Performance Analysis of a Parallel and Distributed Simulation Framework for Large Scale Wireless Systems

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joint work with

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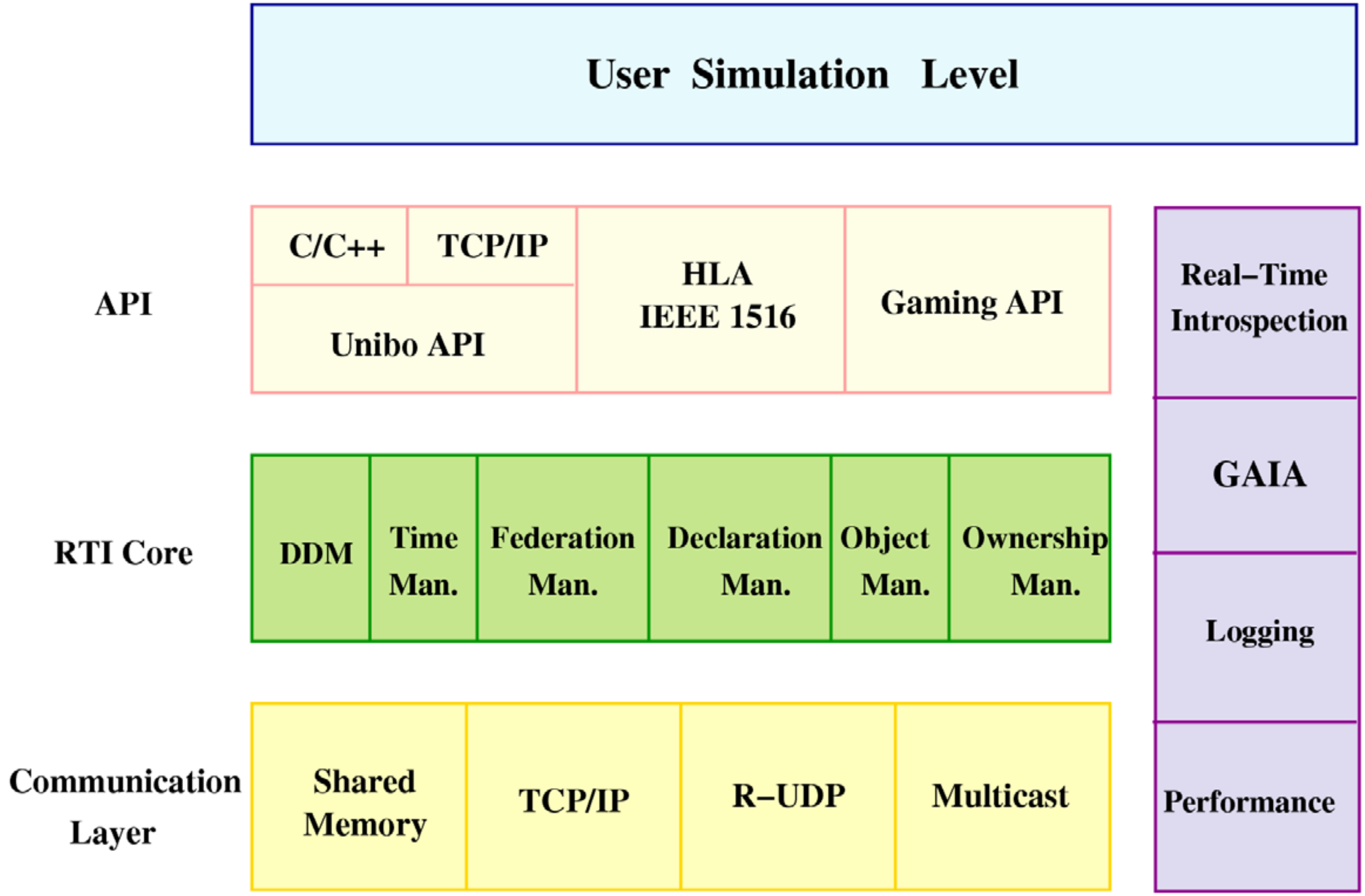
Presentation outline

- Simulation of wireless and mobile systems
- The ARTìS middleware: design and implementation
- Example: Ad-Hoc network simulation
    - a migration based approach (GAIA)
    - performance analysis
- Example: Sensor network simulation
    - simulation of a new energy-aware MAC protocol
    - performance analysis
- Conclusions and future work

Simulation of Wireless and Mobile Systems

- The simulation of Ad-Hoc and Sensor networks often requires a large amount of computation, memory and time to obtain significant results
- The parallel and distributed simulation approach can be a valuable solution to reduce the computation time and to support model components' modularity and reuse
- Distributed synchronization implies communication overheads

The ARTìS parallel and distributed simulation middleware



Mobile and Wireless Networks' model characteristics

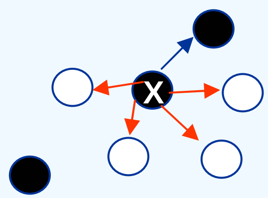
- **"Open broadcast" nature of the wireless transmissions**
  - "space-locality" of causality between neighbor-hosts
  - neighbor-hosts should be notified about transmission events anyway, e.g. to model interference, detection, MAC, etc.
- **Wireless devices can be mobile**
  - the set of neighbor-hosts change as simulated time elapses
- **Communication between hosts is "session-based"**
  - determines a "time-locality" effect
  - the set of neighbor-hosts is interested by transmission events, for a significant time-window

