Sim-Situ

A Framework for the Faithful Simulation of in situ Processing

Valentin Honoré, Tu Mai Anh Do, Loïc Pottier, Rafael Ferreira da Silva, Ewa Deelman, Frédéric Suter

In situ Processing – Historical meaning

- Post-hoc

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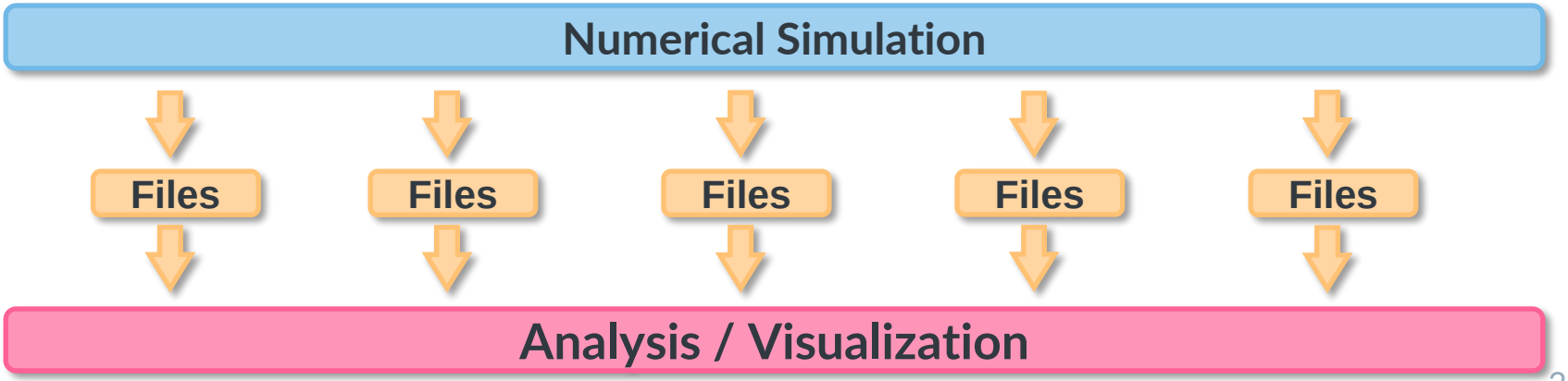
☹ Files becoming too big + Gap increase between CPU and I/O ☹

