

# 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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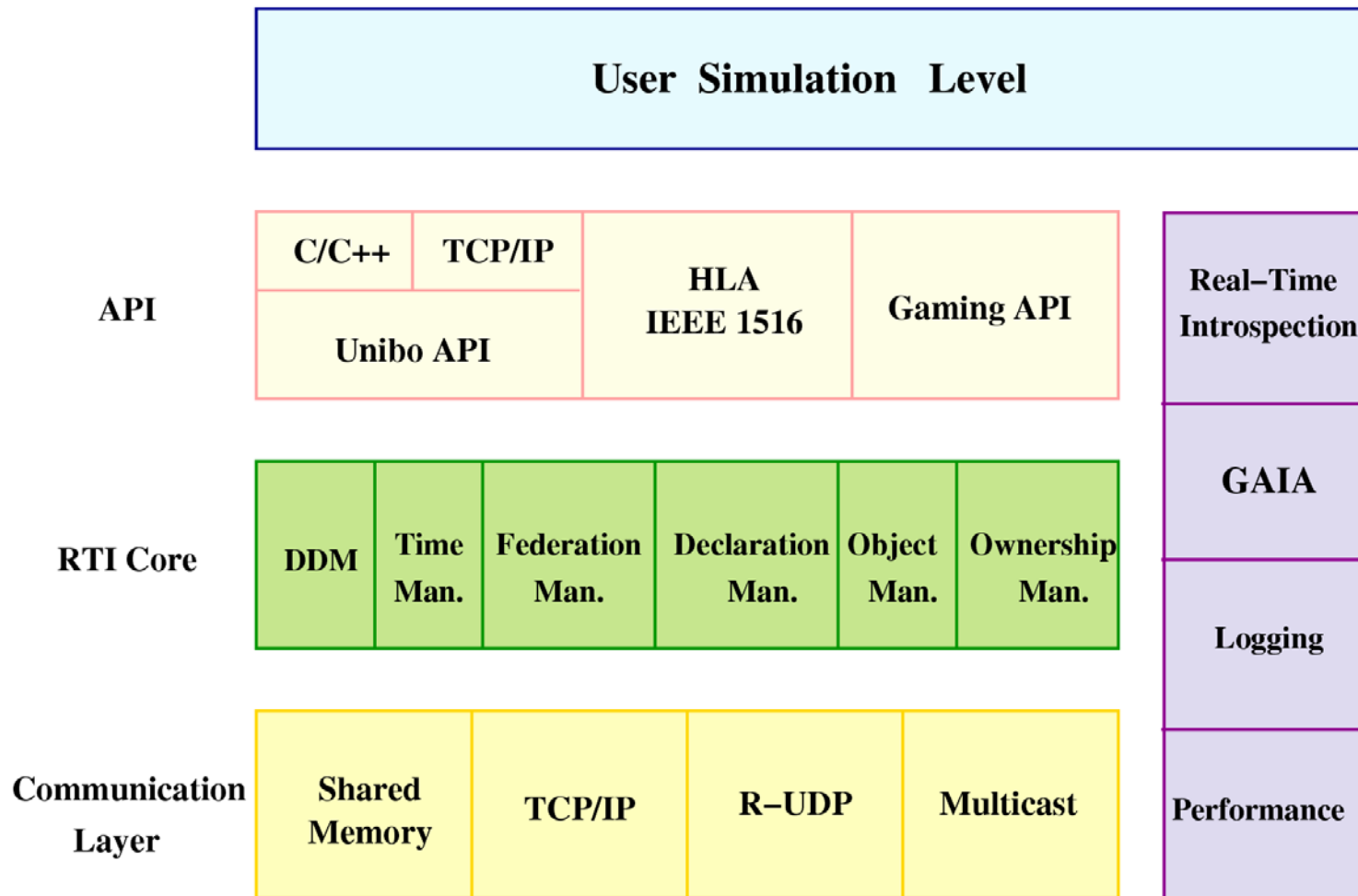
# Presentation outline

- Simulation of wireless and mobile systems
- The ARTiS 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 ARTiS parallel and distributed simulation middleware



# Mobile and Wireless Networks' model characteristics

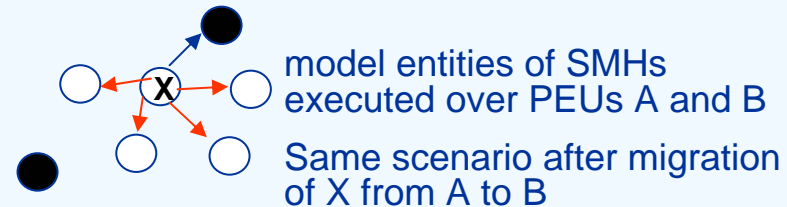
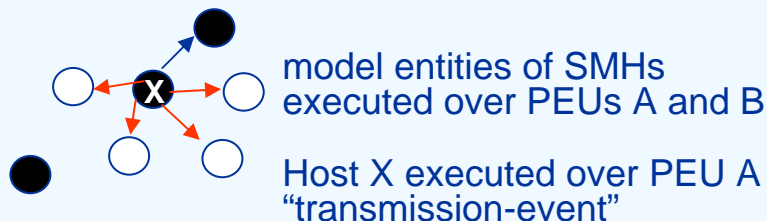
- **“Open broadcast” nature of the wireless transmissions**
  - “space-locality” of causality between neighbor-hosts
  - neighbor-hosts should be notified about transmission events anyway, e.g. to model interference, detection, MAC, etc.
- **Wireless devices can be mobile**
  - the set of neighbor-hosts 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:

