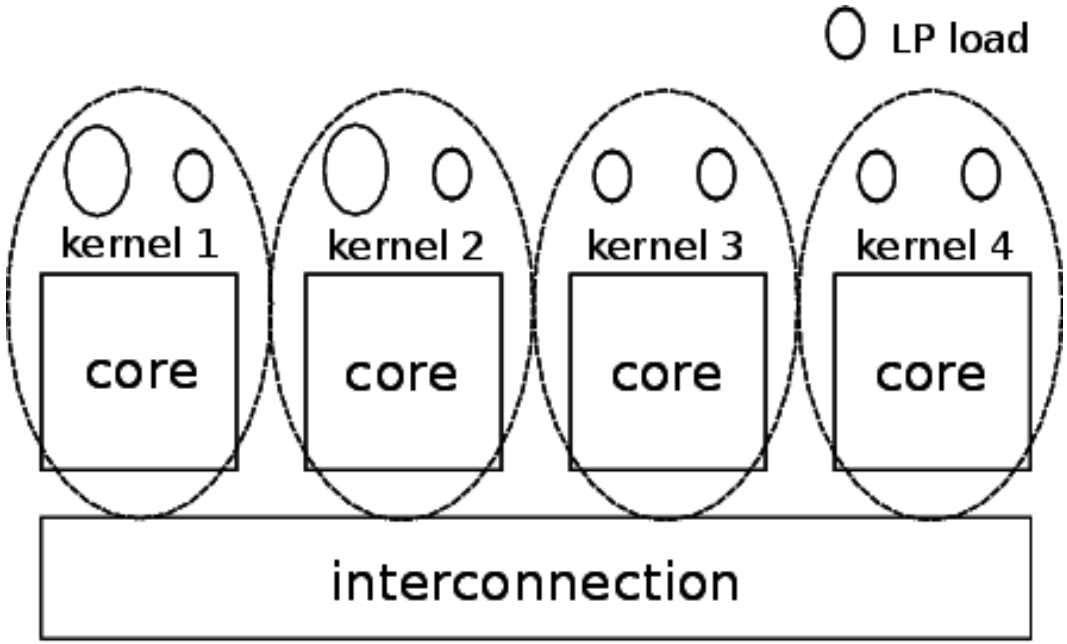
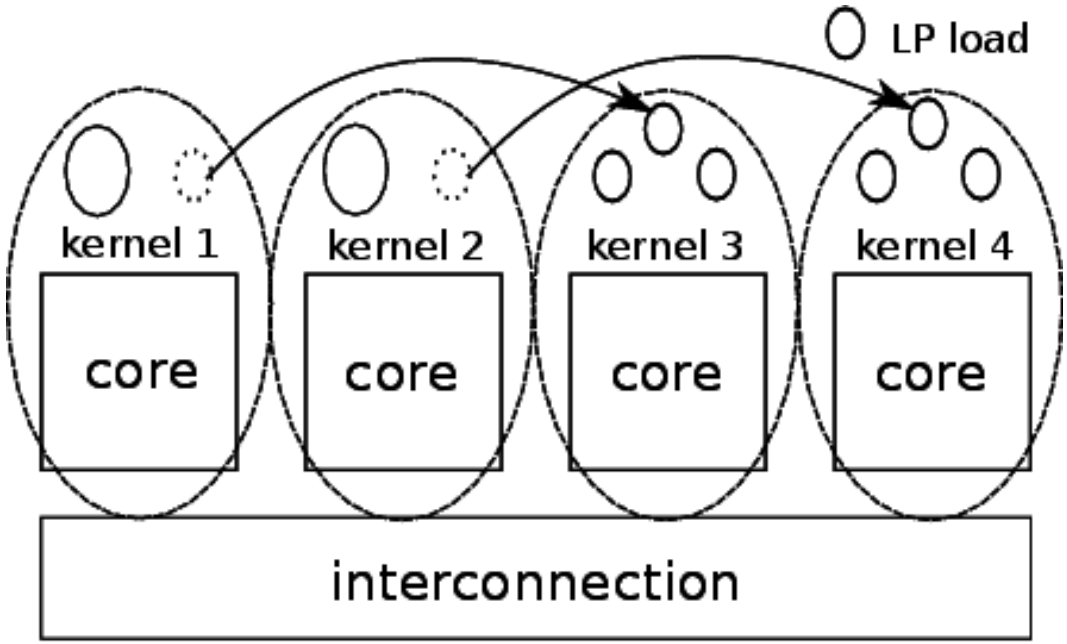