The group of model entities in the shared causal-domain can be highly dynamic:

high degree of communication is required to maintain full synchronization

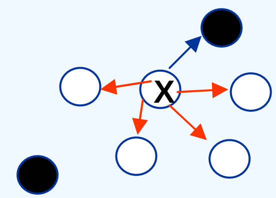
Simulated Mobile Hosts (SMHs) migration

Wireless ad hoc network scenario: (evaluating migration of SMH x)



model entities of SMHs executed over PEUs A and B

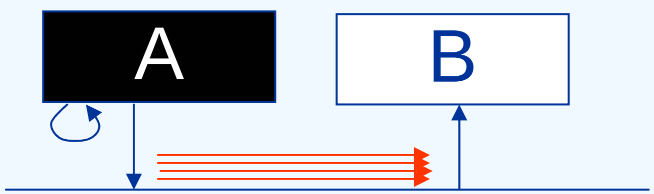
Host X executed over PEU A "transmission-event"



model entities of SMHs executed over PEUs A and B

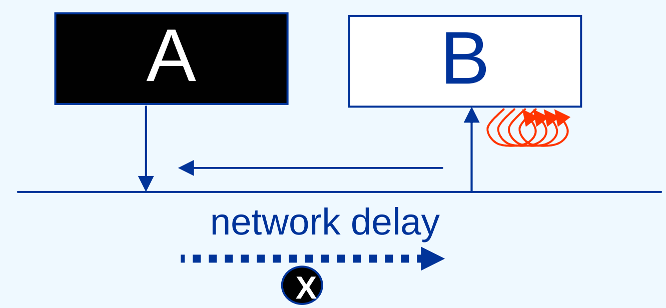
Same scenario after migration of X from A to B

Physical Execution Units for the simulation



network delay

Physical Execution Units for the simulation



X's "transmission-event" must be notified to the 4 model entities executed over B

After X's migration, X's "transmission-event" must be notified to one model entity executed over A