In situ Processing – Historical meaning

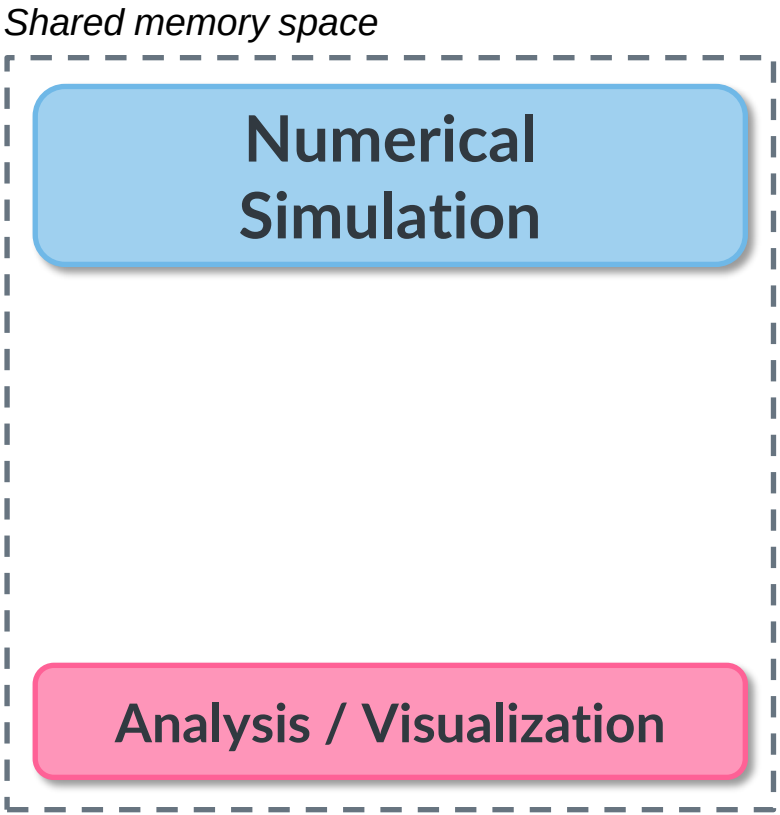
- Post-hoc

☹ Files becoming too big + Gap increase between CPU and I/O ☹

- In situ



In situ Processing – Modern meaning



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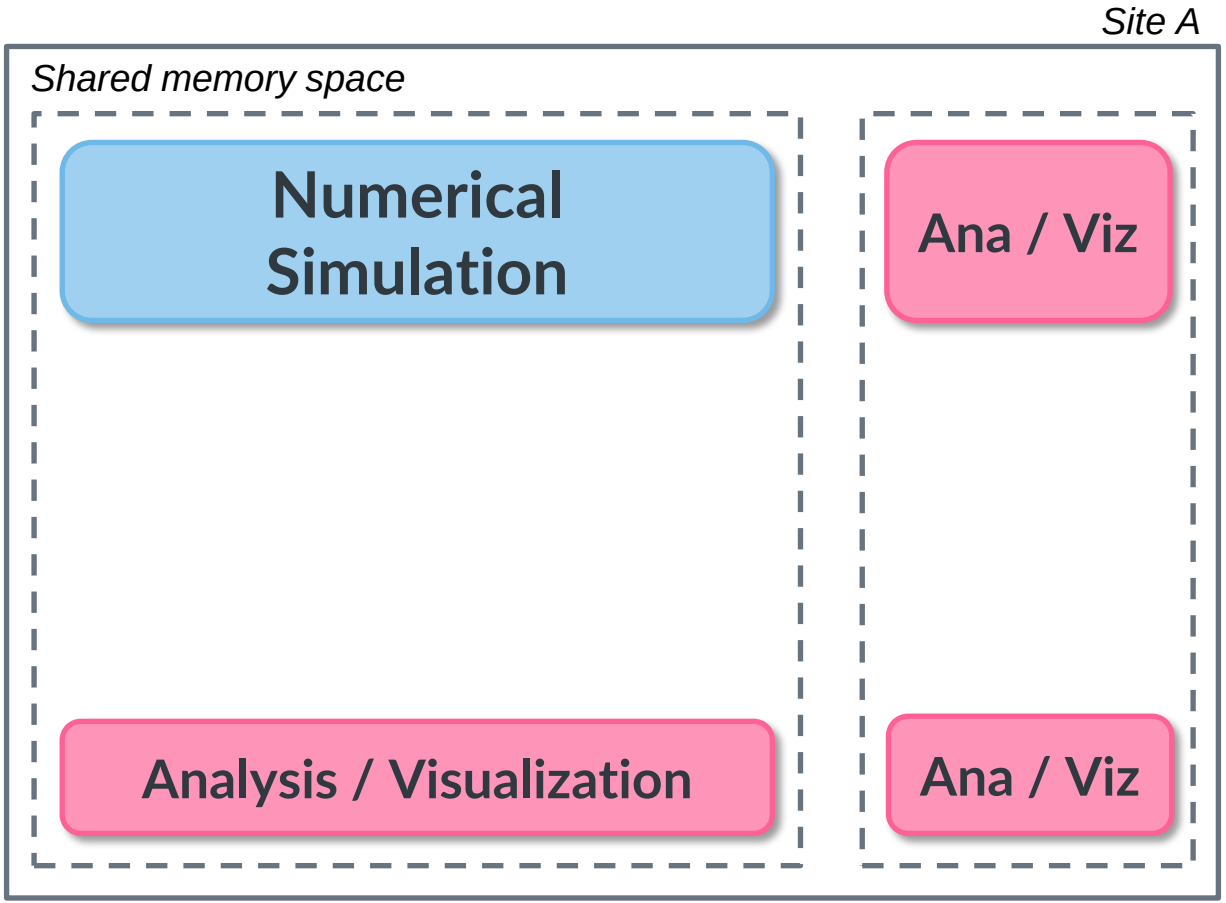

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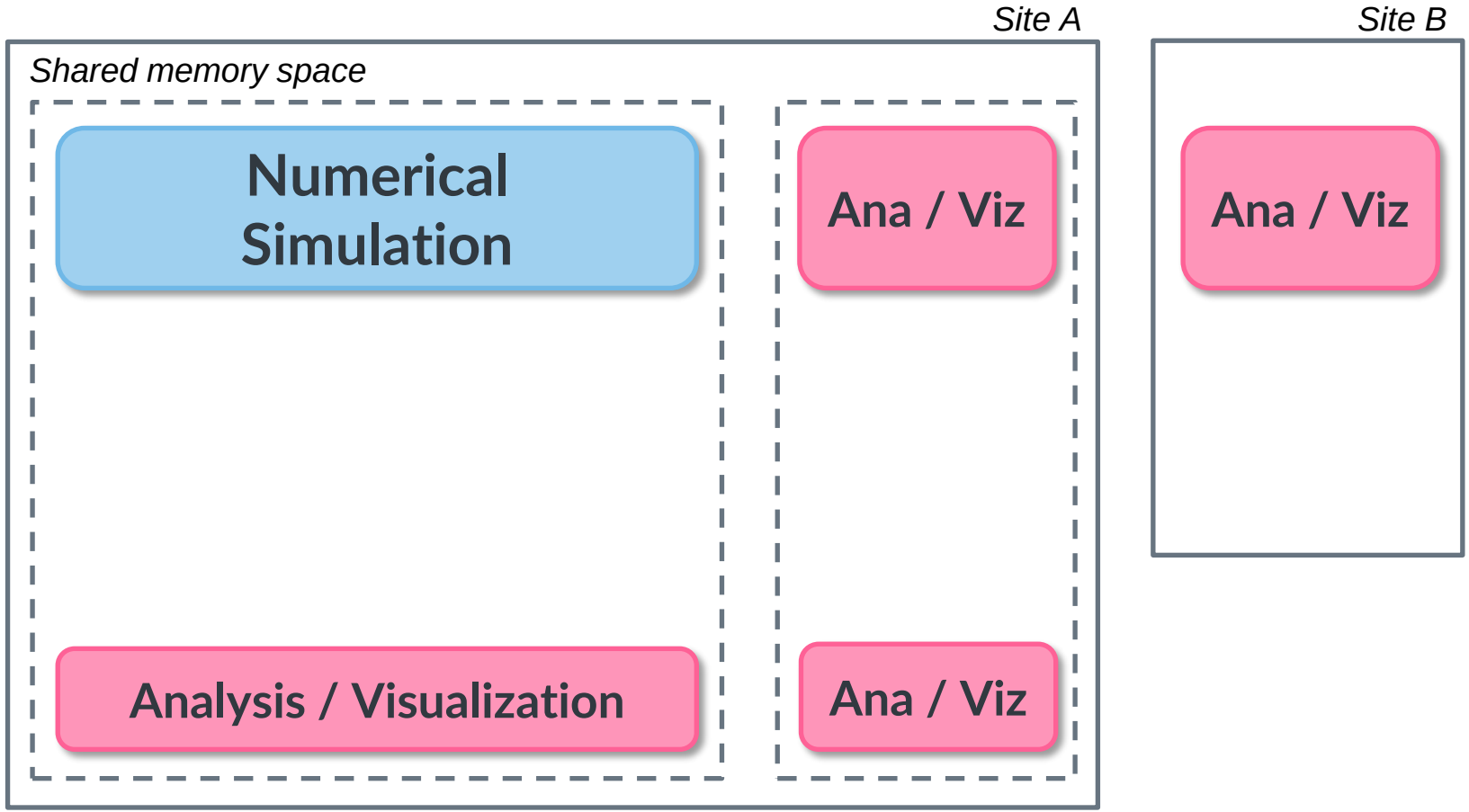