Load Sharing vs. Load Balancing



Load Sharing vs. Load Balancing



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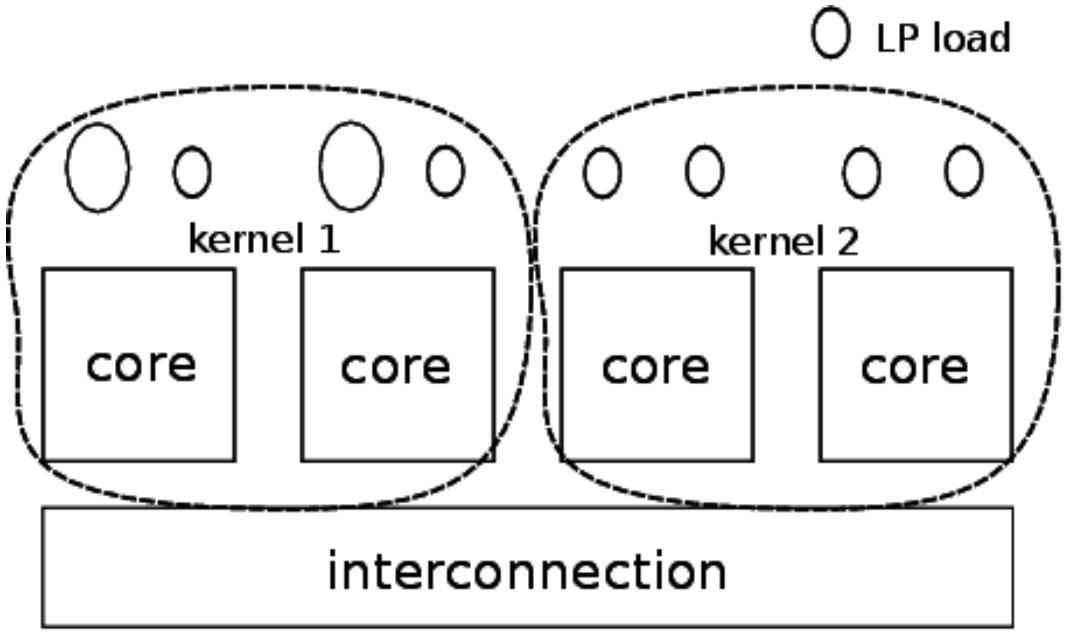
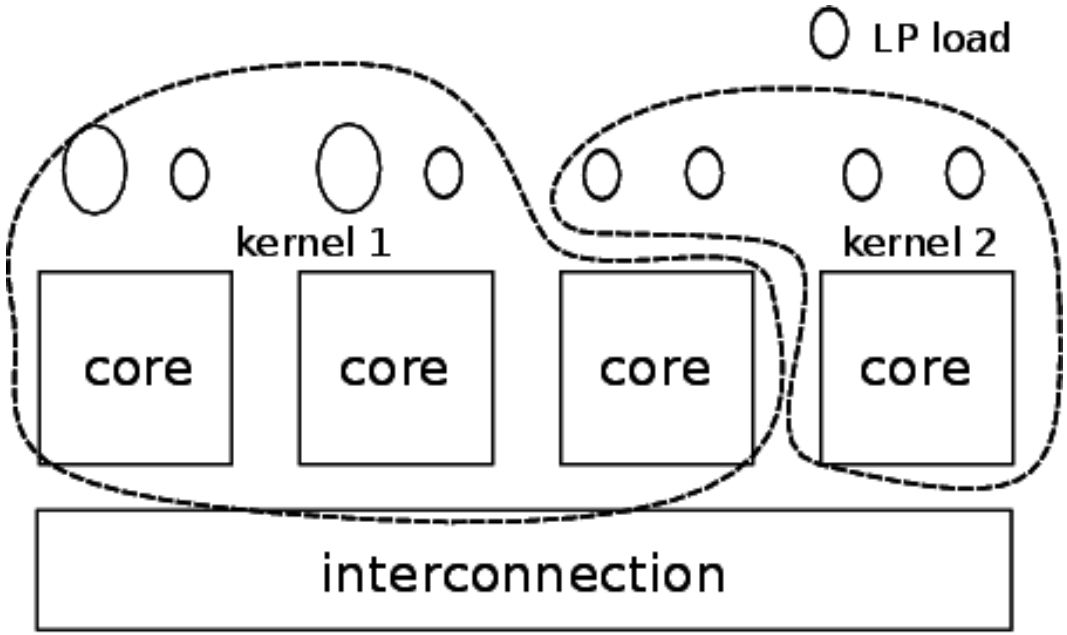


