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Federated Computing for the Masses

Tackling Large-scale Engineering Problems

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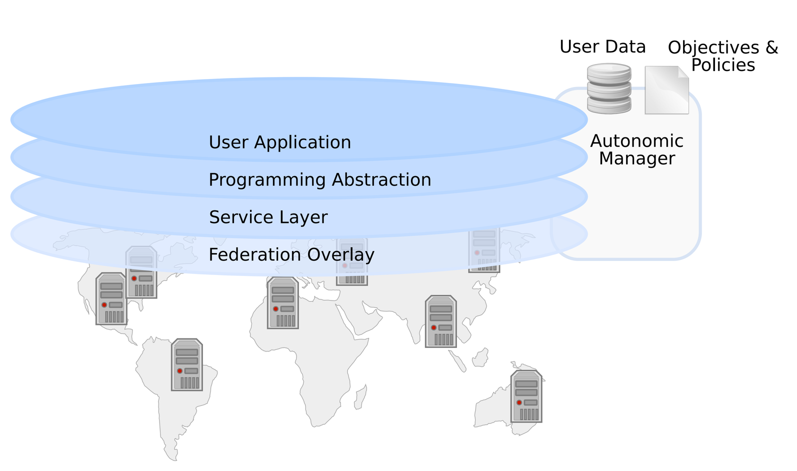
Motivation

- Many problems in science and engineering can be represented as an ensemble of HPC tasks
- Aggregated throughput and computational complexity of such problems often greatly exceed what individual computational center can provide to average user
- Federated computing can empower regular users with computational capability typically reserved for selected high-profile problems

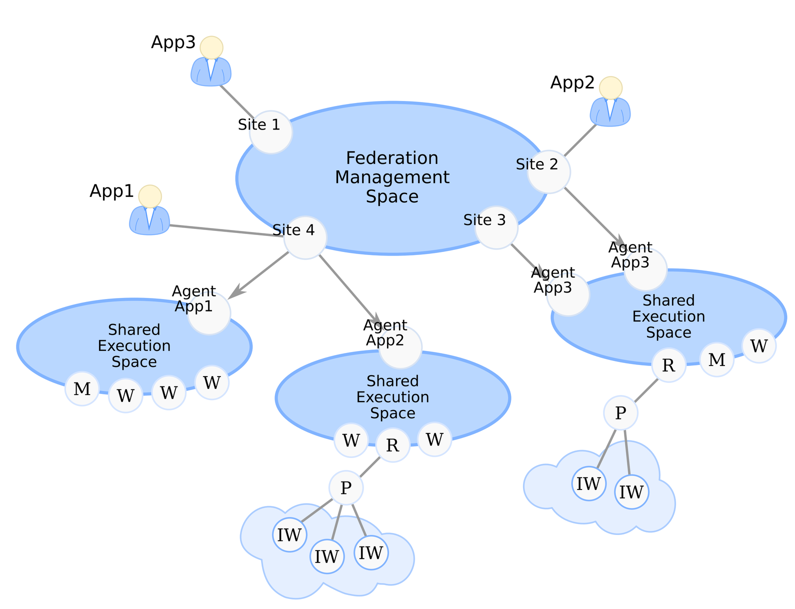
Proposed Solution

We propose to aggregate heterogeneous HPC resources in the spirit of how volunteer computing assembles desktop computers. This requires a software infrastructure with the following properties:

- **Deployability:** Must be easy to deploy by a regular user without special privileges
- **Scalability:** Must be able to scale across geographic locations
- **Interoperability:** Must be able to interact with heterogeneous resources
- **Capability:** Must optimize the resource allocation taking into account their characteristics
- **Elasticity:** Must be able to scale up/down on demand
- **Self-discovery:** Must react to changes in resources availability
- **Security:** Must support common security mechanisms such as public/private key authentication and X.509 certificates



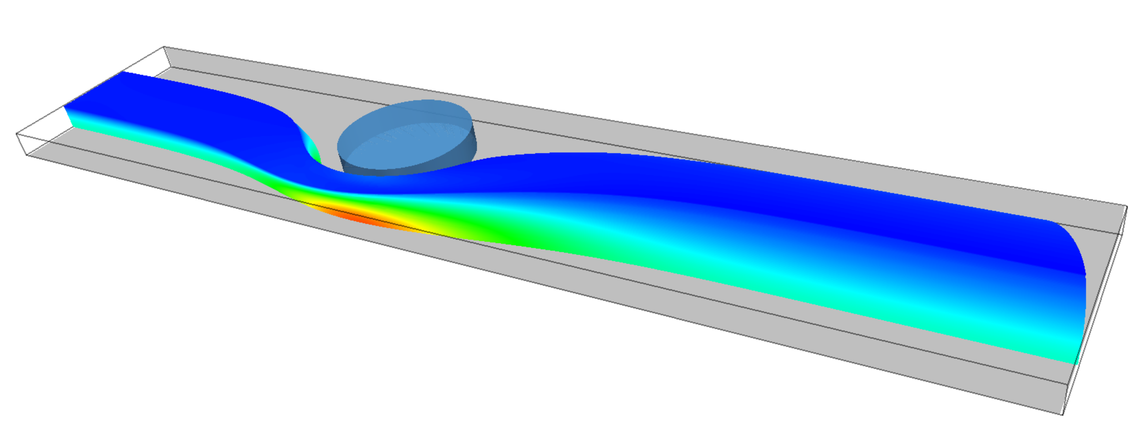
Multi-layer design of the proposed federation model.