SMH = Simulated Mobile Host

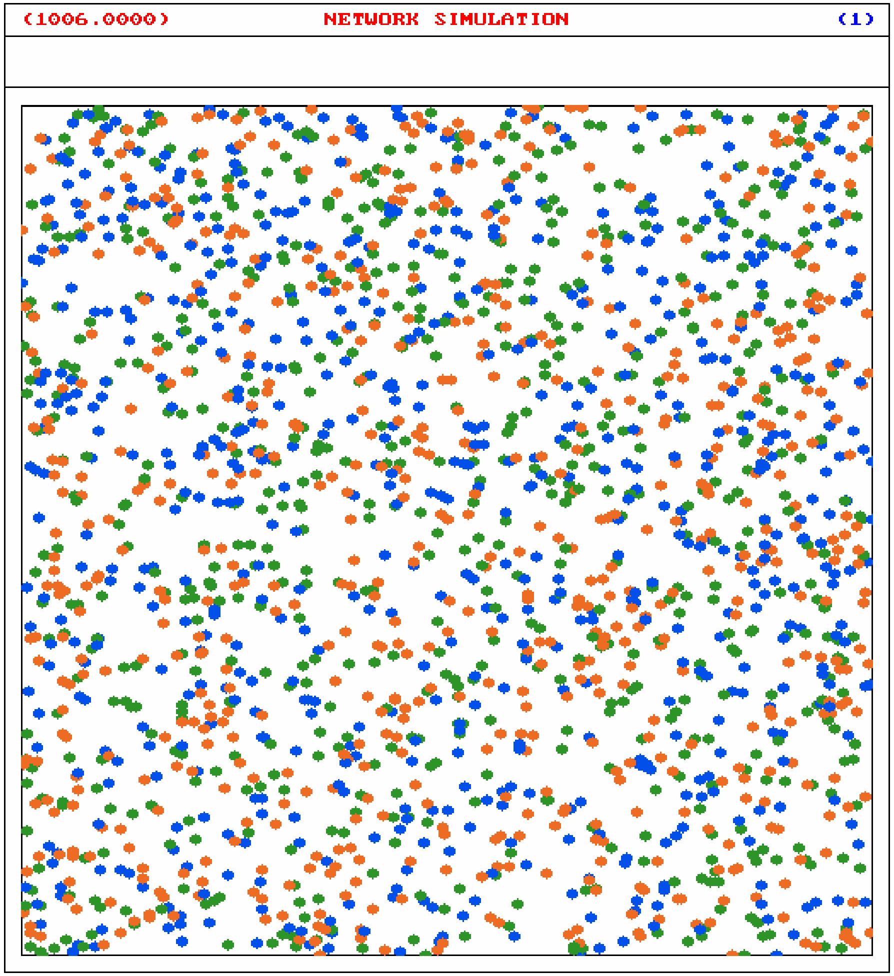
PEU = Physical Execution Unit

Example: Ad-Hoc network model implementation

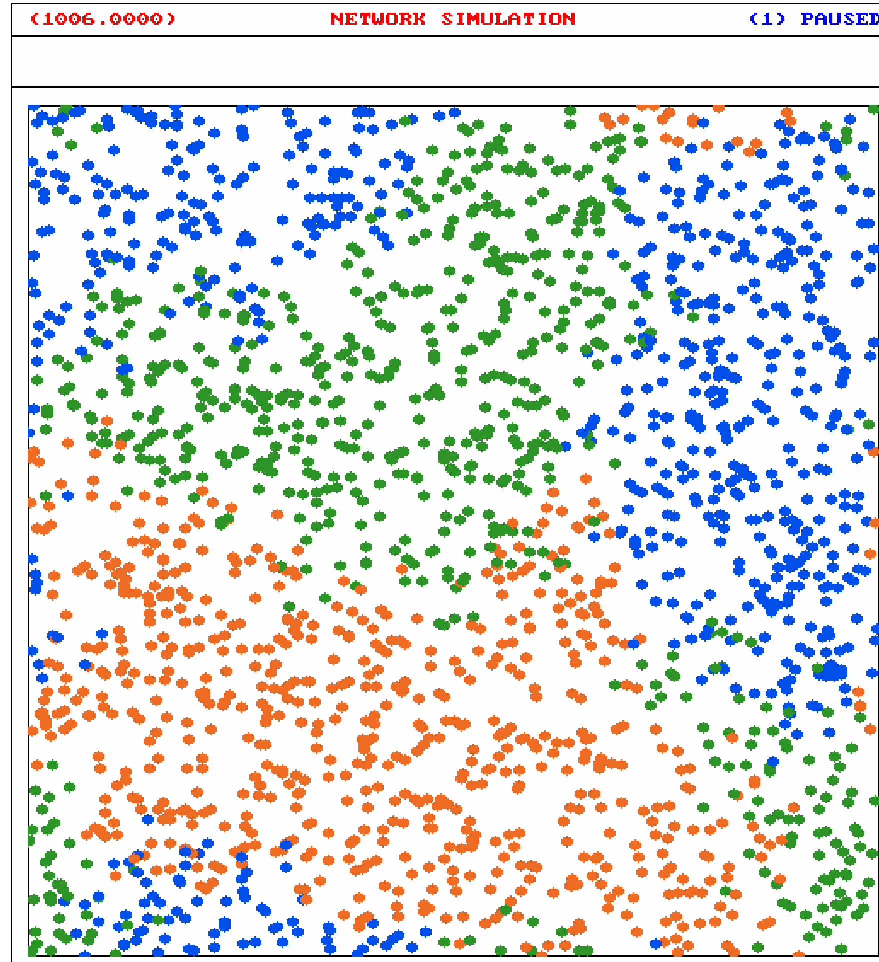
Modeling issues:

- A set of Simulated Mobile Hosts (SMHs)
- Mobility model:
  - Random Mobility Motion model (RMM)
  - Fast- and Slow-RMM (100, 25, 10 m/s)
  - uncorrelated SMHs' mobility (worst case)
- Traffic model:
  - ping messages (CBR) by every SMH to all neighbors within the wireless communication range (250 m)
  - low local computation model (worst case)
- Propagation model
  - open space (neighbor-SMHs within detection range)

Ad hoc network: migration mechanism “off” and “on”