Load Sharing vs. Load Balancing



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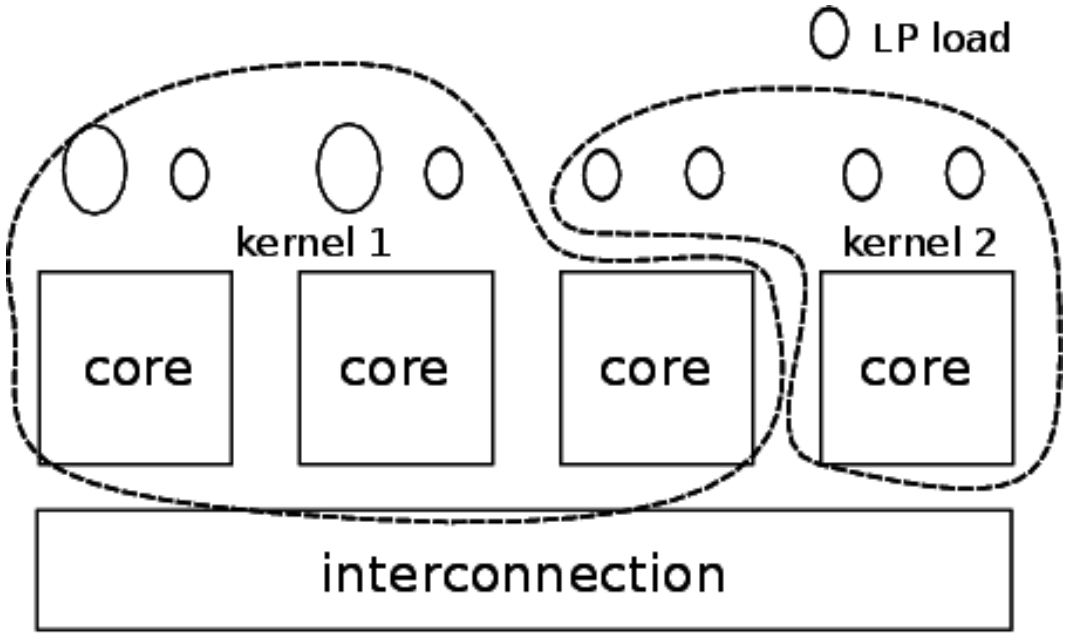


How to decide upon the binding?