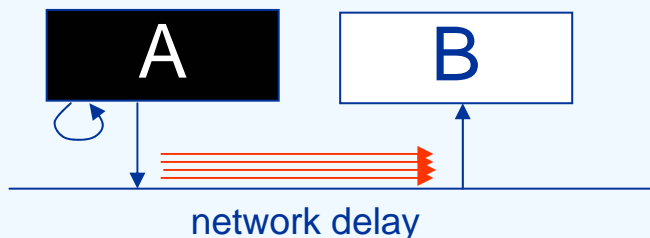
high degree of communication is required to maintain full synchronization

# Simulated Mobile Hosts (SMHs) migration

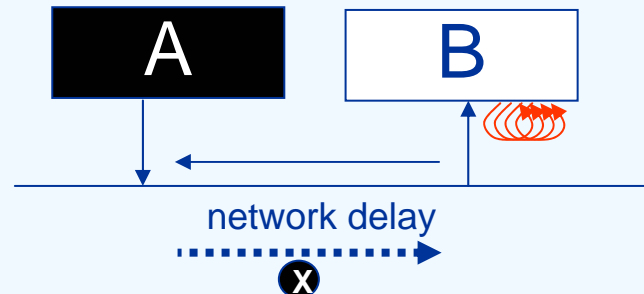
Wireless ad hoc network scenario: (evaluating migration of SMH x)



