Exploiting network structure in NEST: Efficient communication in brain-scale simulations

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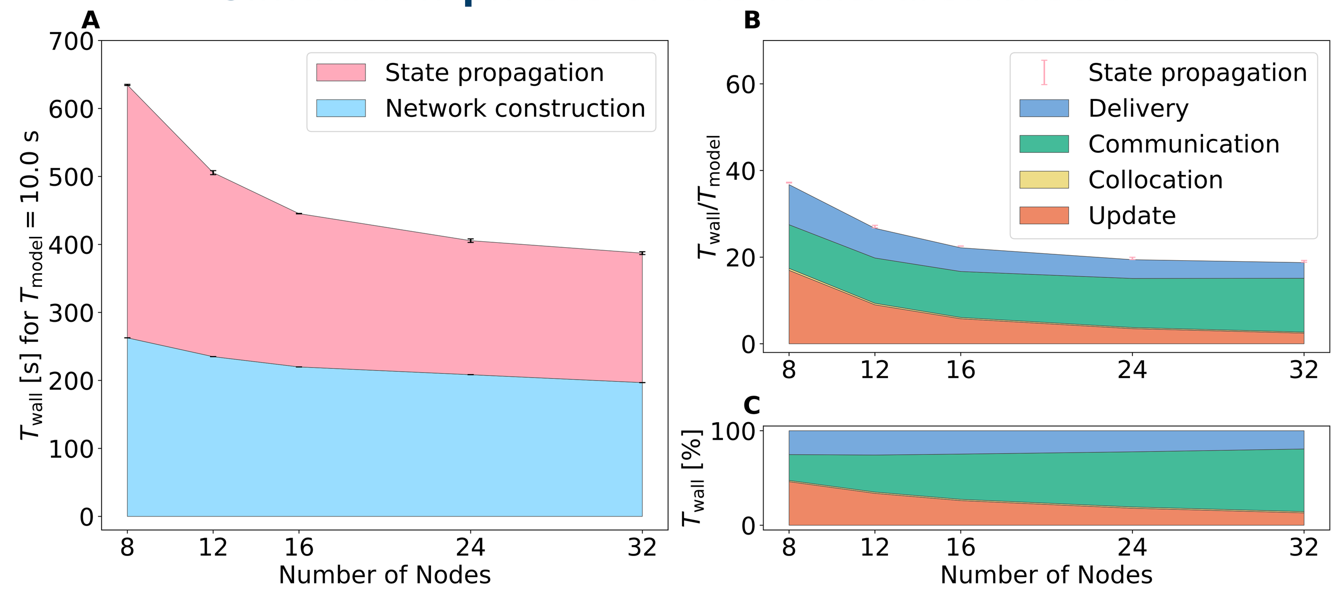
Motivation

- continuous improvement of CPU-based simulation techniques create challenging benchmarking targets for neuromorphic platforms
  - neuronal simulations on conventional hardware still maintain higher flexibility at potentially lower cost compared to novel dedicated hardware [1]
- spike communication is the bottleneck in simulations of brain-scale networks [2]
- e.g. the multi-area model of macaque visual cortex [3]
  - 32 interconnected areas modelled as microcircuits [4]
  - realistic connectivity
  - single neuron resolution

⇒ structure-aware neuron distribution scheme combined with optimized spike-communication framework to speed up neuronal simulations

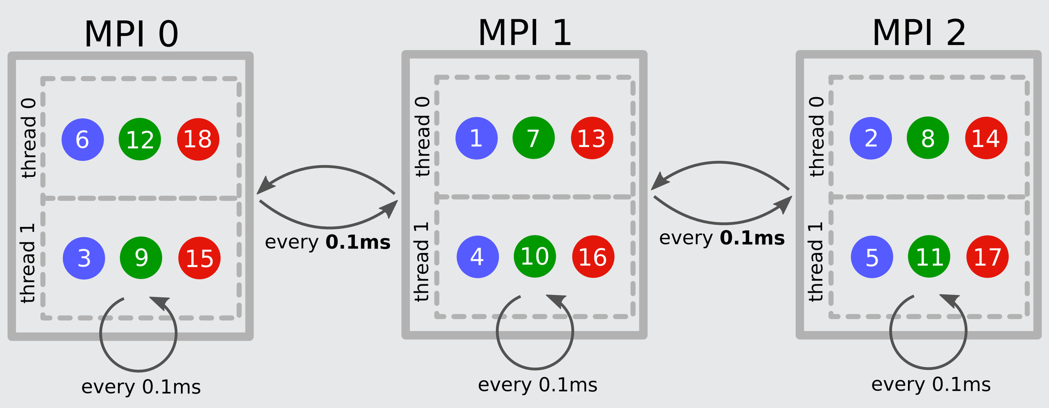
Simulation phases of the multi-area model



Strong-scaling benchmark of macaque multi-area model performed with NEST v3.6 on Jülich Supercomputer JURECA.