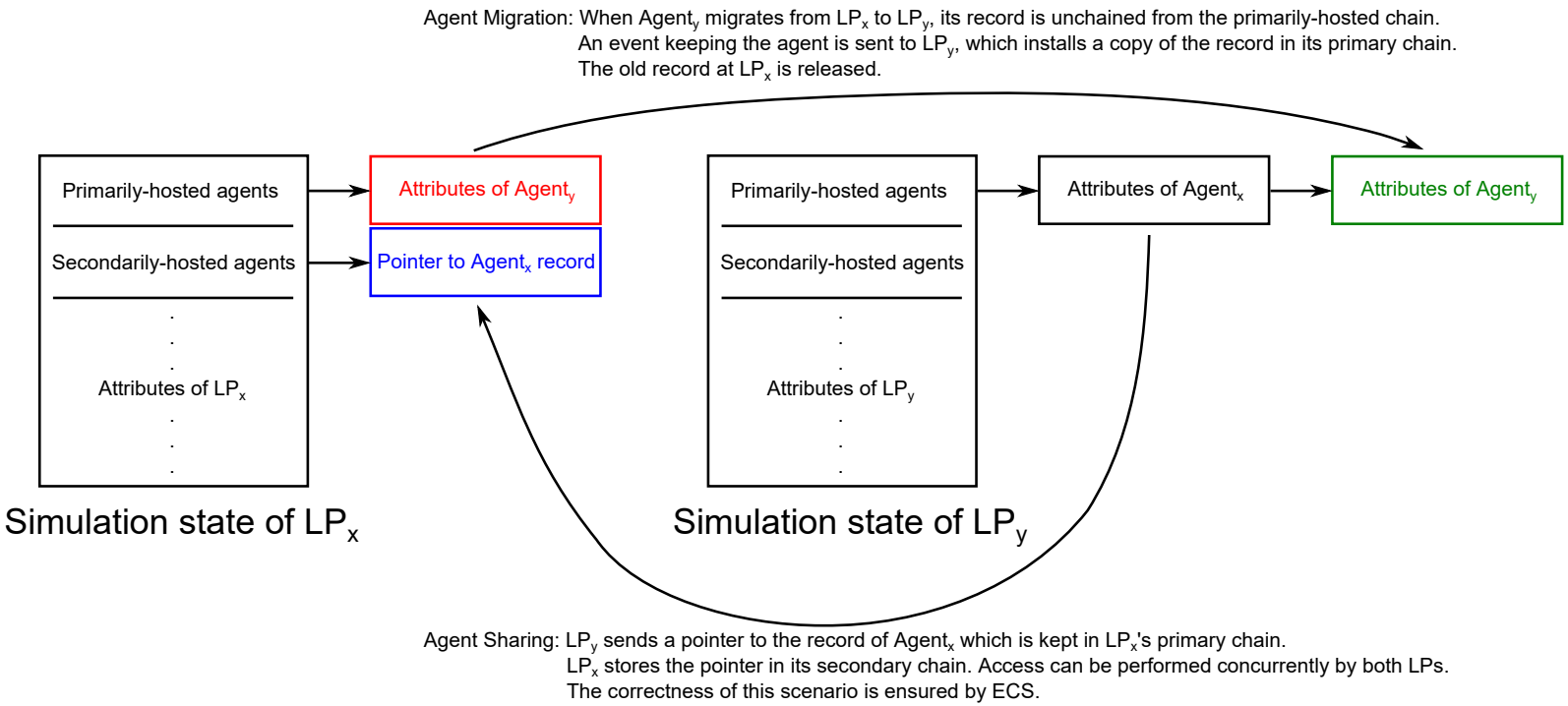
Programming guidelines for Demography on PDES

- The core element is the life course of *individuals*
- Behaviour and decisions depend on the *environment*

- Individuals (*agents*) are mapped to `structs`
- Portions of the environment (*regions*) are mapped to LPs

- Event handlers at LPs implement the logic to manipulate individuals
  - An agent is described in terms of individual-specific explanatory variables
  - State transitions define agent *histories*
- Message passing is used to migrate agents (as the payload)

ABM programming guidelines on PDES



- Easy local interaction
- Easy remote interaction, via direct memory access

Load-Sharing Policy

- The goal is to cluster together LPs that interact most
- For each LP_i we rely on counters:
  - The number of implicit interactions I_j with LP_j
  - The number of explicit interactions E_j with LP_j
- Each LP is thus associated with a tuple:

$$\langle I_0, I_1, \ldots, I_{maxLP-1}, E_0, E_1, \ldots, E_{maxLP-1} \rangle$$

- For the case $i = j$ we set the value to the number of executed events

Load-Sharing Policy

- Each tuple is a point in the n-dimensional space of LPs interactions
- The strategy is to identify *clusters of LPs* which show a high inter-dependence

- We rely on the *k-medoids* algorithm to find evenly-sized Voronoi regions in an Euclidean space
- The LPs are partitioned into K clusters, K being the number of available cores
- The distance between the coordinates $\mathbf{i}$ and $\mathbf{j}$ of LP_i and LP_j is their Manhattan distance:

$$d(\mathbf{i}, \mathbf{j}) = \|\mathbf{i} - \mathbf{j}\| = \sum_{i=1}^{n} |i_i - j_i|$$

Load-Sharing Policy

- This is used in the algorithm's objective function:

$$D = \sum_{k=1}^{K} \sum_{i \in C_k} \sum_{j \in C_k} d_{i,j}$$

- C_k is the set of all LPs in cluster k
- The recomputation can be periodical or triggered by a certain event of the system
- An initial LP is selected having the shortest distance to any other LP in the n-dimensional space, which is *approximately* in the center
- Other $k - 1$ LPs are selected so that they decrease the value of D as much as possible

Experimental Evaluation: Test-bed Platform

- Hardware configuration:
  - HP ProLiant server equipped with 64GB of RAM
  - 4 8-cores CPU (32 total cores)
- Software configuration:
  - ROOT-Sim Optimistic Simulation Kernel, using 32 symmetric worker threads
  - Debian 6
  - 2.6.32-5-amd64 Linux kernel

