Adding Storage Simulation Capacities to the SimGrid Toolkit

A. Lebre, A. Legrand, F. Suter, P. Veyre

Inria, Ecole des Mines de Nantes/LINA
CNRS/INRIA/University of Grenoble
IN2P3 Computing Center, CNRS

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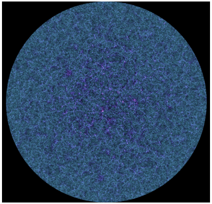
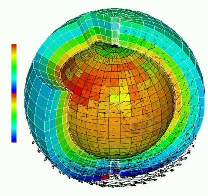
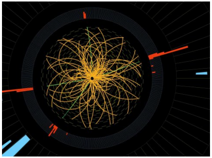
Data is Everywhere!

Age of Data-Intensive Computational Sciences

- Data is the new source of scientific results
  - Fourth paradigm, Data deluge, Big Data, ...
  - $\nearrow$ Volume, $\nearrow$ Velocity, $\nearrow$ Variety, $\nearrow$ Veracity, $\nearrow$ Value







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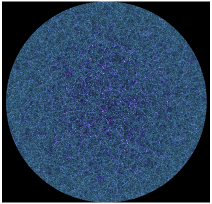
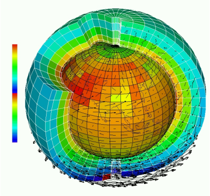
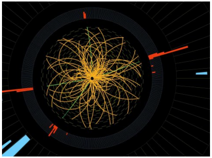
Storage becomes more and more important

- Not only for historical big players
  - E.g., High Energy Physics and LHC data processing on data grids
- But in every scientific field
- And on any large scale distributed infrastructure
  - Clusters, Clouds, Grids, ...

Why Simulate Storage?

Storage: a performance driver to understand

- Independent of scale and type of the computing infrastructure
- As much important as computing and networking
- Simulation is a classical approach in performance evaluation
  - Accuracy, Scalability, and **Versatility** are the keys

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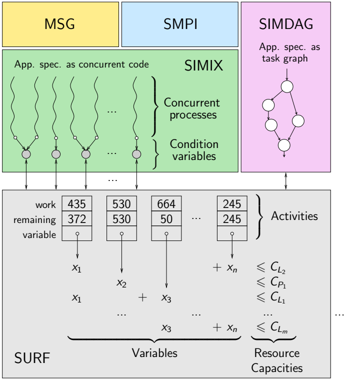
Specifics and concerns of storage subsystems may vary

- Data Centers $\rightsquigarrow$ Hierarchial (mass) storage subsystems
  - Different types of media involved
- Supercomputers $\rightsquigarrow$ Large scale dedicated storage network
  - High-speed network interconnect
- (MapReduce) Clusters $\rightsquigarrow$ Specific and tuned file system
  - Reliable, scalable, and simple
- Grids and Clouds $\rightsquigarrow$ Set of services offered by multiple data centers
  - Hidden underlying infrastructures

Simulating Storage with SimGrid

What is SimGrid?

- 15-years old project for the simulation of distributed systems
  - but lacking of a storage component for about 10 years
- Open source, sustainable, widely used
- Available on http://simgrid.org



Main Strengths

- Versatility: simulates Grids, Clouds, HPC, and P2P systems
- Fast and scalable simulation kernel
- Tractable models: fluid models and Max-Min fairness sharing
- (In)validation studies: simulation results can be trusted

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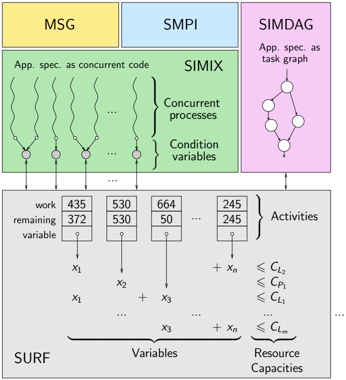

Our claim

- Building a simulator **from scratch** should be **avoided**

Disclaimer

This talk is end-to-end-study-free

- Problem $\rightsquigarrow$ Idea $\rightsquigarrow$ Implementation $\rightsquigarrow$ Evaluation $\rightsquigarrow$ Problem solved!