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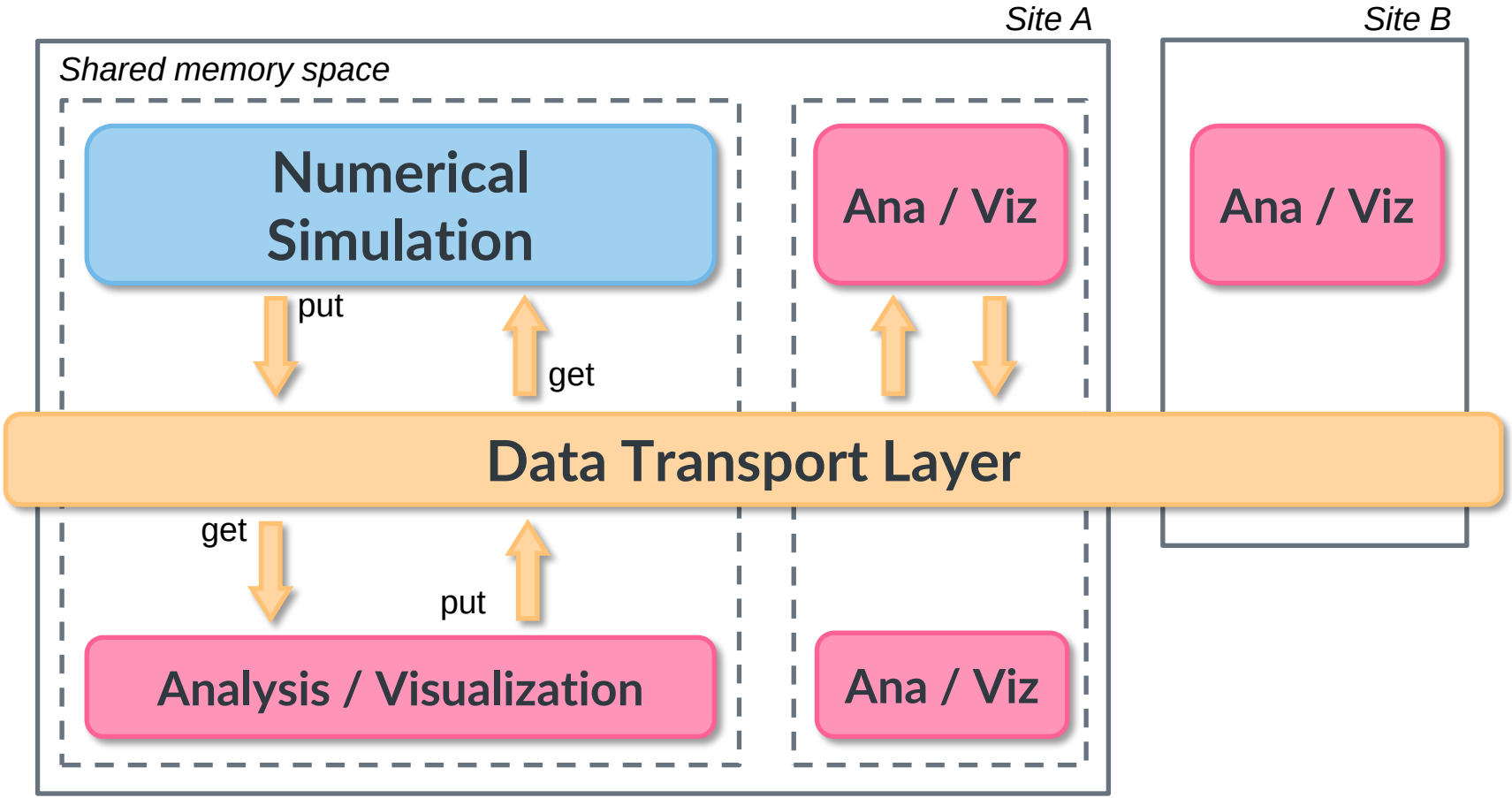