Synthetic Demographic Model

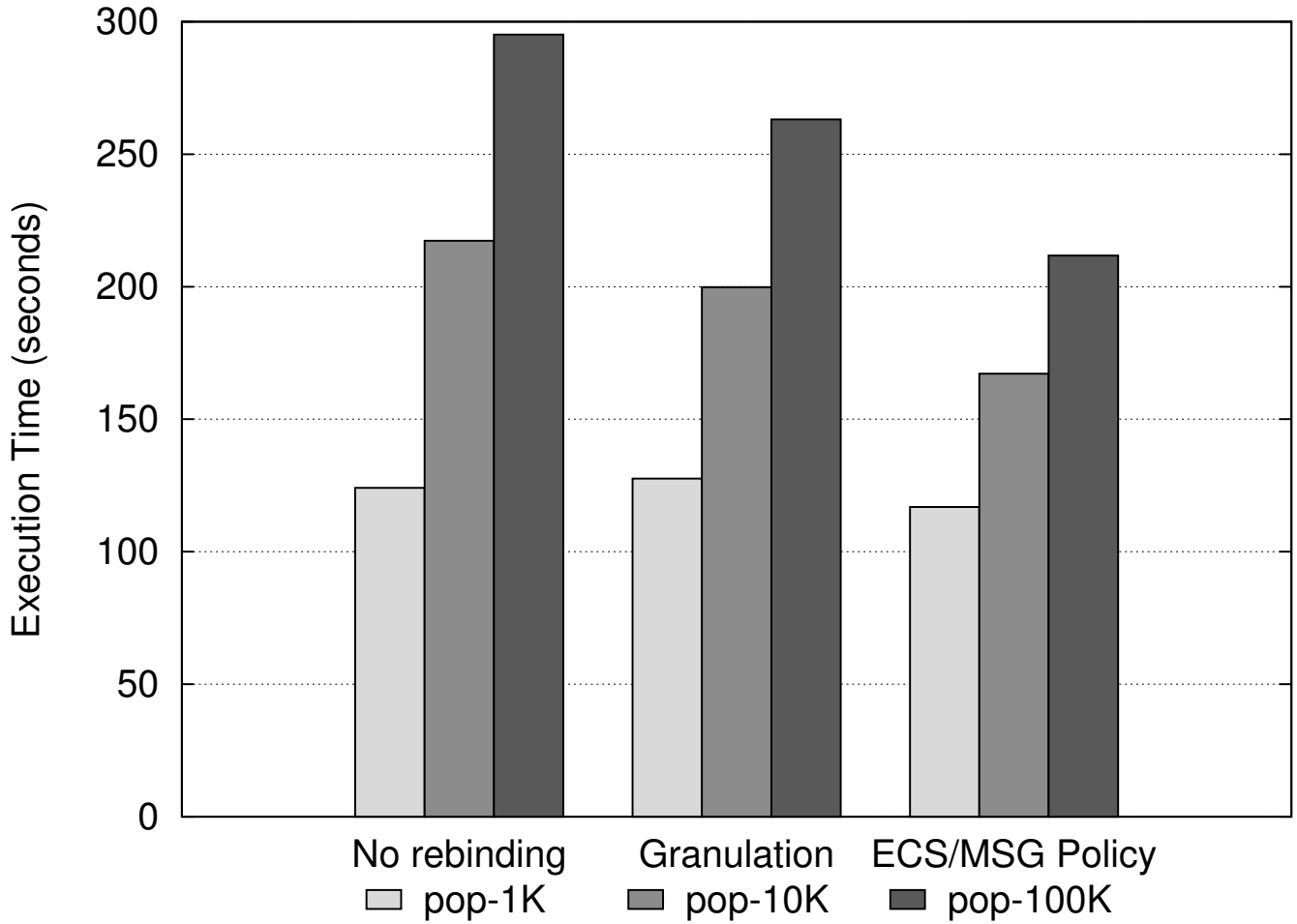
- Built according to our general guidelines
- Explanatory variables are described using a bitmap (concise description)
- Each agent carries as well a non-concise payload

