GrenchMark: A Framework for Analyzing, Testing, and Comparing Grids

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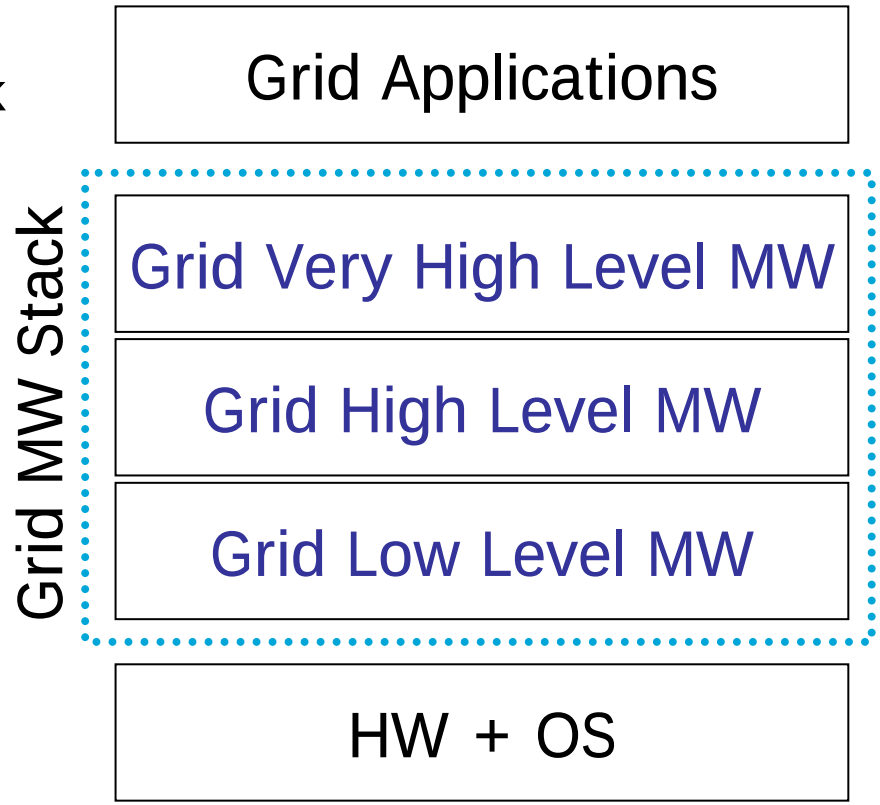
1. Introduction and Motivation

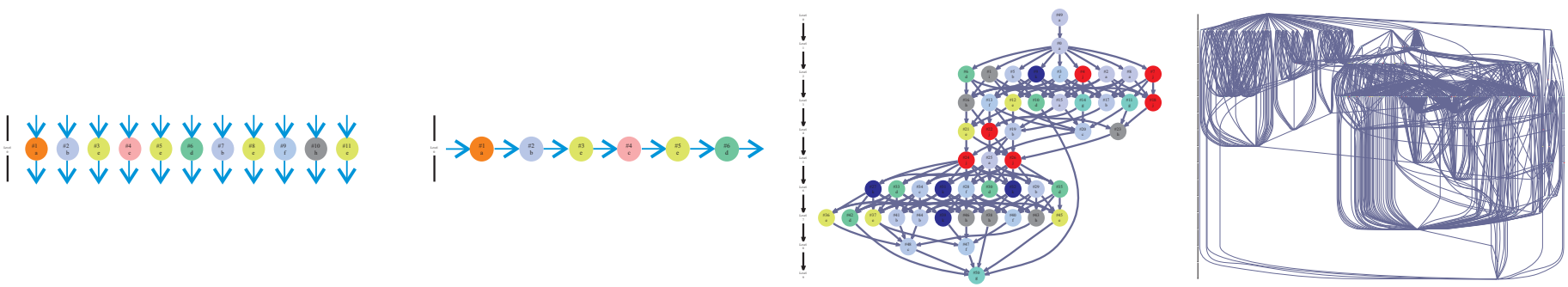
1.1. A Layered View of Grids (1/2)

- Layer 1: Hardware + OS
  - Automated
  - Simple
- Layers 2-4: Grid Middleware Stack
  - Low Level: file transfers, local resource allocation, etc.
  - High Level: grid scheduling
  - Very High Level: application environments (e.g., distributed objects)
  - Automated/user control
  - Simple to complex
- Layer 5: Grid Applications
  - User control
  - Simple to complex



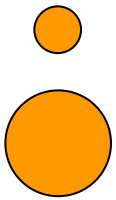
1. Introduction and Motivation
1.1. A Layered View of Grids (2/2)

- **Unitary applications**
  - **Single processor, single node**
  - Parallel/distributed: **MPI**, Java RMI, Ibis, ProActive ...
- **Composite applications**
  - **Bag of tasks**
  - Chain of jobs
  - Direct Acyclic Graph-based Workflows



(a) (b) (c) (d)

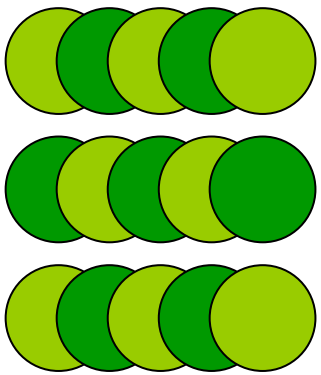
1.2. Complexity => More Testing Required (theory)



Server
- 99.99999% reliable

Small Cluster
- 99.999% reliable

Today's grids are complex and error-prone!