Schematic representation of the proposed approach.

Case Study

- The ability to control fluid streams at microscale is of great importance for biological processing, creating structured materials, etc.
- Flow in a microchannel can be sculpted by placing a pillar obstacle
- Four input parameters – microchannel height, pillar location and diameter, and Reynolds number, affect the flow

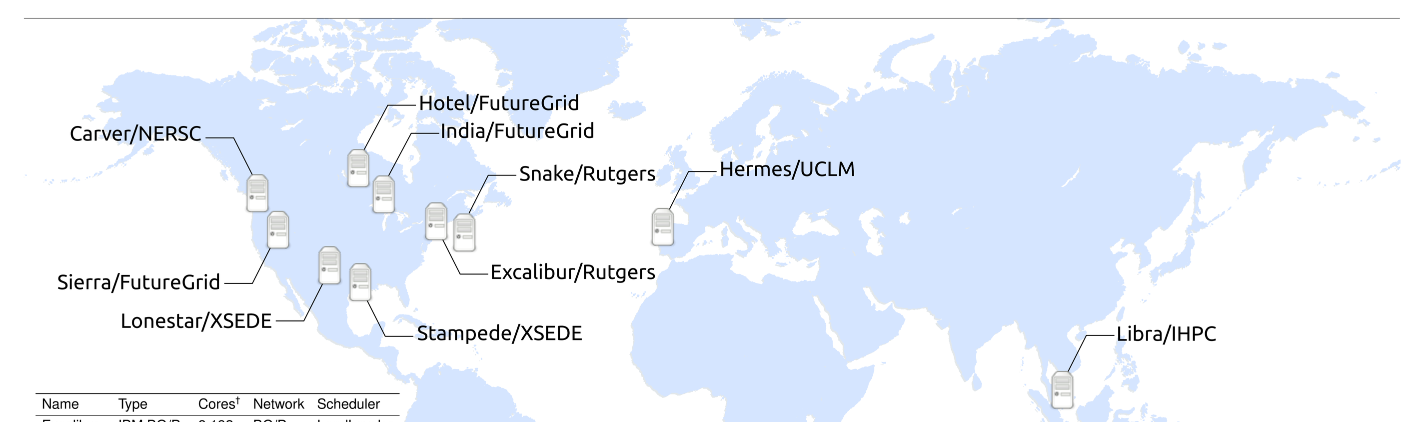


Example flow in a microchannel with an obstacle.

- To understand the flow, the resulting 4D parameter space has to be interrogated
- Each point in the parameter space represents simulation using the Navier-Stokes equation
- To solve the Navier-Stokes equation a parallel, finite element and MPI-based software is used
- To obtain a global view of the parameter space 12,400 simulations have to be performed

Experimental Results

- 10 different HPC resources from 3 countries federated using CometCloud
- 16 days, 12 hours, 59 minutes and 28 seconds of continuous execution
- 12,845 tasks processed, 2,897,390 CPU-hours consumed, 400 GB of data generated