- Additional operative events:
  - *State-machine update*: with probability p_{smu}, a bit in the bitmask is negated (state transition)
  - *Memory update*: with p_{mu}, a portion of the payload of the agent's structure is written with random data;
  - *Remote agent interaction*: with probability p_{rai}:
    - a random LP is selected to send random data
    - Upon receipt, a random hosted agent is picked
    - The payload of the event is copied into the agent's buffer
  - This latter event mimics kinship interactions

Baseline

- No Rebinding
- LP Granulation [PADS 2016]
  - ECS-based interactions are still captured
  - They are used to form *groups of LPs*
  - A group is a *sequential entity*
  - A group is thus bound on a single worker thread
  - Groups are ephemeral

Synthetic Demographic Model: Results



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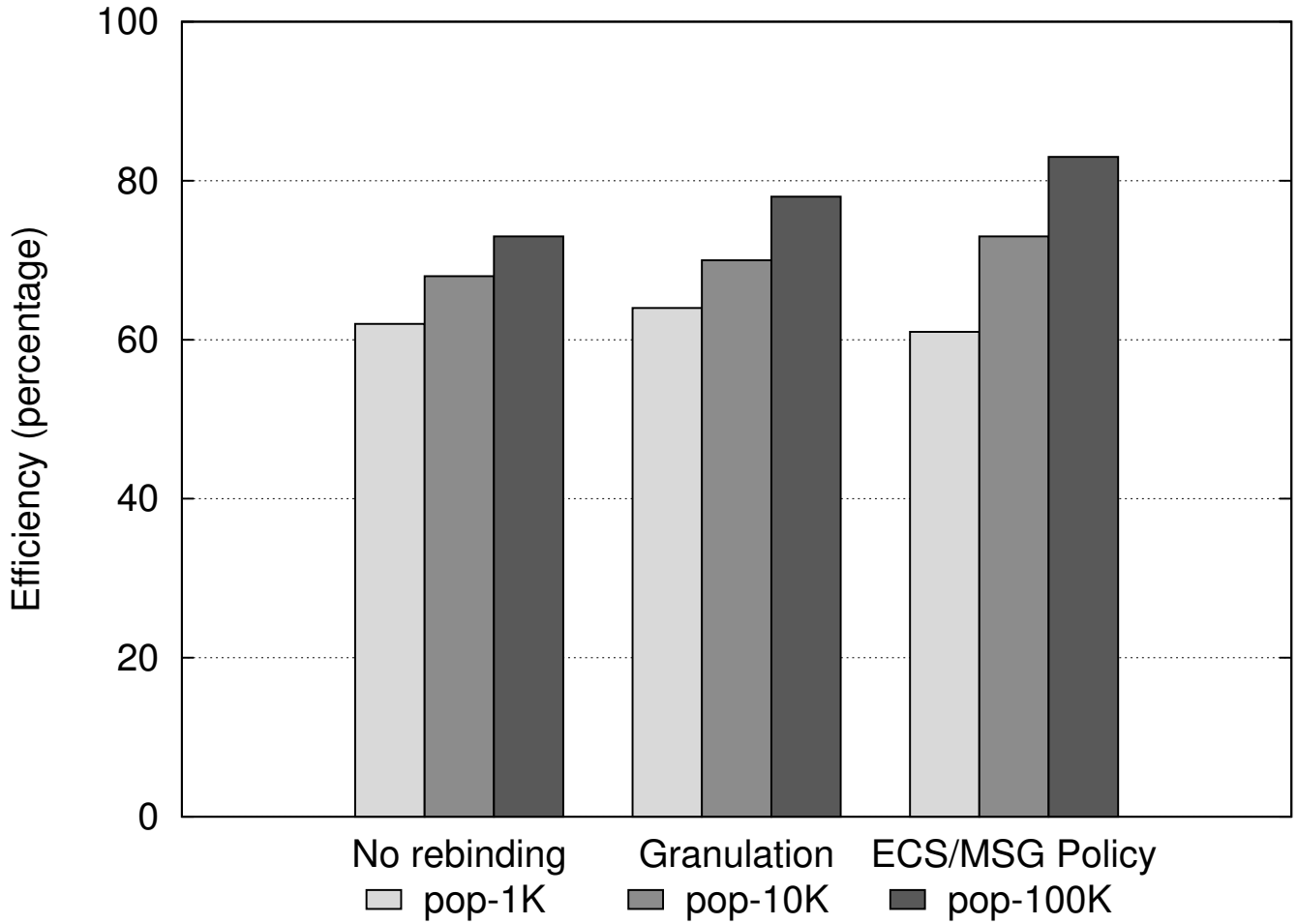
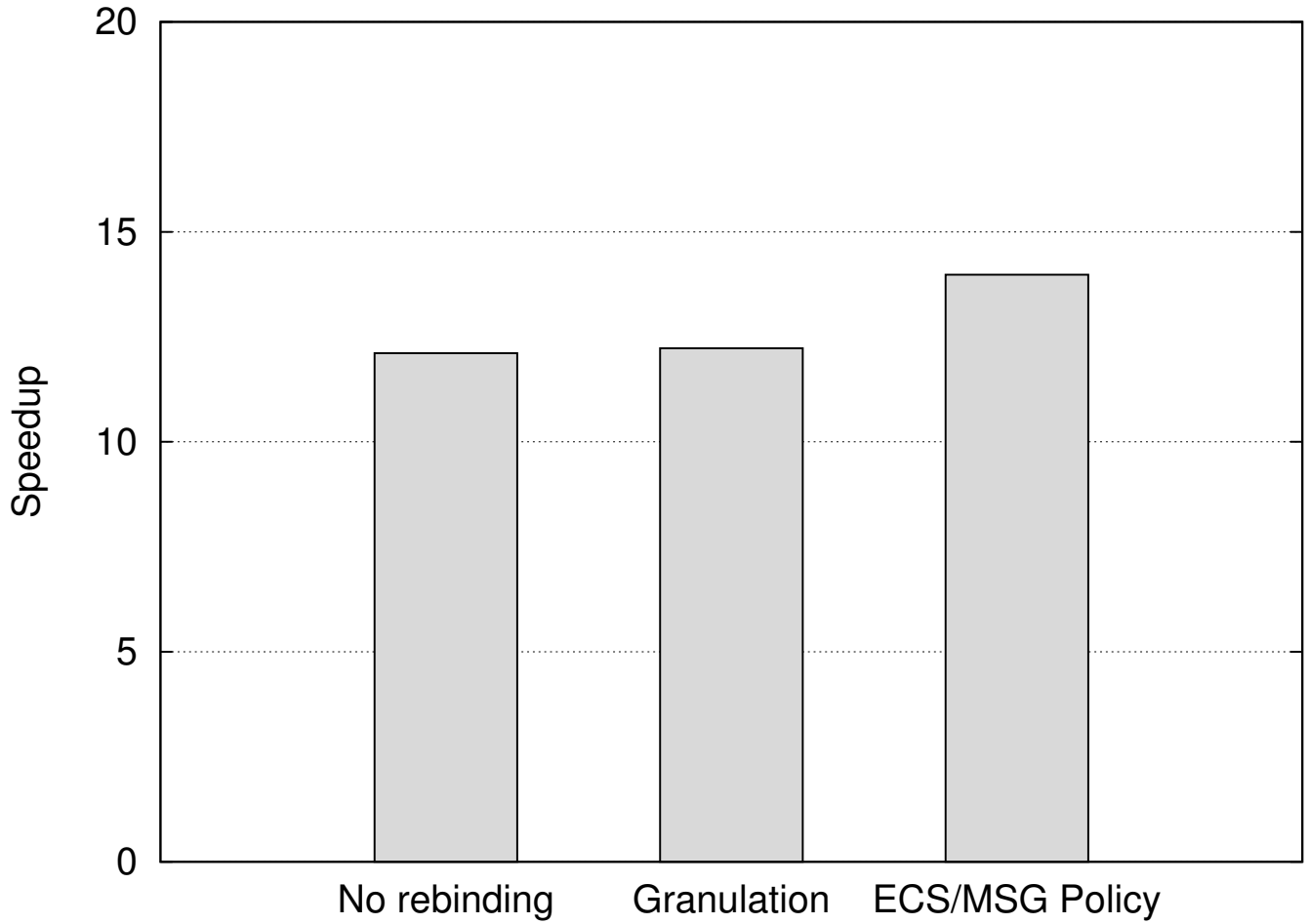


Yades

- Parallel demographic agent-based simulation tool
- Life course of individuals is modeled via agents
  - fertility
  - mortality
  - economic status
  - family composition
  - family migration

- Gambian immigration in Spain during 10 years
- 40,000 families

Yades: Results



Thanks for your attention

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http://www.dis.uniroma1.it/∼pellegrini
http://github.com/HPDCS/ROOT-Sim