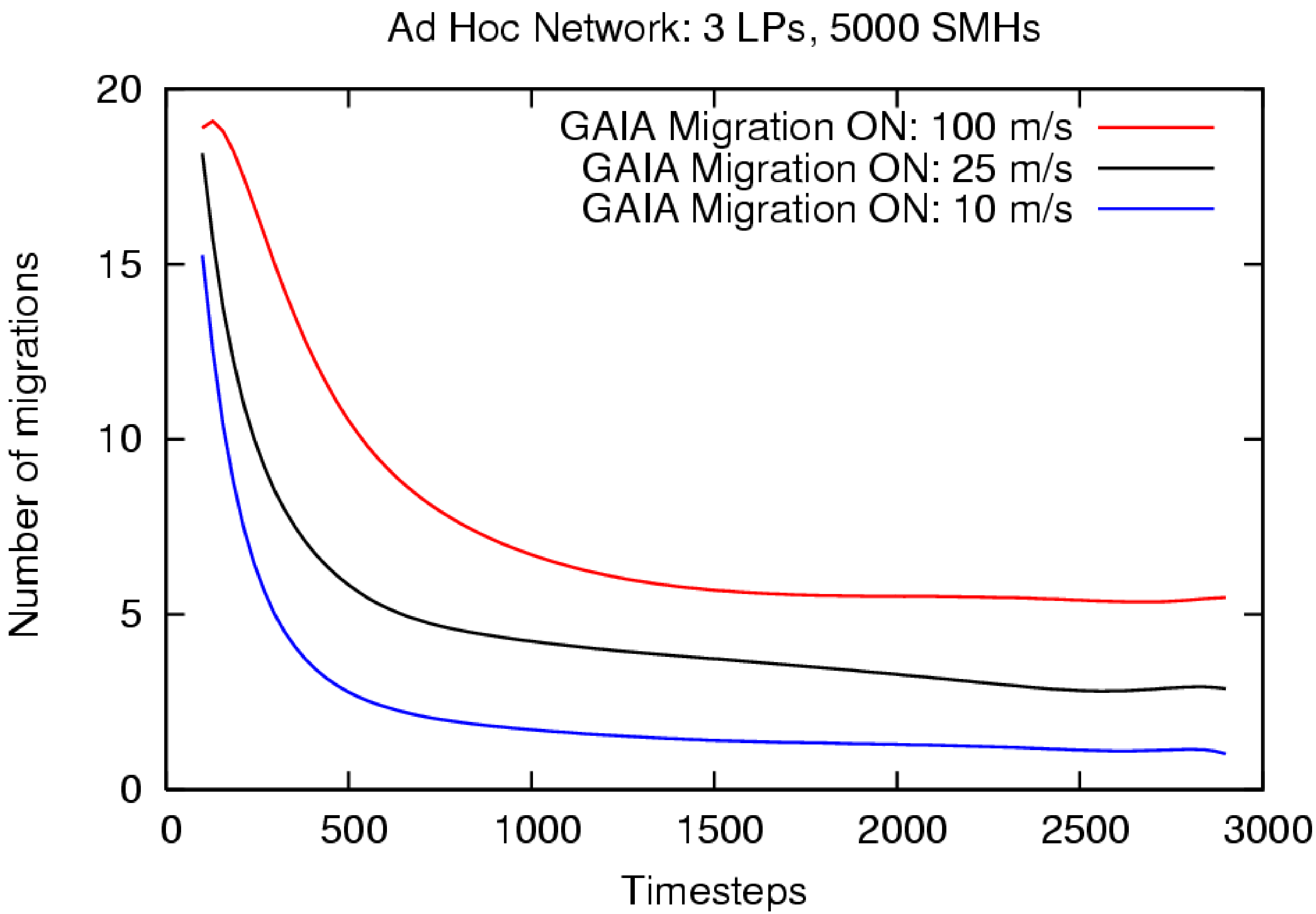


Migration “OFF”

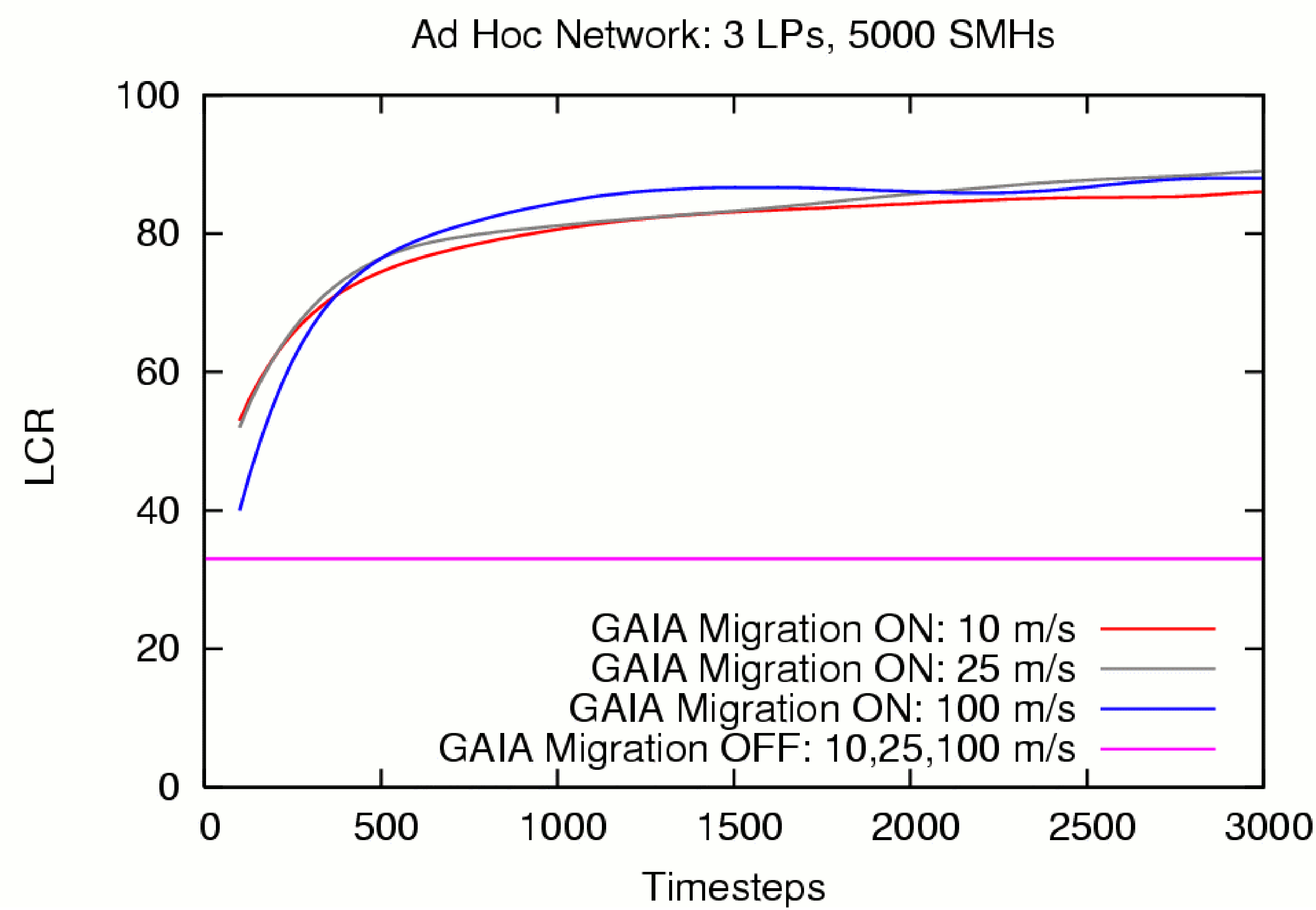


Migration “ON”