But not contribution-free

- Comprehensive description of storage-related concepts
- Original API to develop SimGrid-based simulators
  - Leveraging a sound and reliable simulation kernel
- Performance analysis of various types of disks $\rightsquigarrow$ Derived models

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Our objective

- Convince you to use **our proposal** to conduct **your storage-related simulation studies**

Outline

Concepts and Models

Basic Concepts

- File descriptors
  - Description: Name (= full path) + size [+ user-level properties]
    - Remark: *no UNIX info, no contents*
  - Life cycle: Simulated entity created by open, destroyed by close
  - Local operations: open, close, read, write, seek, tell, move, and delete
  - Remote operations: move and copy
- Storage volumes
  - Description: Name + type + capacity + file list + mount point + attach point + simulation model
    - Remark: *inert file list and no navigation in tree*
  - Life cycle: Instantiated at parsing time
  - Operations: get file list and get [total, used, available] capacity

Fluid models: Tractable and fast

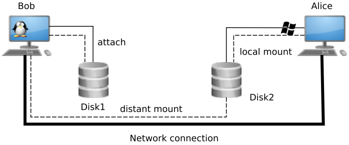
- Assumptions (to be experimentally confirmed)
  - Linearity, negligible latency, fair sharing

MAXIMIZE $\min_{a \in \mathcal{A}} \rho_a$
UNDER CONSTRAINTS
$\left\{ \sum_{a \in \mathcal{A} \text{ using resource } r} \rho_a \leqslant C_r, \right.$