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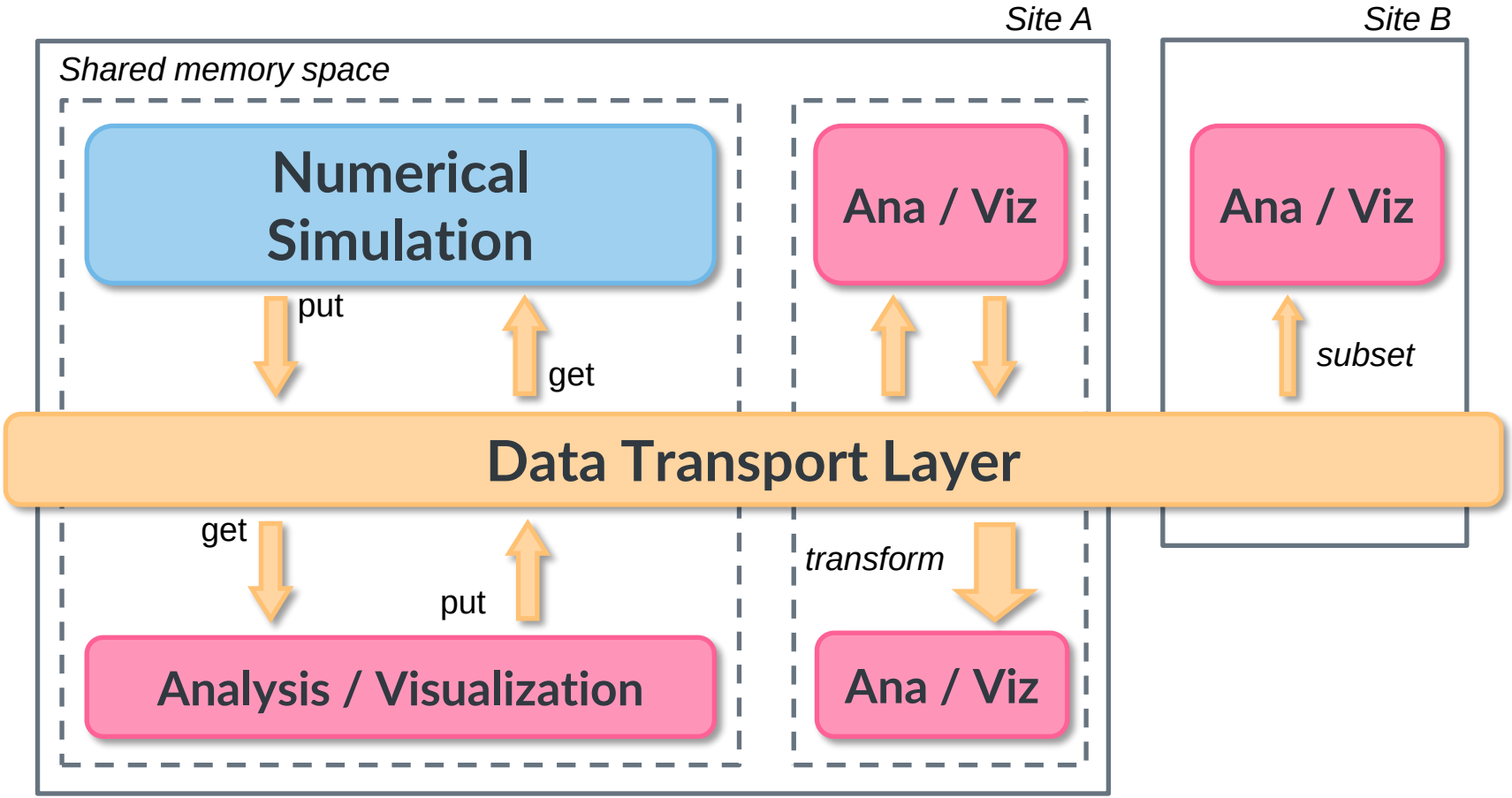