Physical Execution Units for the simulation



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*

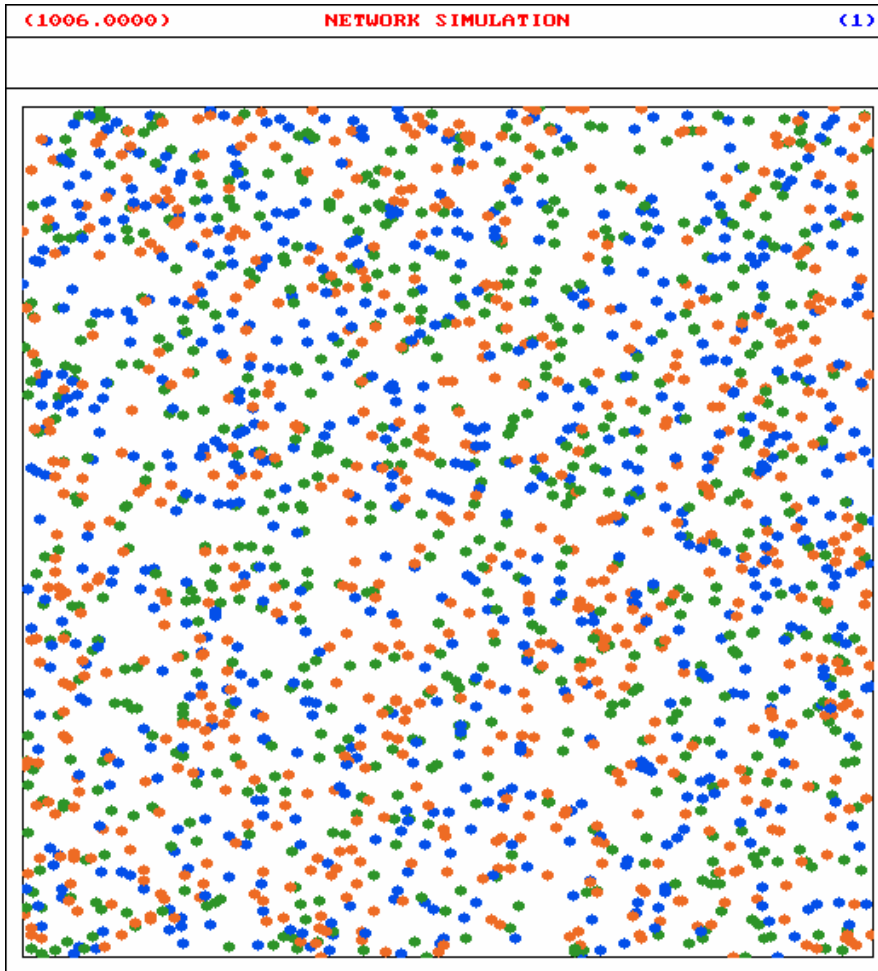
*PEU = Physical Execution Unit*

# Example: Ad-Hoc network model implementation

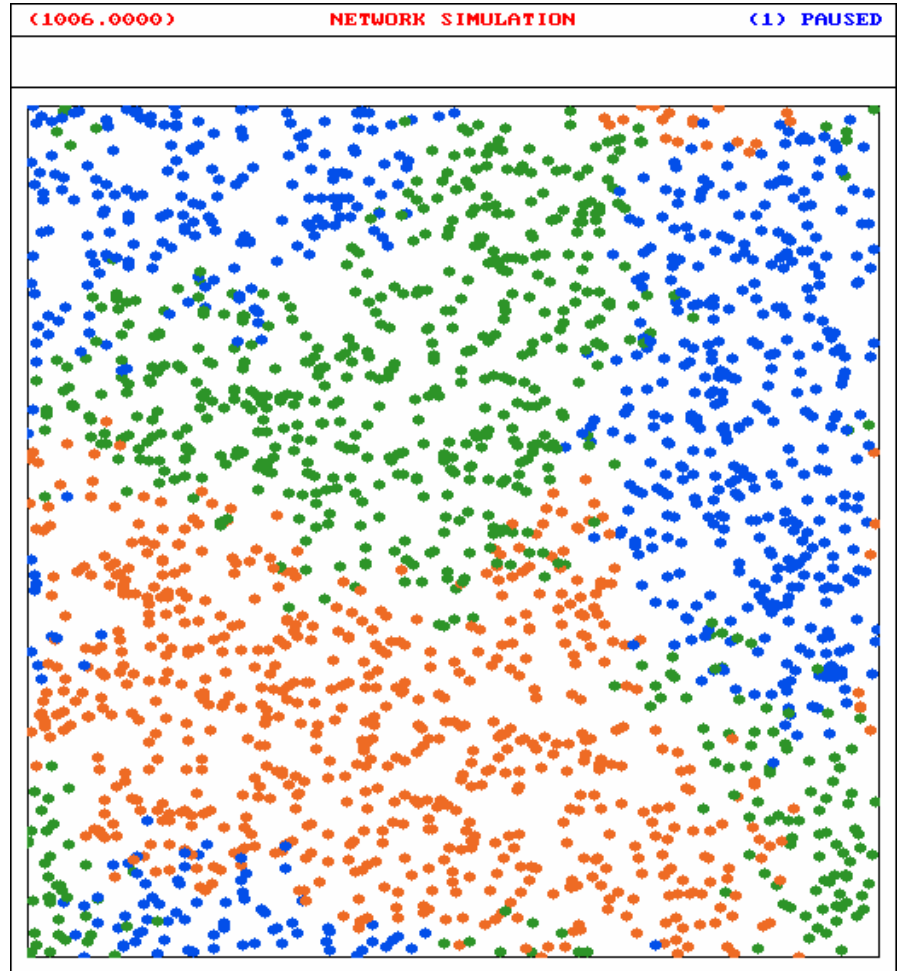
## Modeling issues:

- 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”



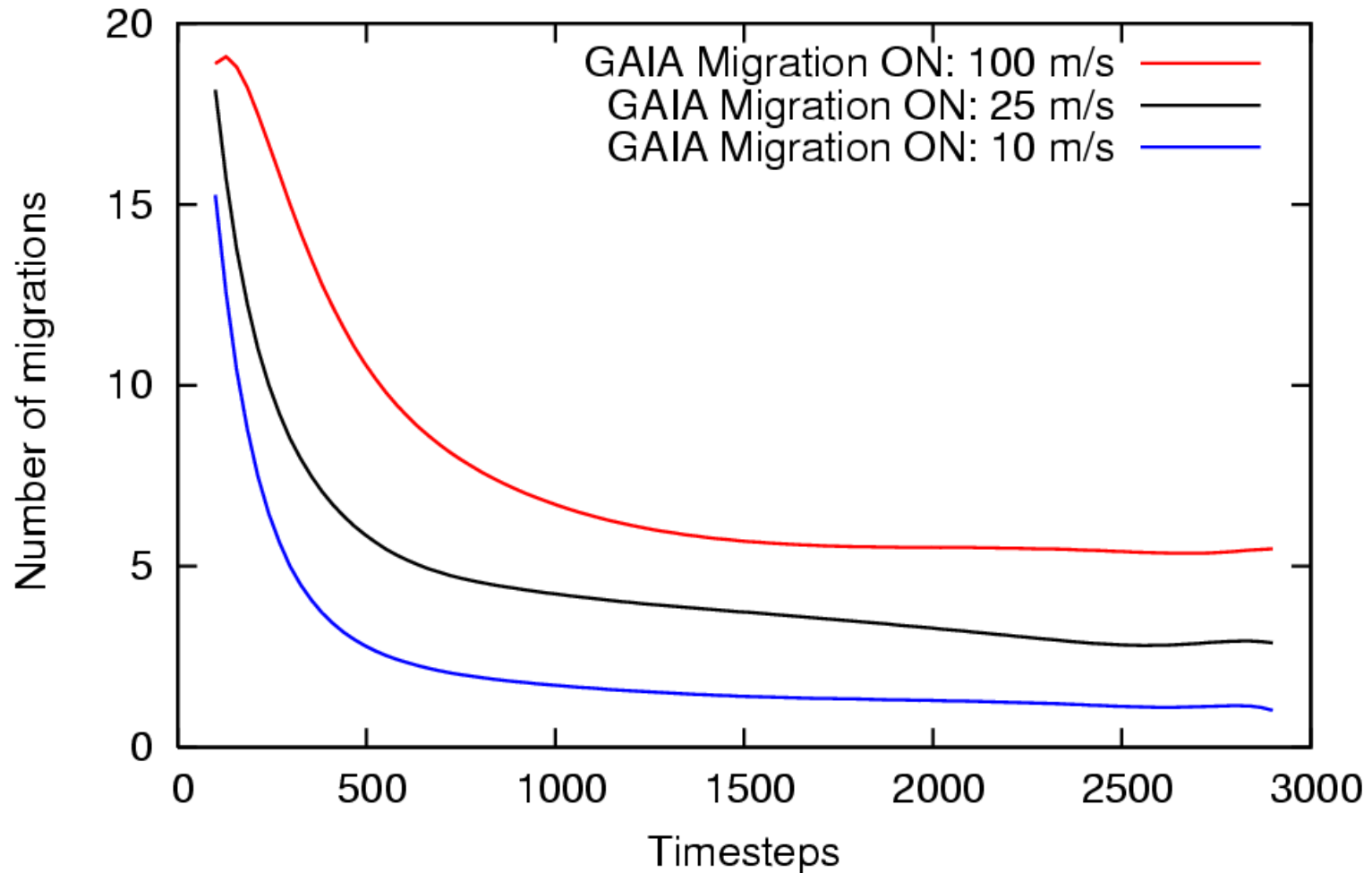
Migration “OFF”