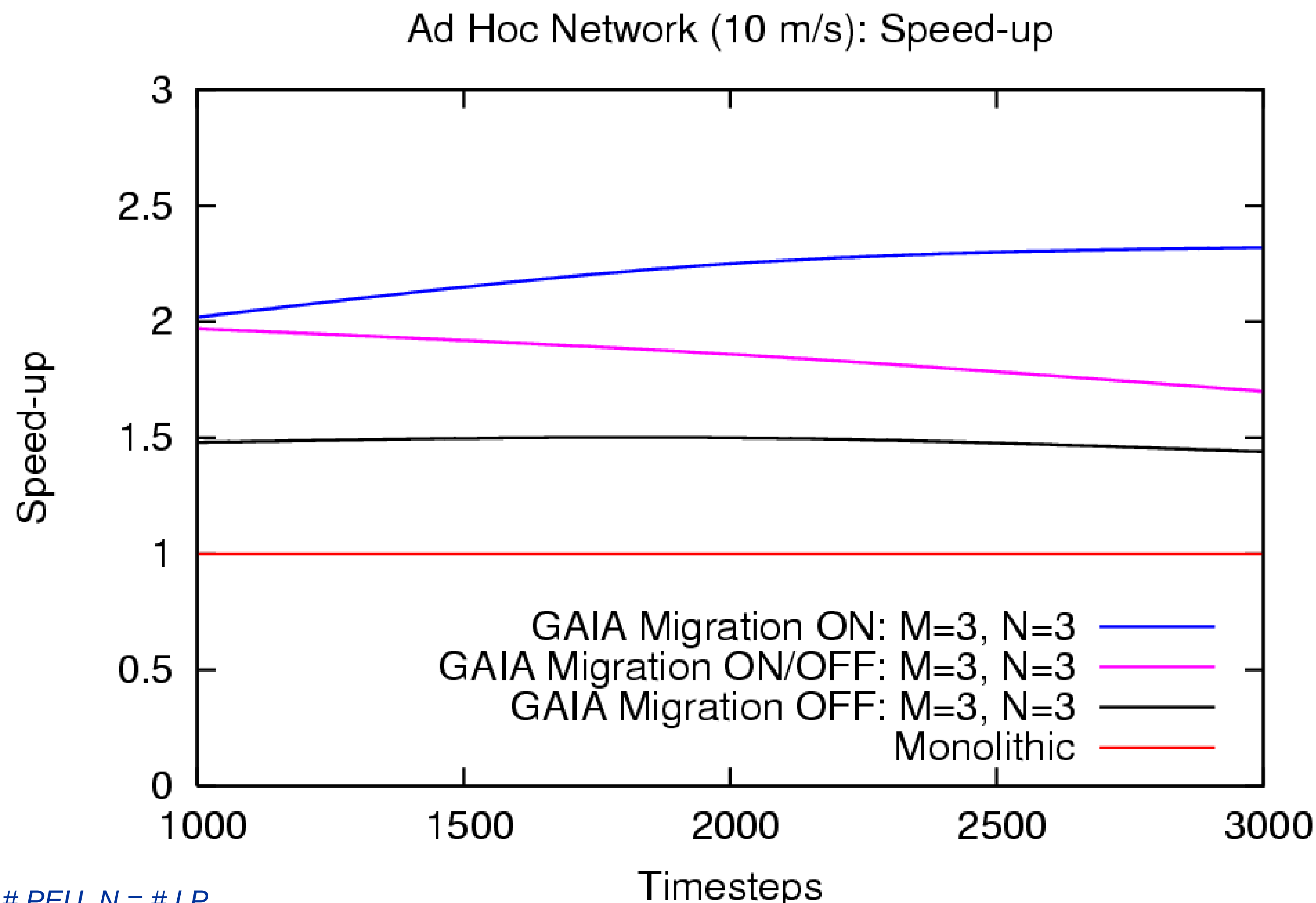
Performance analysis: number of migrations / timestep