DAS-2
- >10% jobs fail [Ios06]

TeraGrid
- 20-45% failures [Kha06]

Grid3
- 27% failures, 5-10 retries [Dum05]

1. Introduction and Motivation

1.2. Complexity => More Testing Required (Grid reality worse than theory)

- NMI Build-and-Test Environment at U.Wisc.-Madison: 112 hosts, >40 platforms (e.g., X86-32/Solaris/5, X86-64/RH/9)
- Serves >50 **grid middleware packages**: Condor, Globus, VDT, gLite, GridFTP, RLS, NWS, INCA(-2), APST, NINF-G, BOINC ...

Two years of functionality tests ('04-'06): over 1:3 runs have at least one failure!

(1) Test or perish!
(2) In today's grids, reliability is more important than performance!

Outline

1. Introduction and Motivation
2. **Testing in Grids**
3. The GrenchMark Framework
4. Experiments with GrenchMark
5. GrenchMark Success Stories
6. Conclusion

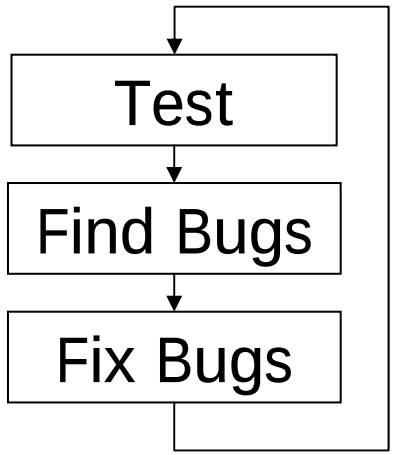
2. Testing in Grids
2.1. Testing for Design Adequacy

- Functional testing
  - Various application types: Ibis, workflows, bag-of-tasks, etc.
  - Delegated submissions
- Operational testing
  - A user cannot get >50% of the system for >1 hour
  - Monitoring data sampled every 15 minutes
- Scalability testing
  - Maximum utilization >95% for an hour
  - Utilization >75% over a month

2. Testing in Grids
2.2. Testing Performance

- Load testing
  - Wait time of jobs under heavy load
  - Detailed application performance
- Benchmarking
  - Number of items completed in 1 hour, or
  - Time to complete 1 item
- Scenario testing
  - Performance in a steady system with Poisson arrivals
  - Performance of two systems, when combined

2. Testing in Grids
2.3. Testing Reliability



- Reliability growth testing
  - Increase reliability after each iteration
- Burn-out testing
  - Systems have “bath-tub reliability curve”
  - Users get a tested system (after burn-out)
- System integration testing
  - Is the sum of reliable components reliable?

2. Testing in Grids
2.4. Analyzing, Testing, and Comparing Grids

- Use cases for automatically analyzing, testing, and comparing grids (or grid middleware)
  - Functionality testing and system tuning
  - Performance testing/analysis of grid applications
  - Reliability testing of grid middleware
  - ...
- **For grids, this problem is *hard* !**
  - Testing in real environments is difficult
  - Grids change rapidly
  - Validity of tests
  - ...

Outline

1. Introduction and Motivation
2. Testing in Grids
3. **The GrenchMark Framework**
4. Experiments with GrenchMark
5. GrenchMark Success Stories
6. Future Work
7. Conclusions