Migration “ON”

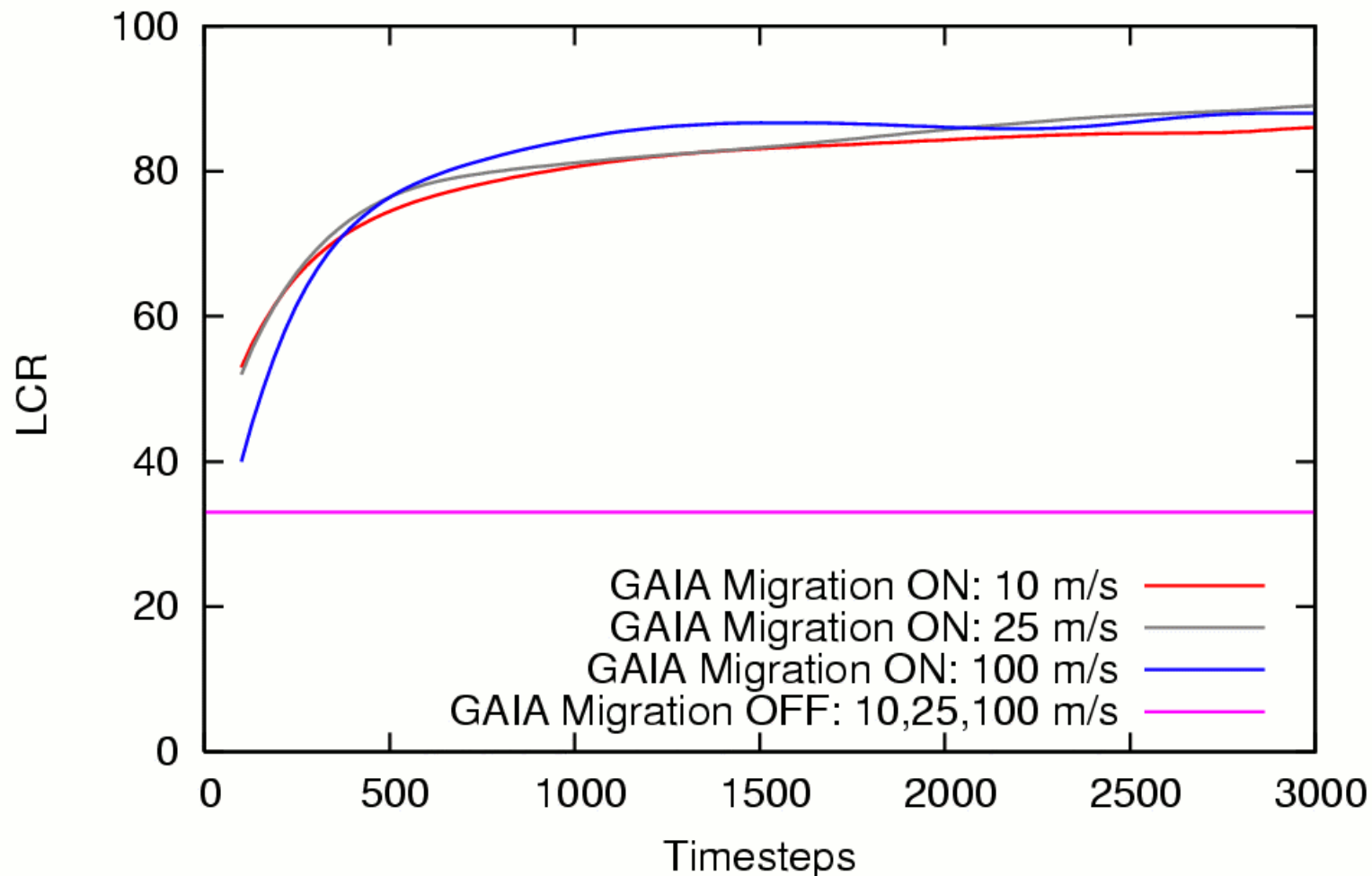
# Performance analysis: number of migrations / timestep