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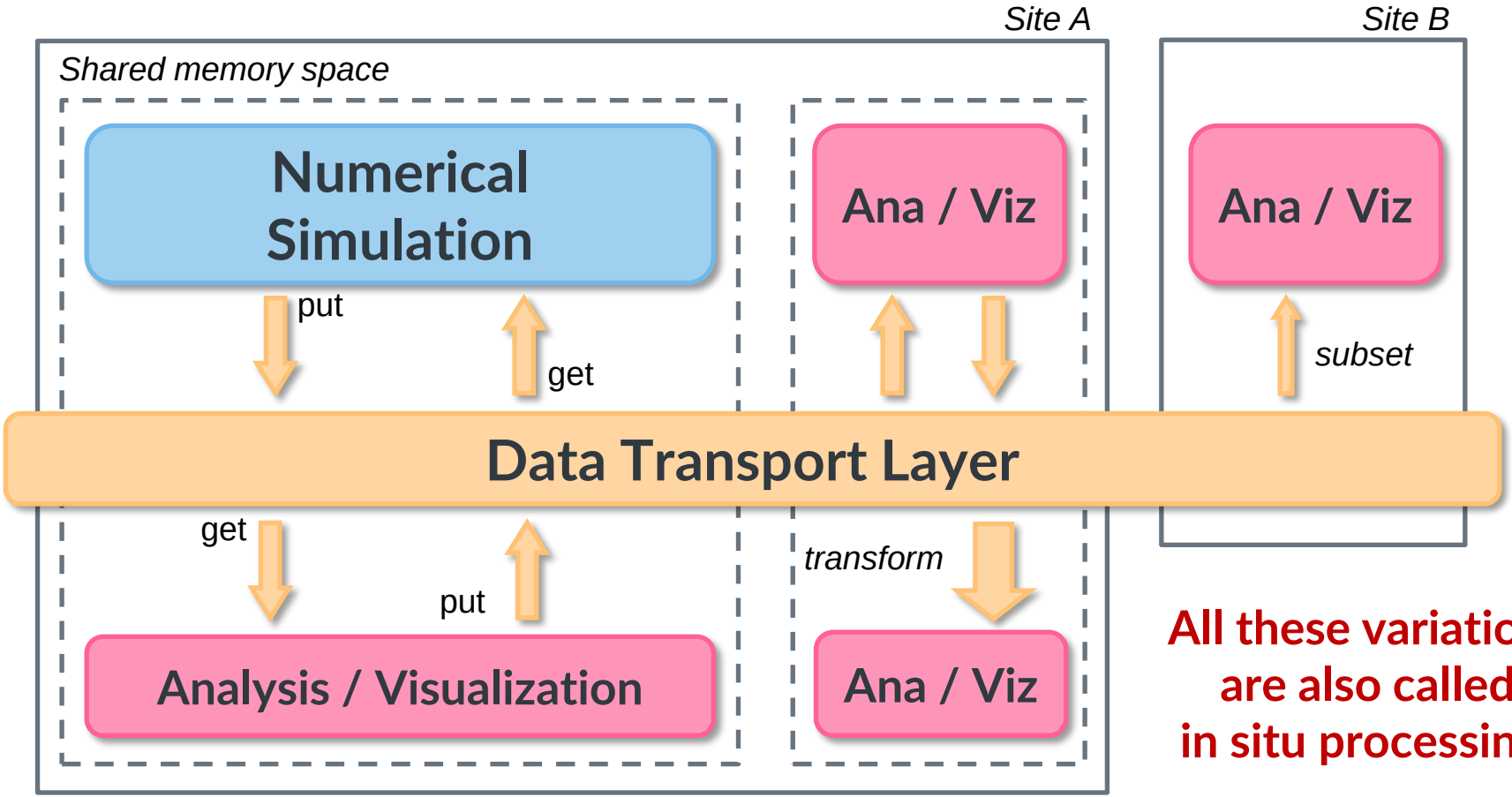
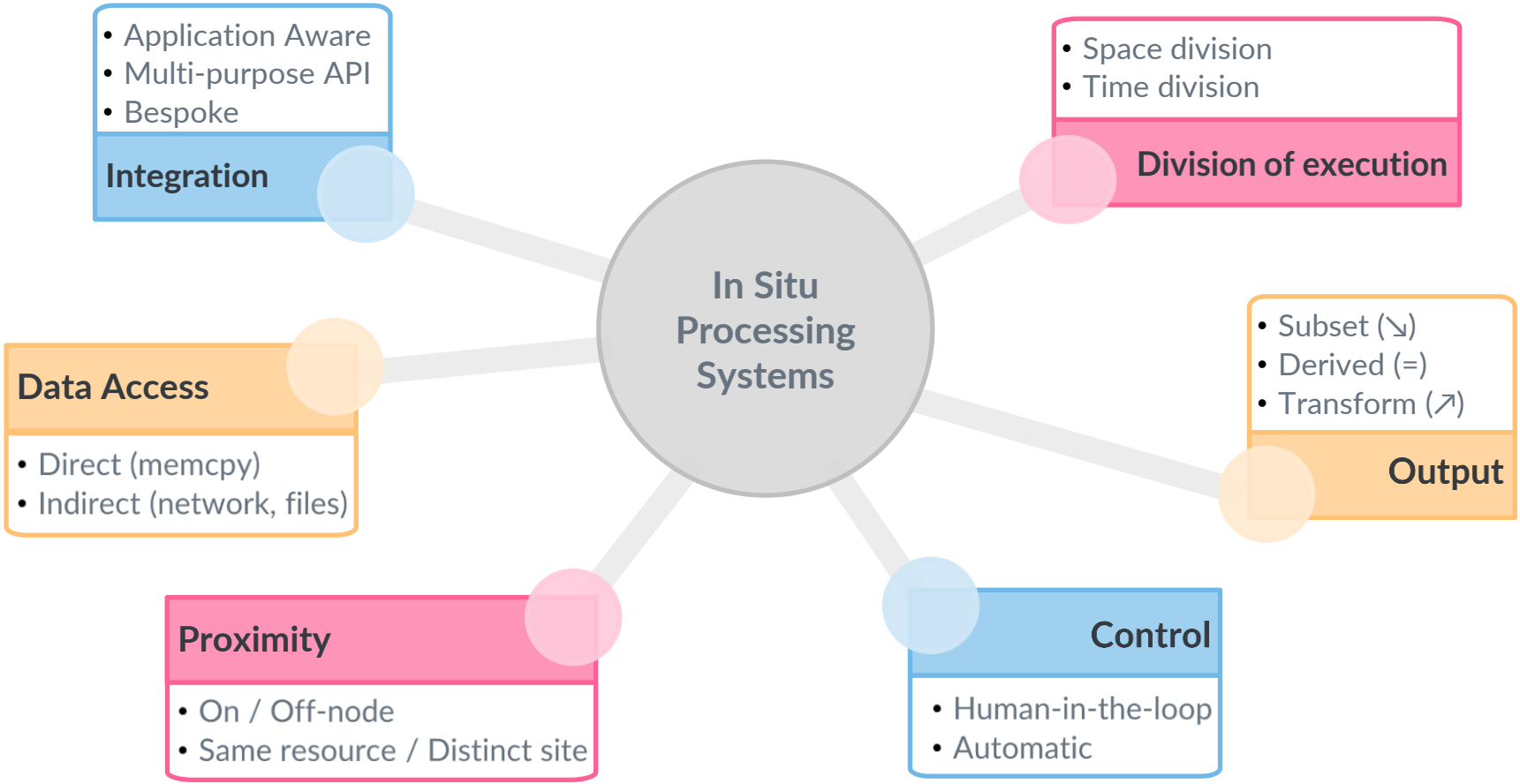


All these variations are also called in situ processing!