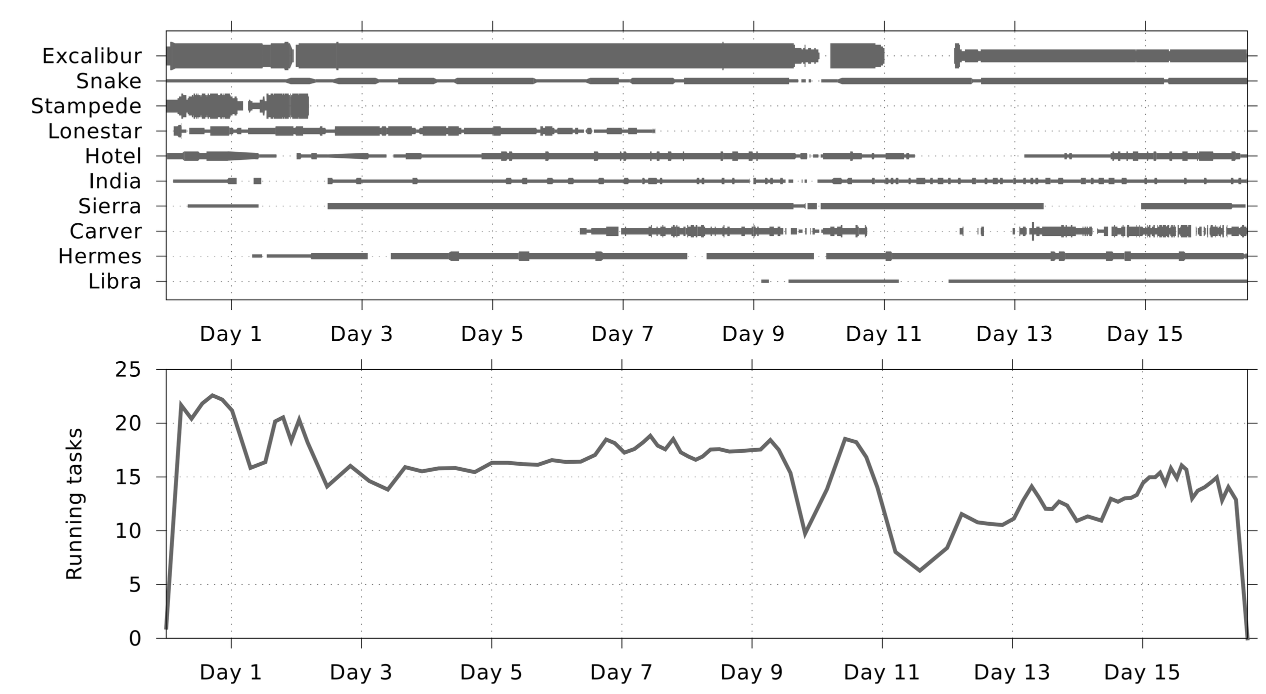


Name	Type	Cores†	Network	Scheduler
Excalibur	IBM BG/P	8,192	BG/P	LoadLeveler
Snake	Linux SMP	64	N/A	N/A
Stampede	iDataPlex	1,024	IB	SLURM
Lonestar	iDataPlex	480	IB	SGE
Hotel	iDataPlex	256	IB	Torque
India	iDataPlex	256	IB	Torque
Sierra	iDataPlex	256	IB	Torque
Carver	iDataPlex	512	IB	Torque
Hermes	Beowulf	256	10 GbE	SGE
Libra	Beowulf	128	1 GbE	N/A

Note: † – peak number of cores available to the experiment.

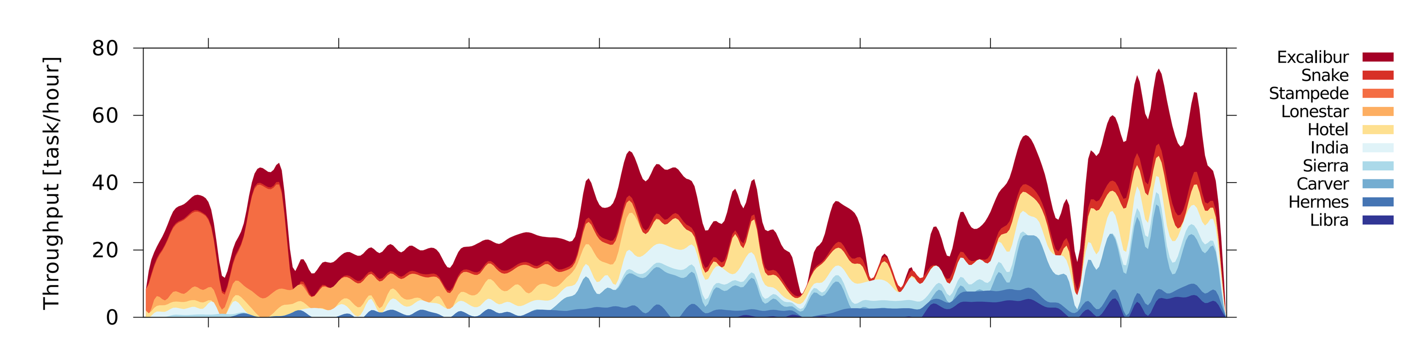
Resources federated during the experiment.

- Thanks to the dynamicity, sites can join and leave the federation without interrupting the execution



Progress of the experiment. Line thickness in the top panel is proportional to the number of running tasks.

- Thanks to elasticity and fault-tolerance the framework sustains throughput



Dissection of throughput measured as the number of tasks completed per hour.

Conclusions

- The framework is extremely easy to deploy to meet expectations of average user
- Encapsulates cloud-like capabilities to provide a sustainable computational throughput
- Provides strong fault-tolerance guarantees through monitoring of tasks and resources
- Can bridge multiple, highly heterogeneous resources exploiting their intrinsic capabilities
- The experiment provided the most comprehensive data to-date on the effect of pillars on microfluid channel flow

Acknowledgments

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