Ad Hoc Network: 3 LPs, 5000 SMHs



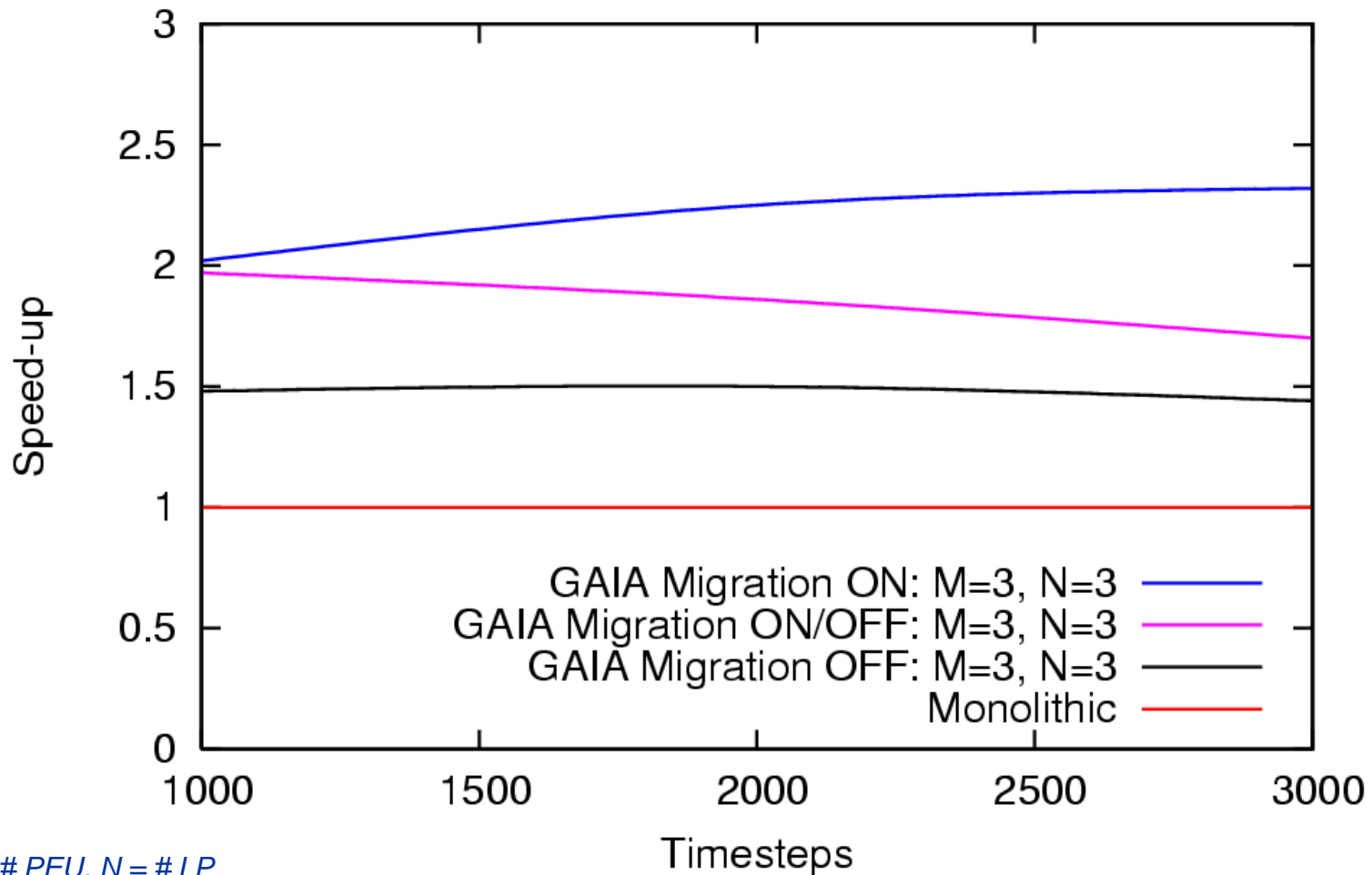
# Performance analysis: Local Communication Ratio