In situ Processing – Terminology

H. Childs, et al. (2020)
IJHPCA 34:6, 676–691



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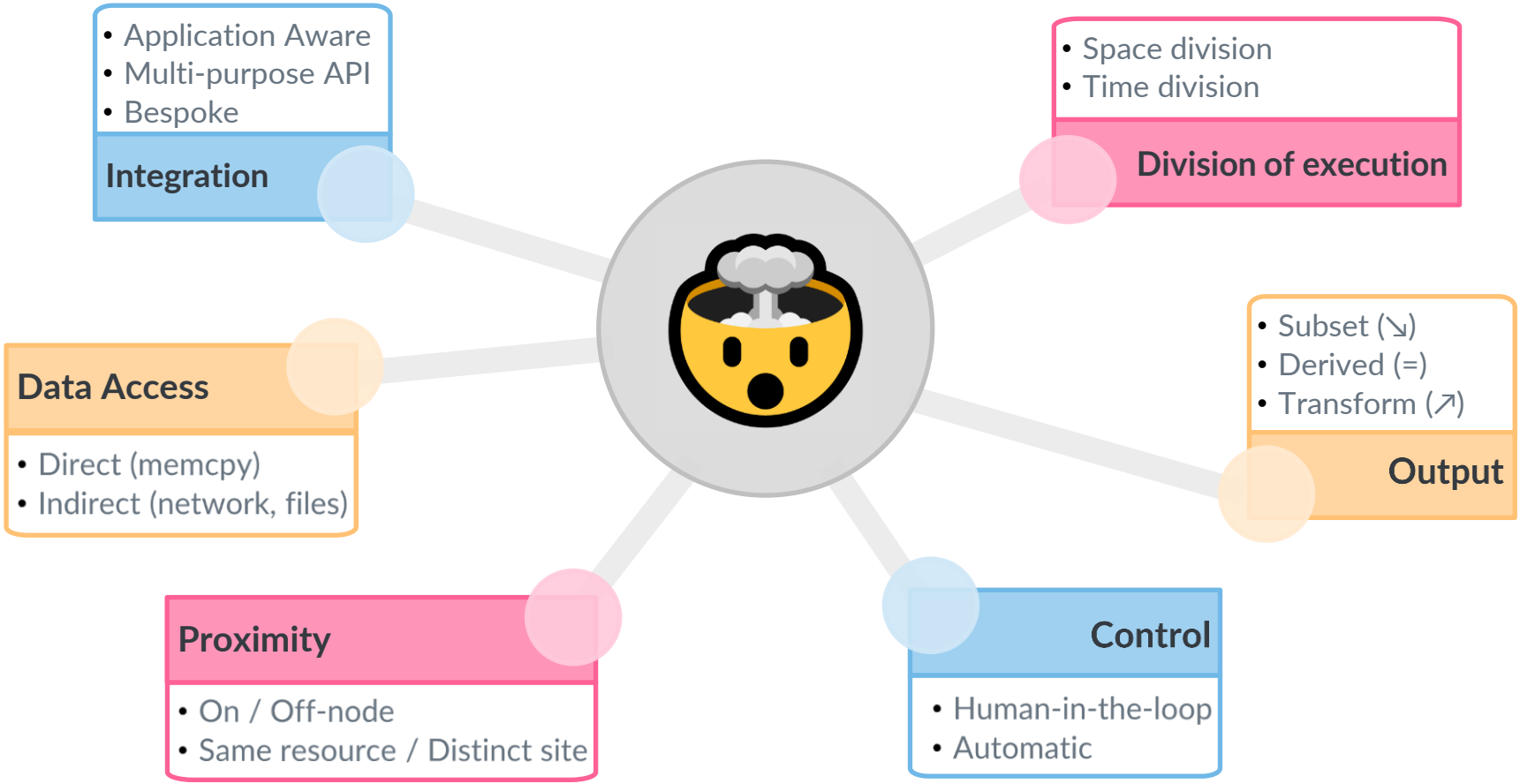

In situ Processing – Research Questions

RQ1 **Allocation**

How much resources give to simulation, analysis, viz?

RQ2 **Mapping**

Where and when run the analysis/visualization?

RQ3 **Data Transport**

Are files out of question? In-memory or over network?

RQ4 **Scalability**

Will choices remain the best one at scale?

RQ5 **Optimization**

Multiple options, not always completion time

Why Sim-Situ?