Performance analysis: Local Communication Ratio

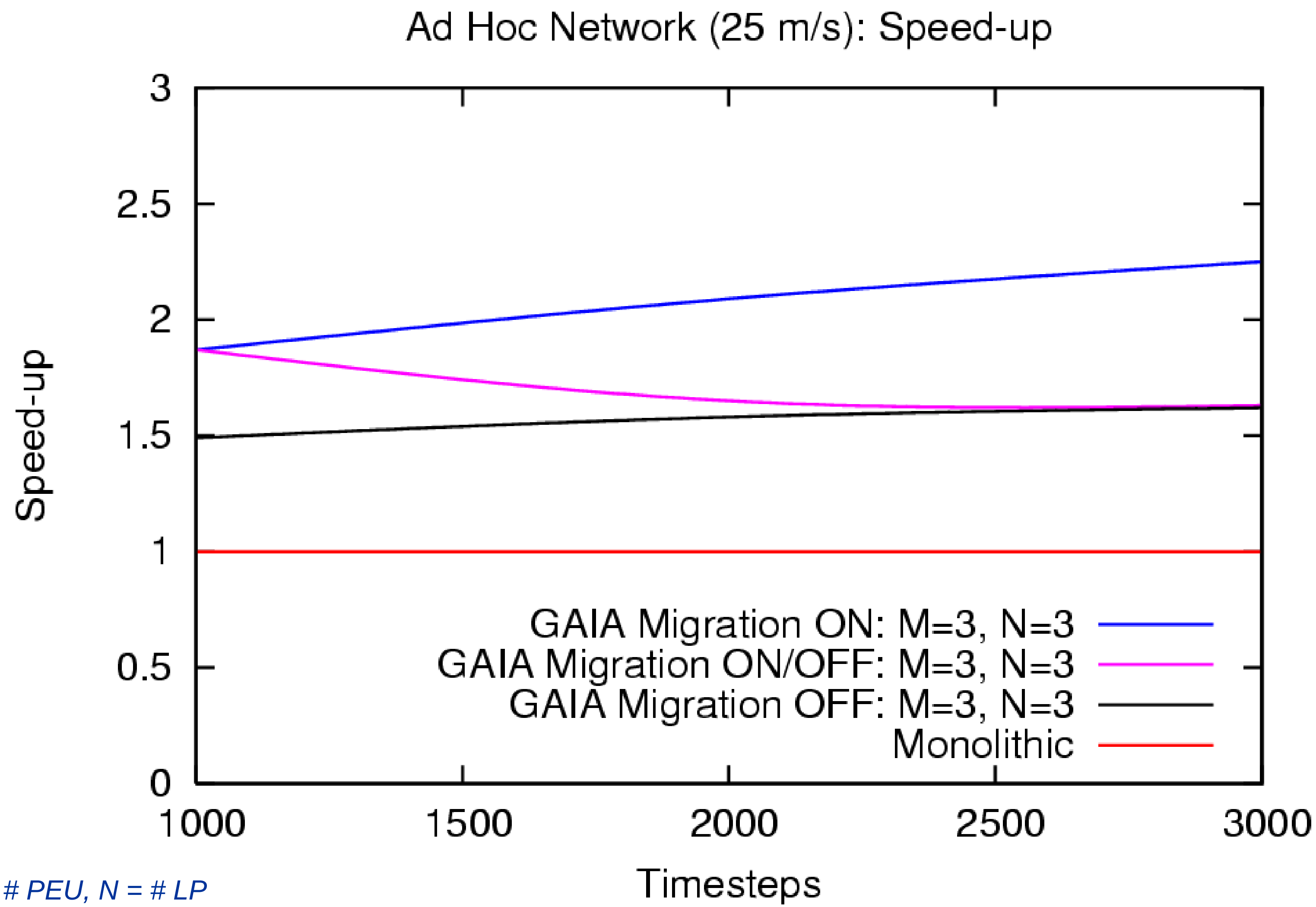


Performance analysis: speed-up



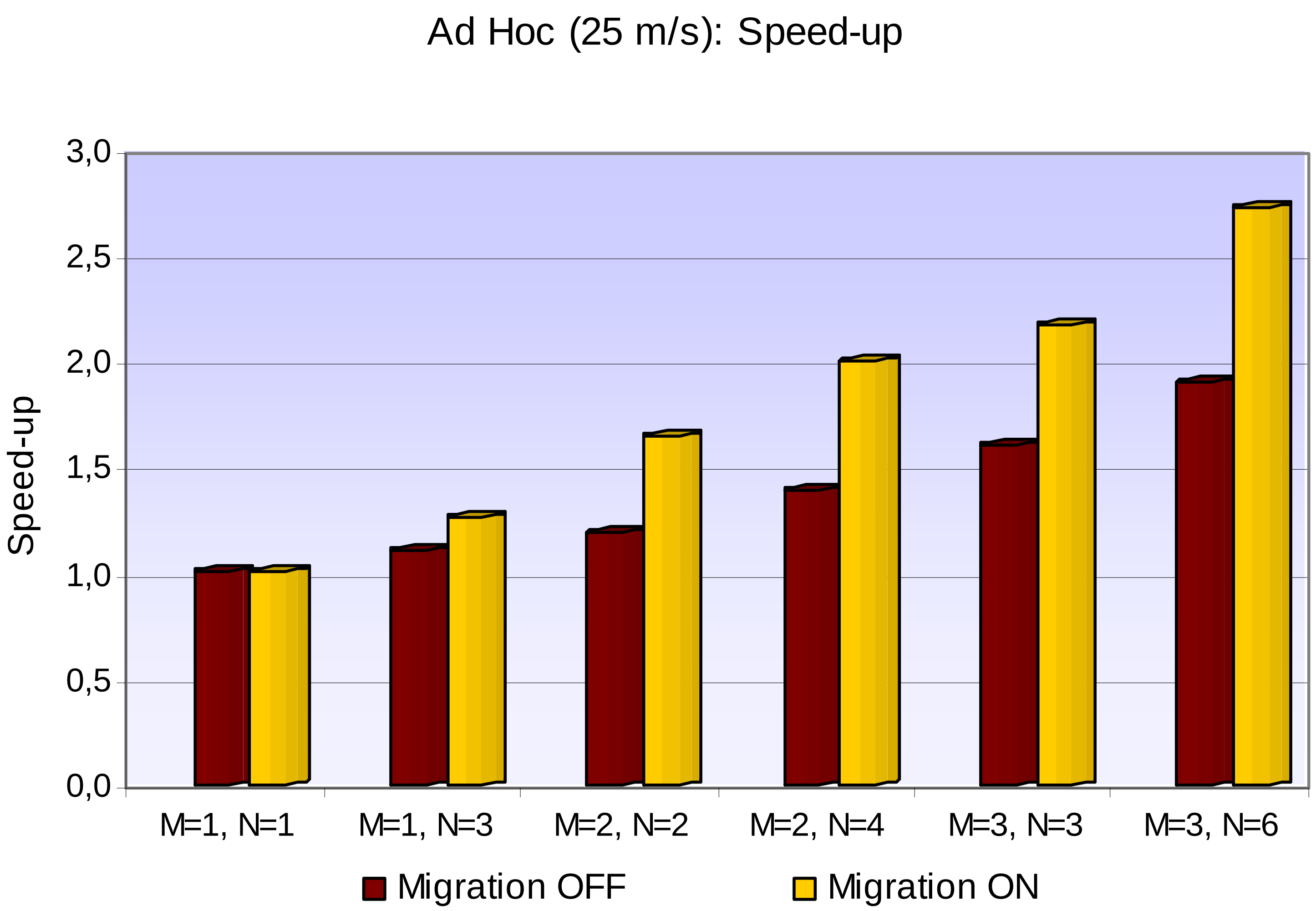
M = # PEU, N = # LP

Performance analysis: speed-up



M = # PEU, N = # LP

Performance analysis: speed-up



M = # PEU, N = # LP

Example: sensor network model implementation

Design of a new energy aware Medium Access Control protocol:

- Up to 40.000 sensors, limited battery resources
- Sensors are static (no mobility model)
- Every sensor implements the MAC protocol, no centralization
- 4 different sensor states (active, power saving, listening, died)
- Every sensor implements a “pressure variation” detector and sends broadcast alerts flooding toward a set of detection points

- The energy aware MAC protocol increases the network lifetime managing the sensors’ state (dinamically switching to power-save state the sensors within areas covered by other active sensors)

Sensor network simulation example

1000 sensors (for this example),

Limited battery resources

4 different states:

- **red = awake**
- **green = power saving**
- **white = listening**
- **black = died**