Ad Hoc Network: 3 LPs, 5000 SMHs



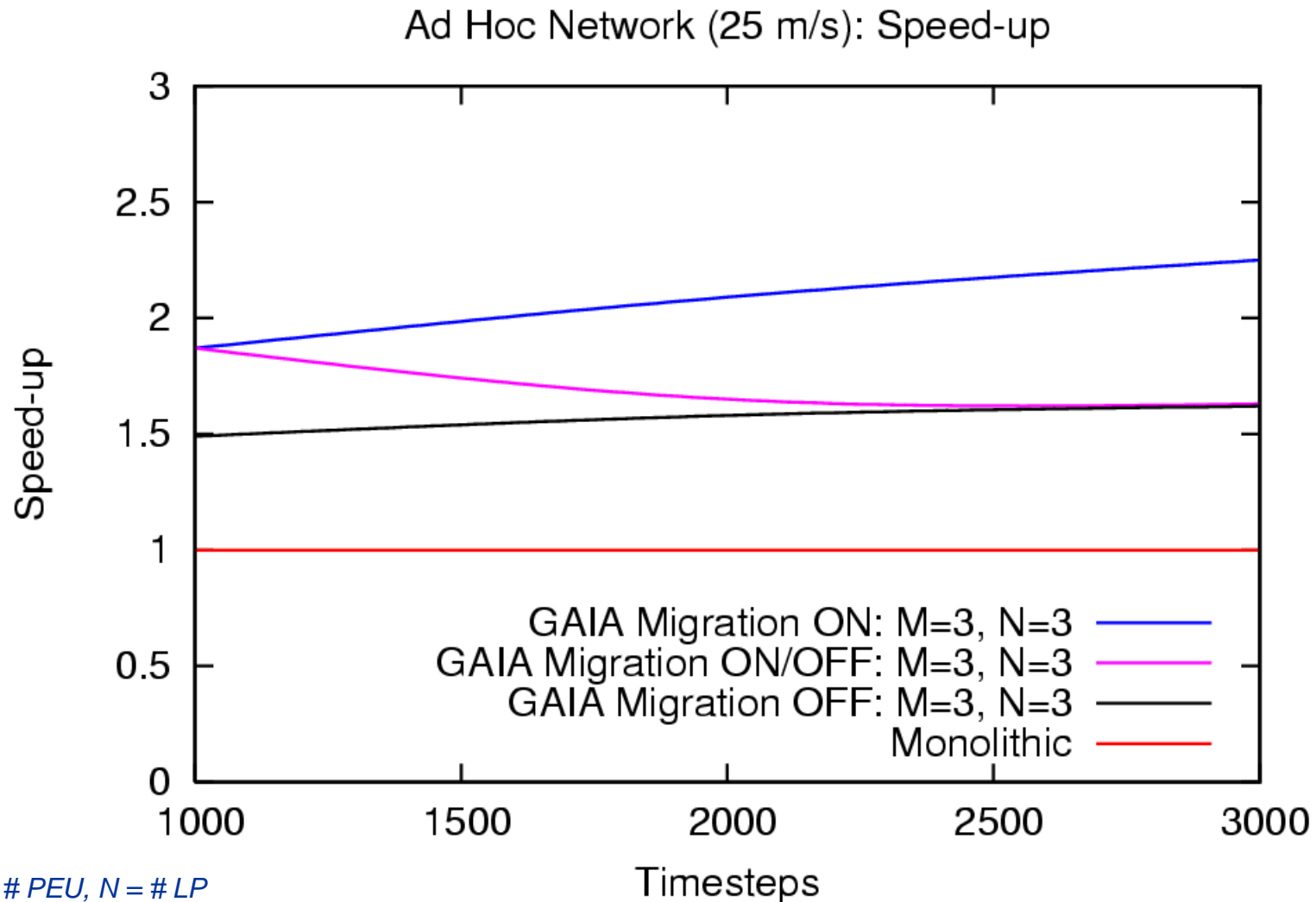
# Performance analysis: speed-up

Ad Hoc Network (10 m/s): Speed-up



$M = \# PEU, N = \# LP$

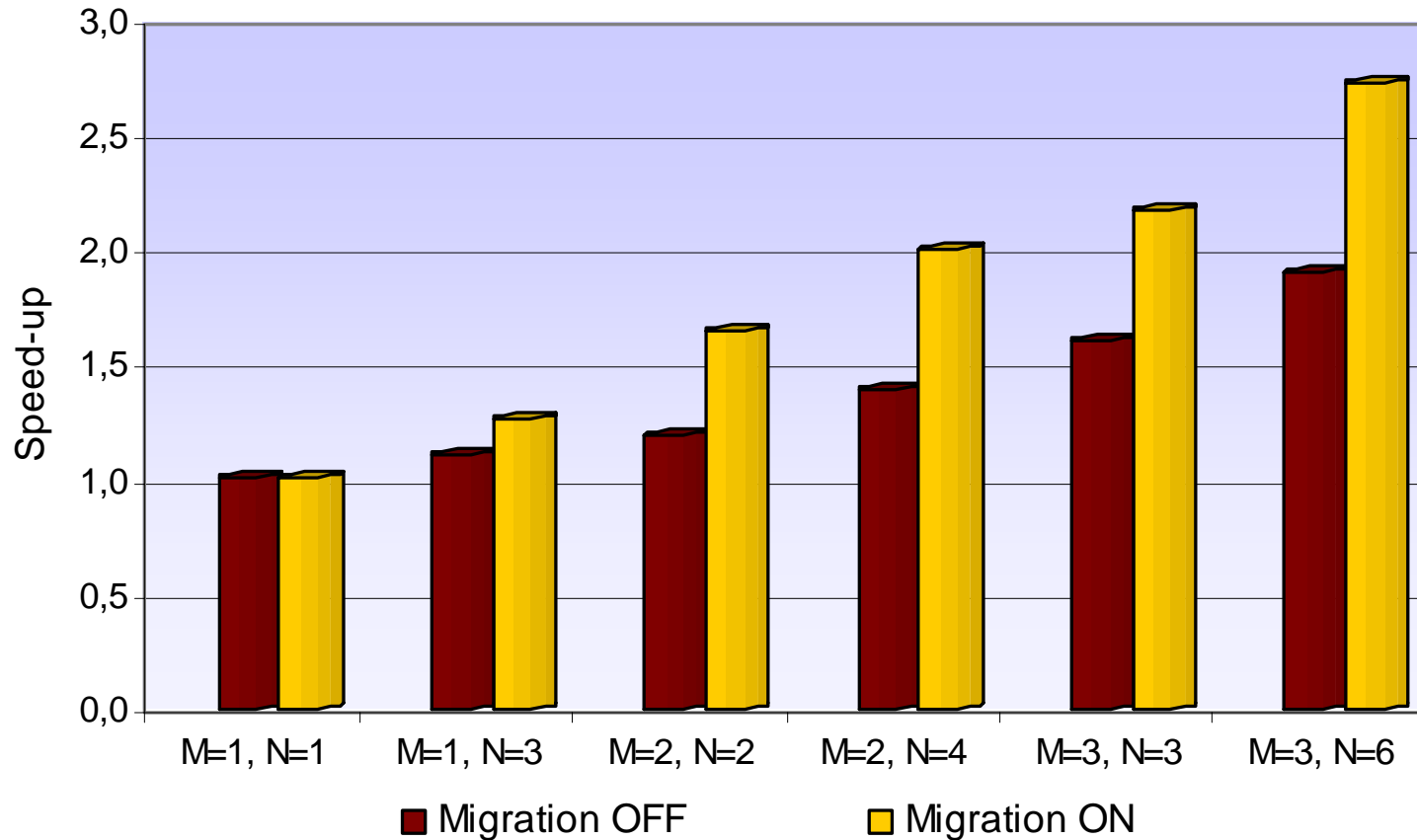