- Answer RQs → **Performance evaluation**
  - Take good decisions → **Objective performance indicators**
- **Go beyond the traditional empiric guess** → **Speed and Flexibility**
  - Explore many unconventional scenarios
  - Consider unconventional performance metrics

Experiments

→ Time- and resource-consuming
→ Complex to set up
→ Limited in scope
→ Sensitive to exogenous factors

Simulation

→ Run on a laptop
→ Highly flexible
→ What-if scenarios
→ Reproducibility and control

Sim-Situ Architecture

Fundation – SimGrid

https://simgrid.org

A scientific instrument on your laptop

- Open Project since 1998
- Key strengths
  - **Usability:** Fast, Reliable, User-oriented APIs
  - **Validated performance models:** Open Science → Predictive Power
  - **Versatility:** HPC, Cloud, Fog, Grid, P2P, …

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- SimGrid's fundamental concepts (the **S4U** API)

Actors

Execute user-provided functions

Program anything you want/need

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Actors	Activities
Execute user-provided functions	Computation, communication, I/O
Program anything you want/need	Synchro mechanisms

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Actors	Activities	Resources
Execute user-provided functions	Computation, communication, I/O	CPUs, Links, Disks
Program anything you want/need	Synchro mechanisms	Hosts, VMs, Netzones, …

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Actors	Activities	Resources
Execute user-provided functions	Computation, communication, I/O	CPUs, Links, Disks
Program anything you want/need	Synchro mechanisms	Hosts, VMs, Netzones, …
Mailboxes	Rendez-vous points between actors	

Faithful Simulation – SMPI

Numerical Simulation

- **Have faith: do not modify anything, run your application!**
- (Sim/em)ulation of (unmodified) MPI applications
  - Support of (the essential of) MPI-3.1
  - **Collective operations:** Borrowed selection logic of popular runtimes
  - **Coupling:** With S4U codes or multiple MPI codes

```
$ smpicc source.c -o application  # The code is now compiled
$ smpirun -platform cluster.xml -hostfile hostfile.txt  ./application # It starts
[...]  # Some debug information about your data provenance
Got 42 from rank 0
```

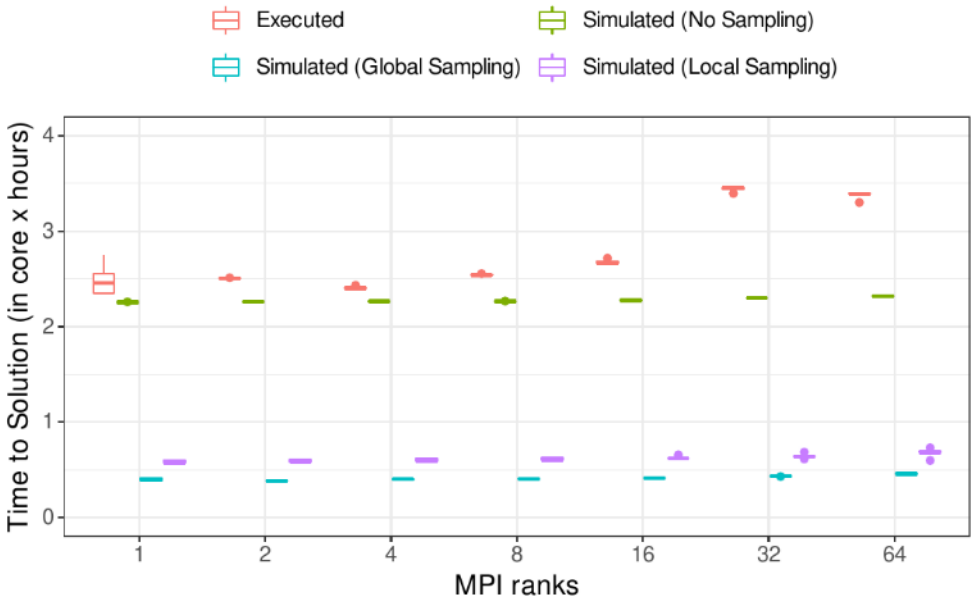
- **Integration testing**
  - Compile and run 100+ proxy-apps every night
  - C, C++, F77, F90, kokkos, and some OpenMP

https://framagit.org/simgrid/SMPI-proxy-apps/

Faster to run or simulate?

Numerical Simulation

- **Running** the application
  - Acquire cores /nodes
  - Run in parallel
  - Less predictable
- **Simulating** the application
  - Use your laptop
  - Fold execution on one core
  - Reproducible



Use **sampling** to speed up the simulation (**x5**)

- By just adding a SMPI macro to one function call

Flexible data management

Data Transport Layer

- Inspired by popular data management frameworks (ADIOS, DataSpaces)
  - Client/Server library
  - Put/Get mechanism
  - Self-descriptive variables
  - Configurable data transport method

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- Current implementation status (**v0.1**)
  - **Dynamic** client connection/deconnection
  - Multiple **data channels**
  - **Multi-dimensional** arrays
  - **Synchronous/asynchronous** transfers
  - Two transport methods (**memcpy** and **network**)

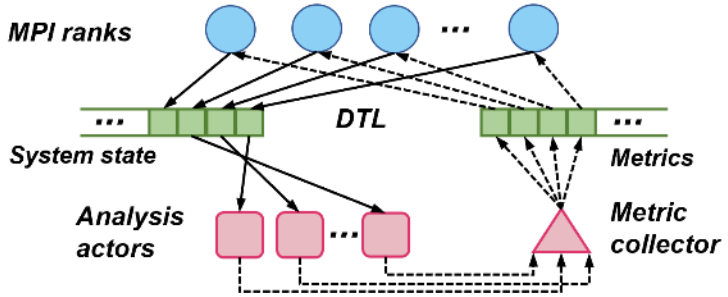
Customizable Analysis Actors

Analysis Visualization

- **Be flexible: use simple abstractions for analysis**
  - Simple amount of work, complex cost models, small program, …
  - Connect them at will in an **analysis workflow**

- Basic structure of an analysis actor
  1. Connect to the DTL on a specific channel
  2. Get some variables
  3. Perform the analysis
  4. Put some new variable in the DTL (optional)

- **Sim-Situ** provides **stock implementations**
  - **Distributed** analysis
  - **Parallel** analysis
  - Data **aggregator**



Sim-Situ in Practice

- Add customizable in-situ processing to an MPI application
  - **Slightly modify** the application
    - Handling extra configuration parameters — ~10 lines
    - Interacting with the DTL — ~20 lines
    - Compile against SMPI and Sim-Situ — ~5 lines
  - Define your analysis workflow(s) — Configurable
    - Define **actor behaviors** and use **data channels** to compose them
  - Add 3 extra files — Configurable
    - XML: Target **simulated infrastructure**
    - Text: Analysis actors **mapping** and MPI **hostfile**
- Define your experimental scenarios
- Run them!