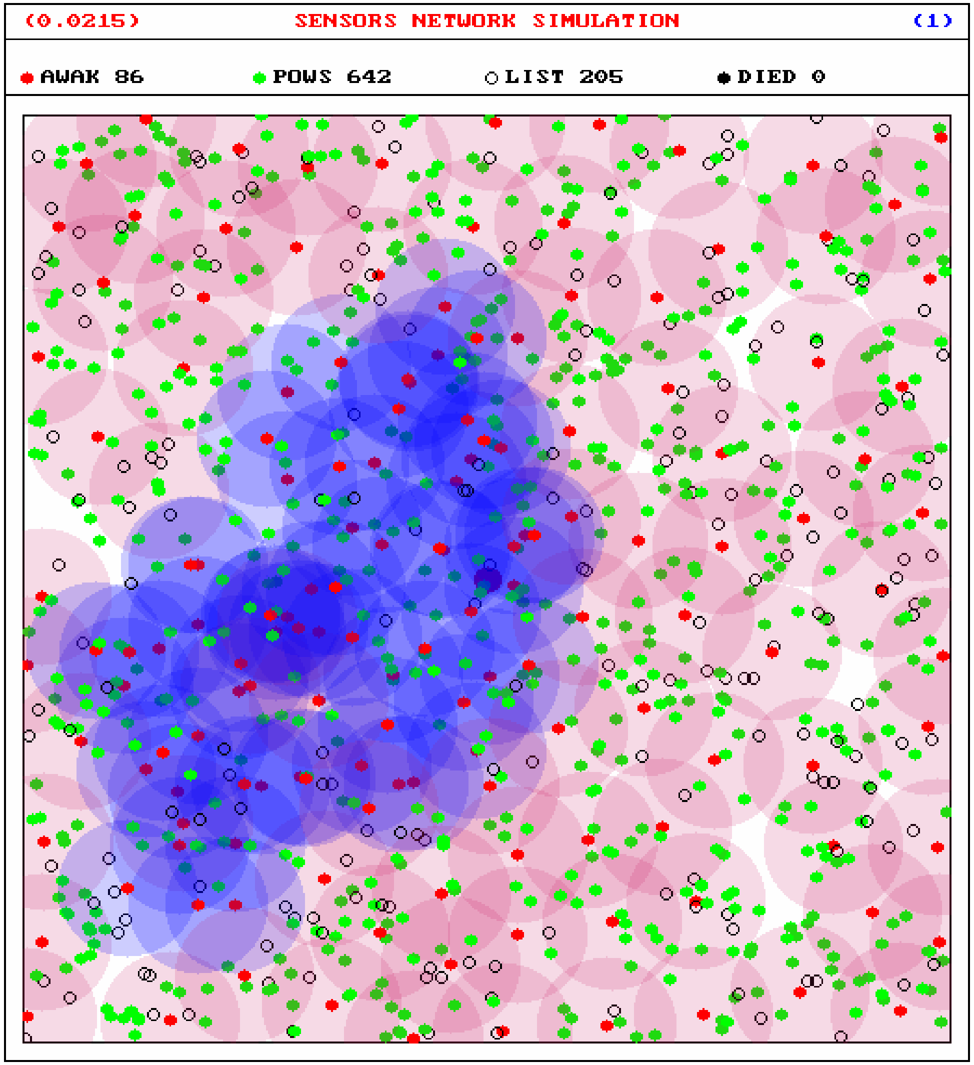
Pink circle =

active transmitting range

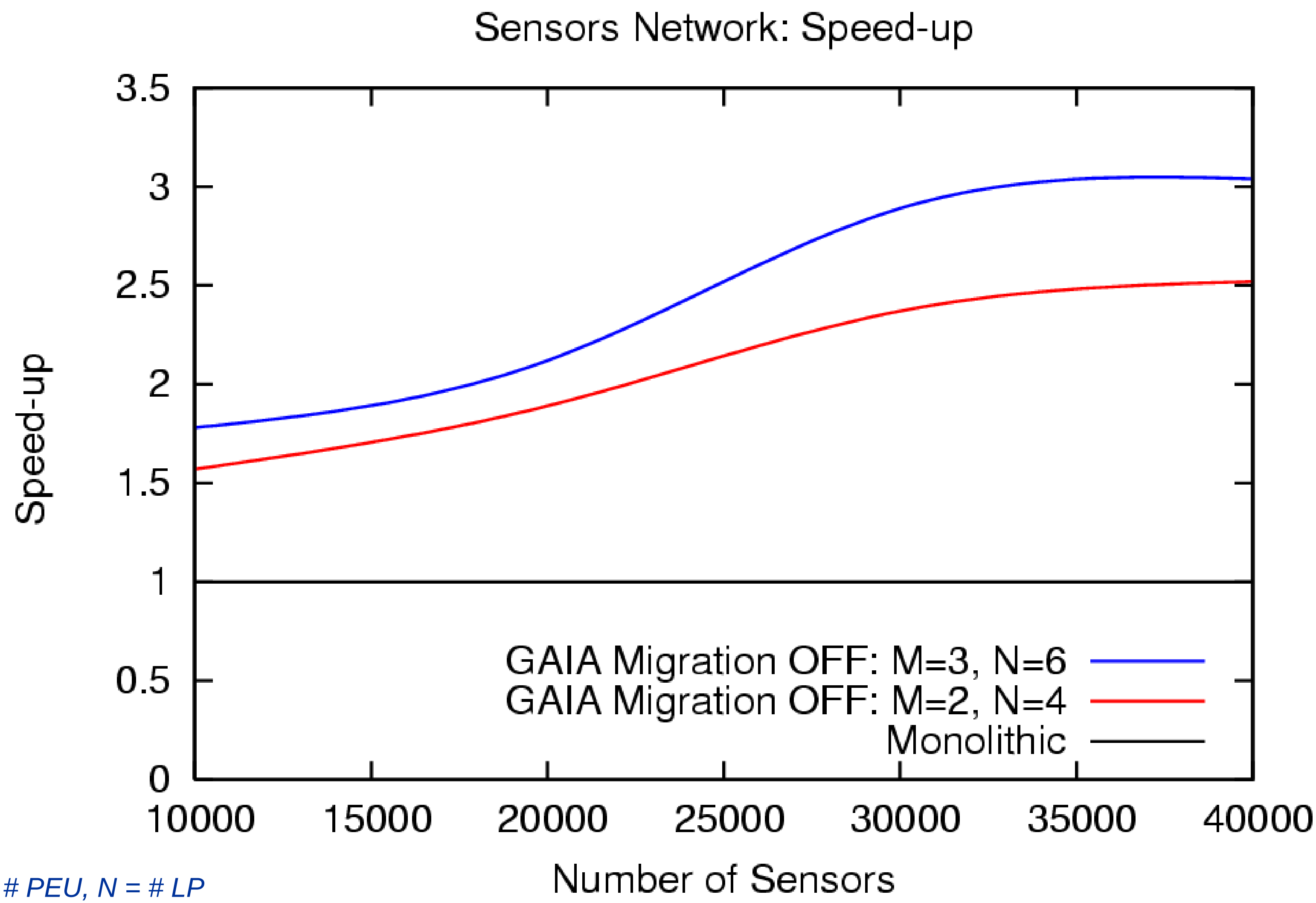
Blue circle =

alert-message transmission

GOAL: extend the network lifetime maintaining network connectivity



Performance analysis: speed-up



M = # PEU, N = # LP

Conclusions and future work

- Design and implementation of the ARTìS middleware
- GAIA: adaptive allocation of model entities in a parallel and distributed simulation
- Examples: ad hoc and sensor network
    - increasing the simulation scalability and speed-up
- Future work
    - ARTìS extension (i.e. optimistic syncronization)
    - GAIA load balancing and migration heuristics improvement
    - Design and implementation of new models (scale free-networks, P2P model, detailed 802.11 MAC protocol)

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