# Performance analysis: speed-up



$M = \# PEU, N = \# LP$

# Performance analysis: speed-up

Ad Hoc (25 m/s): 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

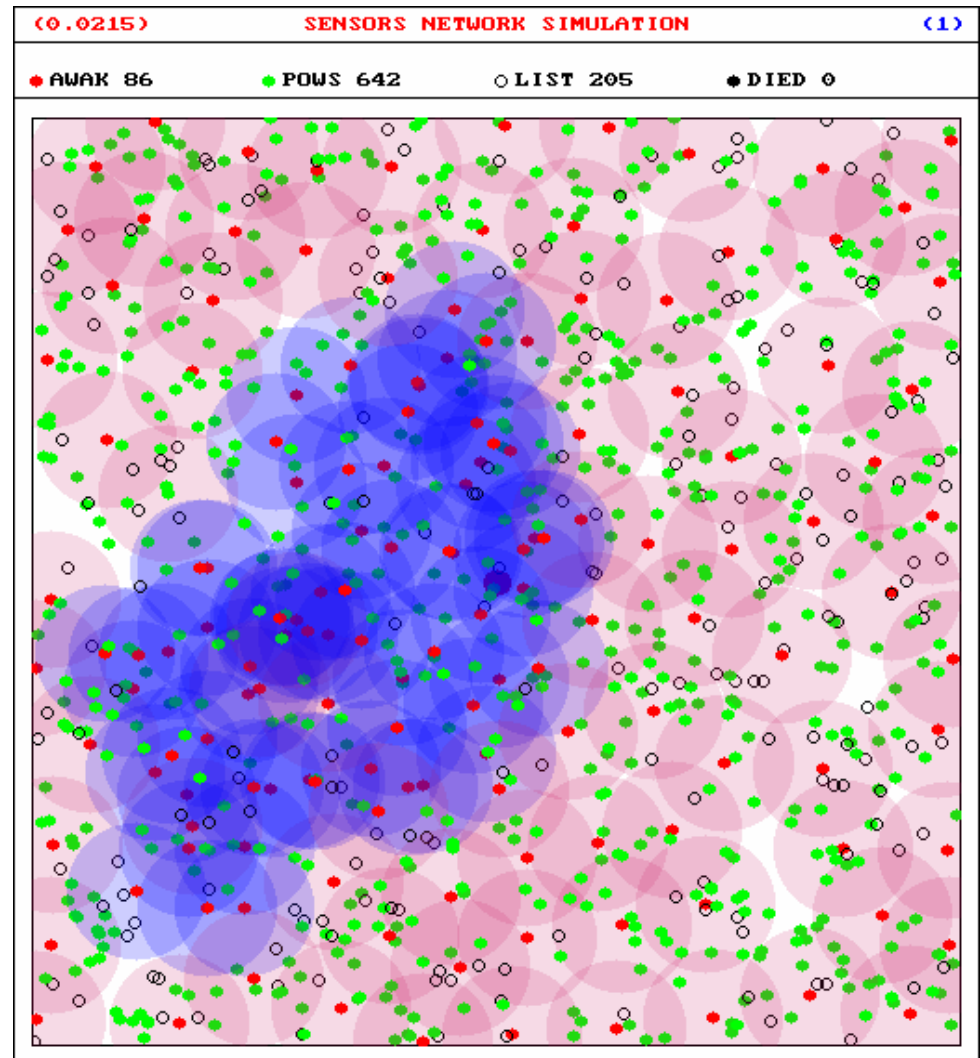
4 different states:

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

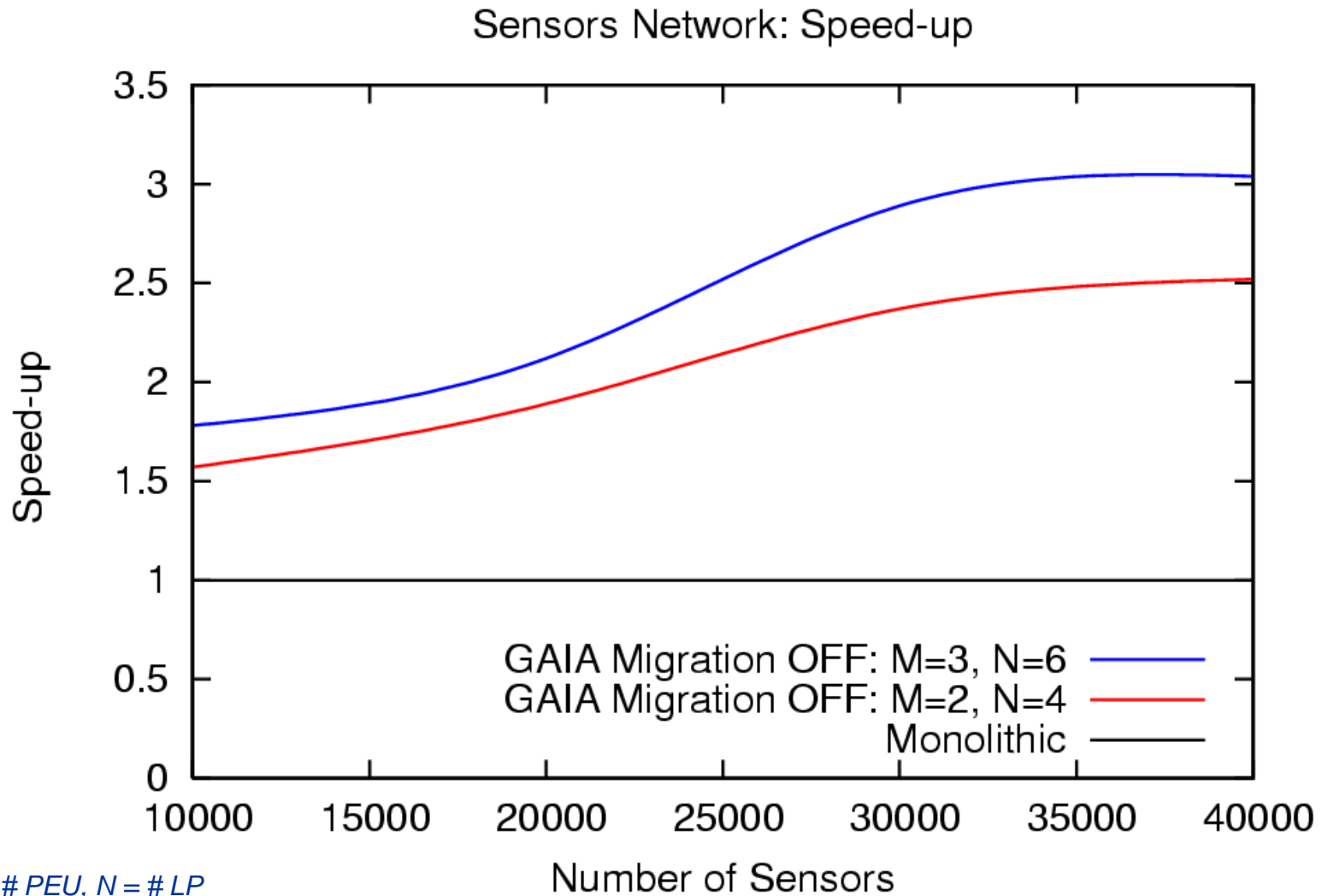
Pink circle =  
active transmitting range

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 ARTiS 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
  - ARTiS extension (i.e. optimistic synchronization)
  - 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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