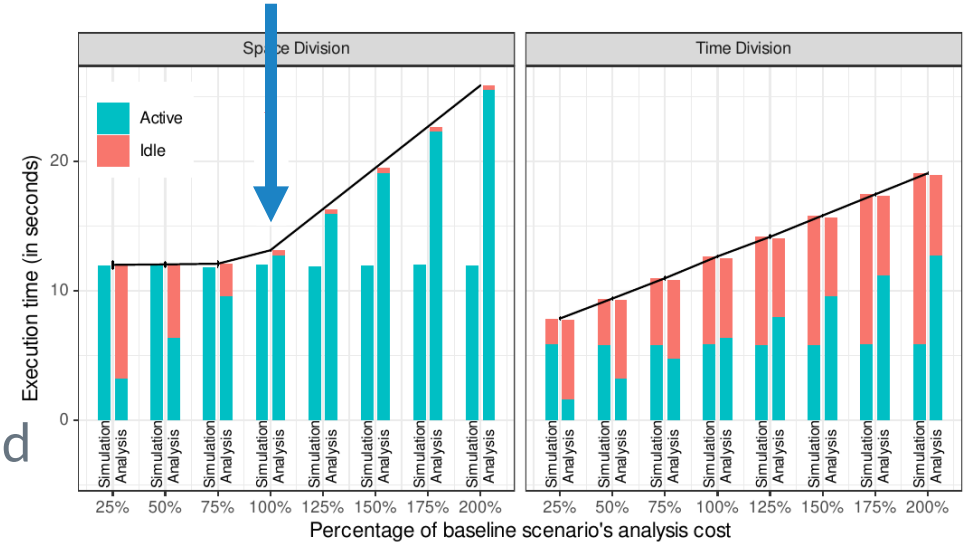
Check our experimental artifact *https://doi.org/10.6084/m9.figshare.20416008.v1*

Use Cases

Time or Space Division of Execution?

RQ1
RQ2
RQ5

- **Hypothesis:** Existing balanced scenario with space division
- **What-if** analysis cost changes?

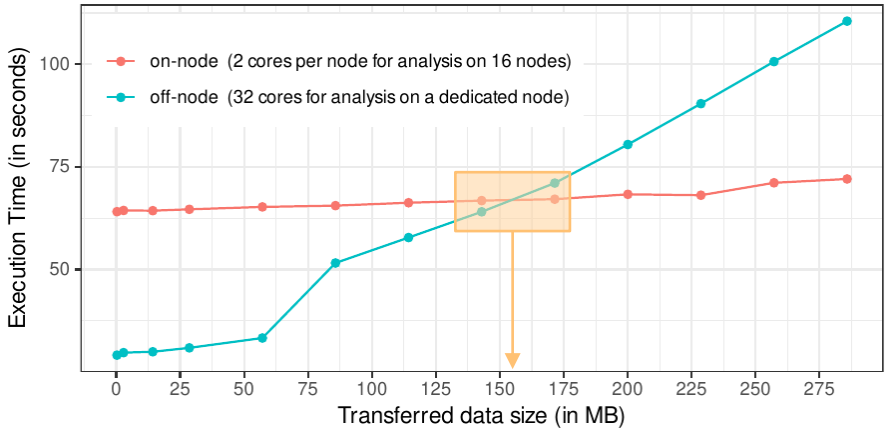


- Space Division
  - No impact on duration of numerical simulation
  - No idle time
  - Analysis results may be delayed
- Time Division
  - More resource for numerical simulation
  - … but has to wait for the analysis to proceed
  - Completion of numerical simulation may be delayed

On-node or Off-node?

RQ2
RQ3
RQ4

- **Hypothesis:** analysis time increases when distributed across more nodes
- **On-node**
  - Simulation and analyses share nodes (30/2 ratio on 16 nodes)
  - Direct access (memcopy)
  - Distributed analysis
- **Off-node**
  - 15 nodes for simulation + 1 node for analysis
  - No distribution of analysis
  - Indirect access (network)



- Measure the impact of size of staged data on execution time
  - With only 2 host files and a variable configuration parameter

Conclusion and Future work

- **Sim-Situ:** a simulation-based framework to study **in-situ processing**

Numerical Simulation

Faithful (Sim/Em)ulation of the unmodified application
Keep the exact execution pattern

Data Transport Layer

Flexible data management with a simple API (Put/Get) and a Pub/Sub model

Analysis/Visualization

Customizable and composable abstracted actors to enable complex workflows

A configurable tool to go beyond the traditional empiric guesses!

- **Future work**

More applications
From proxy-apps to full scale

More stock implementations
Models of visualization routines
Complex analysis workflows

More transport methods
Capture behavior of advanced algorithms

Thanks!

Any questions?

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