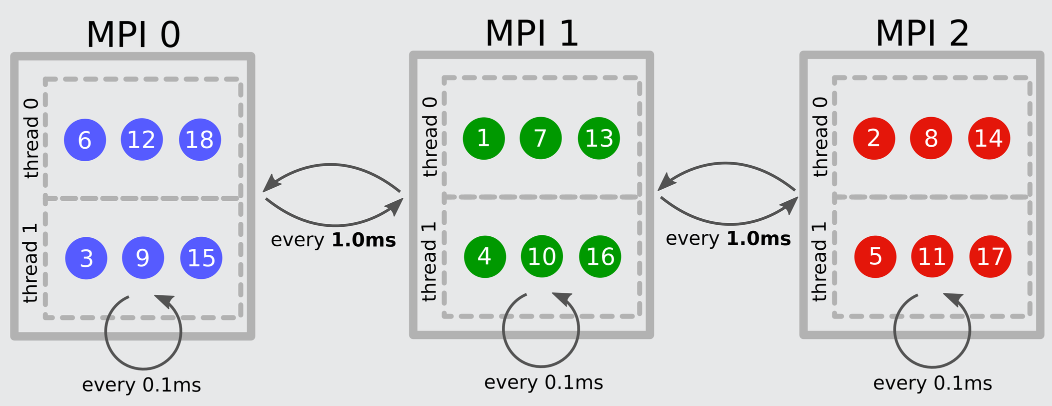
Algorithm

Conventional neuron distribution scheme



- uniform occupation of compute nodes: "round-robin"
- neurons of the same area are spread out on the hardware
- communication between compute nodes every smallest delay of e.g. 0.1 ms

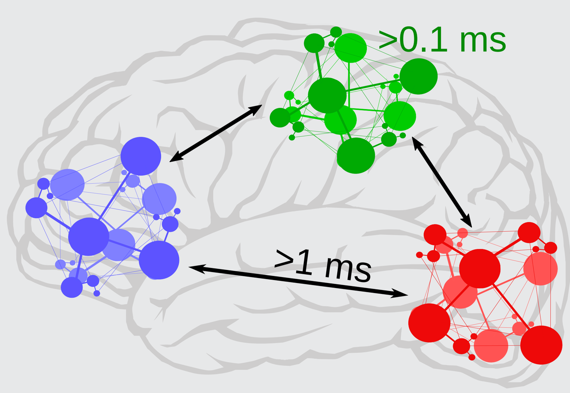
Structure-aware neuron distribution scheme



- one/few compute nodes per area
- two communication pathways
  - within an area: short delays (e.g. 0.1 ms)
  - between areas: long delays (e.g. 1.0 ms)