Implementation Highlights

Comprehensive platform description

- Scalable XML format




```
<storage_type id="SATA-II_HDD" size="500GB"
              content_type="txt_unix"
              content="unix_content.txt"
              model="linear">
  <model_prop id="r_bw" value="92MBps"/>
  <model_prop id="w_bw" value="62MBps"/>
</storage_type>

<storage id="Disk1" typeId="SATA-II_HDD"
         attach="bob"/>

<storage id="Disk2" typeId="SATA-II_HDD"
         attach="alice"
         content_type="txt_windows"
         content="windows_content.txt" />

<host id="bob" power="1Gf">
  <mount id="Disk1" name="/home"/>
  <mount id="Disk2" name="/windows"/>
</host>

<host id="alice" power="1Gf">
  <mount id="Disk2" name="c:"/>
</host>

<link id="link1" bandwidth="125MBps"
      latency="50us"/>

<route src="bob" dst="alice"
       symmetrical="YES">
  <link_ctn id="link1"/>
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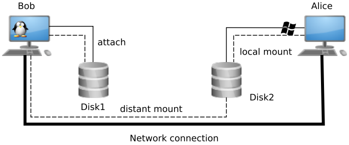
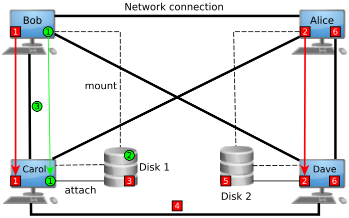


Seamless remote operations

- I/O operations $\leadsto$ network transfers
  - in a store-and-forward mode

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Outline

Experimental Setup

Testbed

- Grid'5000 experimental platform (http://www.grid5000.fr)

Name	Model	Interface	Size	Max. Bandwidth
griffon	Hitachi HDP72503	SATA-II	320 GiB	79 MiB/sec
granduc	Seagate ST9146802SS	SAS	146 GiB	84.7 MiB/sec
edel	C400-MTFDDAA	SATA/SSD	128 GiB	244.8 MiB/sec

Methodology

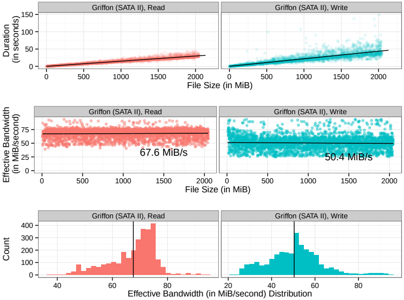
- Randomized benchmarks with FIO 2.0.8 managed with execo
  - Additional `dd` benchmark on *granduc* to cope with faulty raid controller
- Synchronous, non-buffered I/O operations
  - Independent: From 32kiB to 2GiB with a fixed block size of 32KiB
  - Concurrent: 1 to 15 operations
    - for 10, 50, 100, 500, 1024, and 2048 MiB files

Feel free to check and/or reproduce our results

- Everything is available online (http://dx.doi.org/10.6084/m9.figshare.1175156)
  - Engines, raw data, analysis scripts, graphs and article sources

Modeling the Behavior of SATA-II Disks

- Top: Size vs. Duration
  - Confirms the linearity assumption
  - But heteroscedastic behavior
    - Variability proportional to size
    - Negligible latency
- Middle: Size vs. Bandwidth
  - Independent of file size
  - Variability $\rightsquigarrow$ Random variables
- Bottom: Bandwidth distribution
  - Single mode but not following any well-known distribution

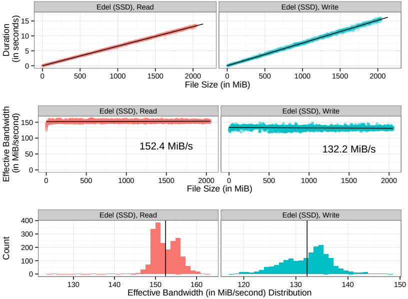


Properties of derived model

- Linear w.r.t. bandwidth with no latency
- Modeling the bandwidth-dependent variability
  - Inject sample distribution and draw random variable upon access

Modeling the Behavior of SSD Disks

- Top: Size vs. Duration
  - Linear with very little variability
- Middle: Size vs. Bandwidth
  - Far from `hdparm` results
  - Default `ext4` config prevents getting maximum performance
- Bottom: Bandwidth distribution
  - Regular but not following any well-known distribution



Properties of derived model (similar to SATA-II)

- Linear w.r.t. bandwidth with no latency
- Modeling the bandwidth-dependent variability
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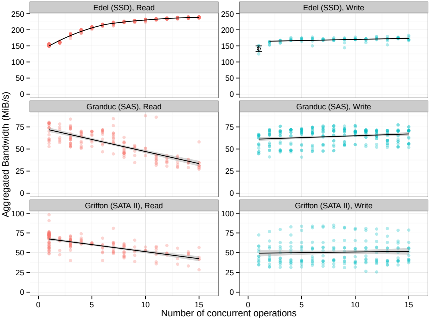
Modeling Concurrent Accesses

Performance improvements on SSD

- Significant and non-linear for reads
- When having more than one write
  - Likely because of bad ext4 setup

On SAS and SATA-II

- Fixed bandwidth for writes
- Linear decay fro reads
  - Explained by arm movements



Properties of derived model

- Modify resource capacity as concurrency increases
- Reevaluation each time a transfer begins or ends
- Easy to implement in SimGrid's kernel

Outline

- Introduction
- Adding Storage to SimGrid
- Checking Modeling Assumptions
- Added Value of Using SimGrid
  - Build (and Trust) your own Simulator
  - Design (and Plug) your own Storage Model
- Conclusions and Future Work

Build (and Trust) your own Simulator

Rationale

- Developing a full DES from scratch is counterproductive!
  - Already there: open, fast, and scalable kernel
- Better focus on the applicative part of the simulator
  - With confidence on lower layers: (in)validated and reliable models
- Leverage versatility
  - Mixing concepts $\neq$ stacking features

Examples of added value

- Versatility $\leadsto$ Study more performance drivers w/o oversimplification
  - Storage study + network interconnect + CPU heterogeneity
- (In)validation studies $\leadsto$ get realistic results, not just some results
  - Leverage predictive value in performance studies
- Scalable does not necessarily means inaccurate
  - Both can be obtained simultaneously

Design (and Plug) your own Storage Model

There is more than disks to model

- Tape libraries $\leadsto$ Access time (arm movements) + I/O time
  - Combination of models
- Parallel/Distributed File Systems $\leadsto$ Disks + management layer
  - File system simulator + disks models
  - Model experienced throughput
- Storage on unknown infrastructures (Clouds) $\leadsto$ Black boxes
  - Model with bandwidth vs. #requests matrices

How to design and plug a new model?

- Designing and plugging a fluid model is pretty straightforward
  - Behavior for a single operation + Sharing policy
- Instantiation is more complex (yet crucial)
  - Benchmarking and analysis procedures available online
- Contributions are welcomed!

Conclusion and Future Work

Conclusions

- Comprehensive description of storage-related concepts
- Original API to develop SimGrid-based simulators
  - Leveraging a sound and reliable simulation kernel
- Thorough Performance analysis of various types of disks
  - Derived Fluid models $\rightsquigarrow$ tractable, fast, and accurate
- Only a first step . . .

Conclusion and Future Work

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- Only a first step ...

Future Work

- Extend API to handle block storage, handle cache policies
- Integrate other resource models
  - Only after thorough (in)validation studies
- Study other performance metrics (e.g., energy consumption)
- Welcome contributions from external users
  - Now I hope you are convinced to use SimGrid ☺