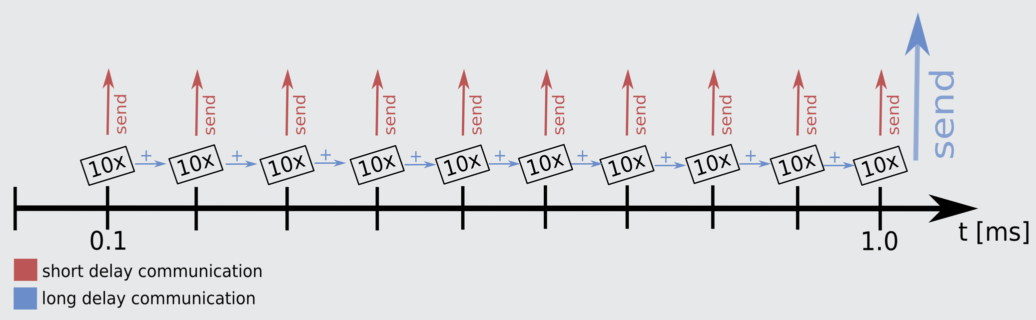
⇒ faster communication within areas

⇒ fewer communication between areas



Example: structure-aware approach

- 10.000 neurons per area; 10 spikes/s

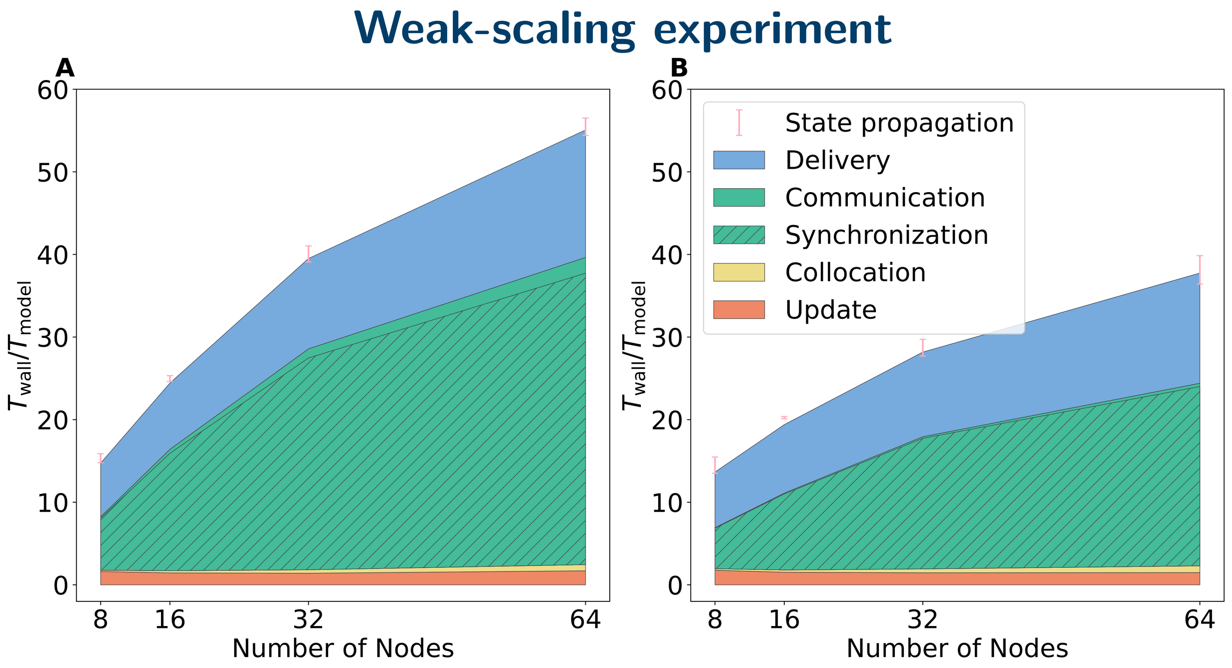


Results

Setup

- neuronal simulator tool NEST [5,6]
- benchmarking model
  - similar to macaque multi-area model in connectivity and work load
  - easily scalable while retaining constant activity levels
  - ≈ 130.000 neurons per area
  - ≈ 3000 inter- and intra-area connections per neuron, respectively
  - average spike rate of 2.5 spike/s
- Jülich Supercomputer JURECA
  - 2 areas per compute node
- communication phase
  - synchronization between all compute nodes (only long-range communication)
  - spike data exchange (both short-range and long-range communication)

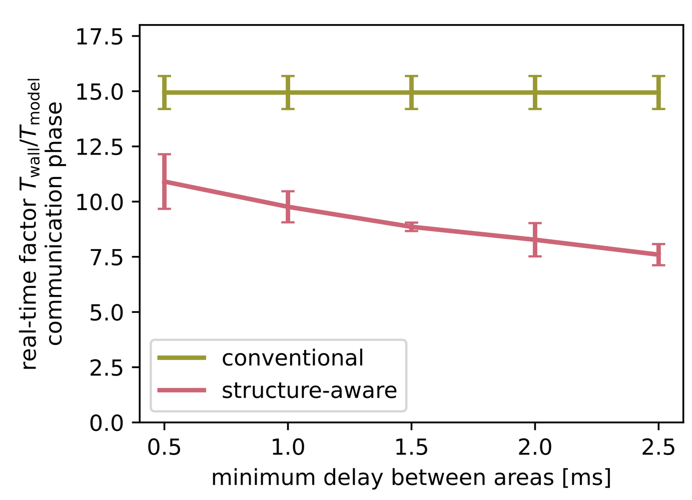
Weak-scaling experiment



A Conventional round-robin neuron distribution with single communication pathway.
B Structure-aware neuron distribution with separate communication pathways for short- and long-range connections

- significant speed up of spike communication
- benefit lies in reduced time spent on compute node synchronization
- promising scaling behavior for large number of areas and compute nodes

Delay dependence



- delay distr. within an area: $\mathcal{N}(1.25, 0.625)$
- delay distr. between areas: $\mathcal{N}(5.00, 2.50)$
- lower cutoff of inter-area delay distribution defines inter-node communication frequency in structure-aware approach

⇒ benefit of implementation increases with decreasing amount of inter-area communication

References

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Outlook

- benchmarking of networks with inhomogeneous activity or size
- benchmarking state of the art models (e.g. multi-area model of macaque visual cortex)

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