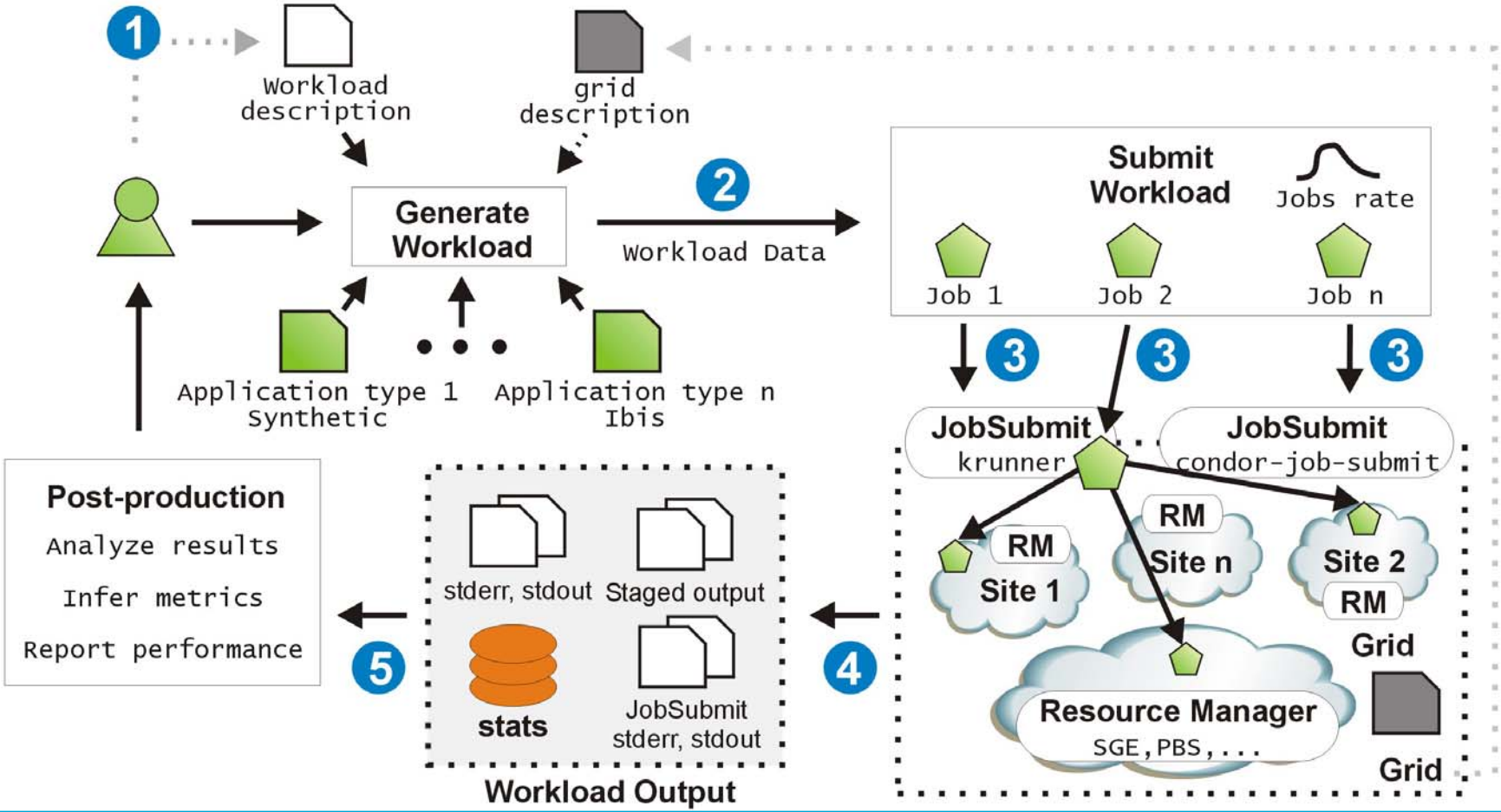
3. The GrenchMark Framework
3.1. GrenchMark: Generic (Grid) Testing

- **What's in a name?**
  grid benchmark → working towards a generic tool for the whole community: help standardizing the testing procedures, but benchmarks are too early; we use
- settings, based on synthetic workloads
  - **A set of metrics** for analyzing grid settings
  - **A set of representative grid applications**
    - Both real and synthetic
  - **Easy-to-use tools to create synthetic grid workloads**
  - **Flexible, extensible framework**

GrenchMark can generate and run synthetic grid workloads

3. The GrenchMark Framework

3.2. GrenchMark Overview: Easy to Generate and Run Synthetic Workloads



3. The GrenchMark Framework
… but More Complicated Than You Think

- **Workload structure**
  - User-defined and statistical models
  - Dynamic jobs arrival
  - Burstiness and self-similarity
  - Feedback, background load
  - Machine usage assumptions
  - Users, VOs
- **Metrics**
  - A(W) Run/Wait/Resp. Time
  - Efficiency, MakeSpan
  - Failure rate [!]
- **Notions**
  - Co-allocation, interactive jobs, malleable, moldable, ...
- **Measurement methods**
  - Long workloads
  - Saturated / non-saturated system
  - Start-up, production, and cool-down scenarios
  - Scaling workload to system
- **Applications**
  - Synthetic
  - Real
- **Workload definition language**
  - Base language layer
  - Extended language layer
- **Other**
  - Can use the same workload for both simulations and real environments

3. The GrenchMark Framework
3.3. Workload Generation (1/2)

- Trace-based
  - Replay user requests
  - Data: Grid Workloads Archive, Parallel Workloads Archive
- Model-based
  - Mathematical distributions for workload characteristics
  - Use parameters from traces (!)
  - Data: Hui Li for grid, Lublin-Feitelson for HPC
- User-specified
  - New or Hybrid models
  - Mixing of traces

3. The GrenchMark Framework
3.3. Workload Generation (2/2)

- Workload description file, simple format + extensions
- **Simple format:**

```
# File-type: text/wl-spec
#NJobs Composition Type    SiteType Compo SiteInfo ArrivalTimeDistr OtherInfo
25      composite   DAG     single   1     *:?      Poisson(120s)   StartAt=0s
25      unitary     sserio  co-alloc 5     *:?      C(120s)         StartAt=60s,,ExternalFile=1.xin
25      unitary     smpi1   single   1     *:?      C(120s)         StartAt=30s,ExternalFile=2.xin
25      unitary     smpi1   single   1     *:?      C(120s)         StartAt=90s,ExternalFile=3.xin
```

Number of jobs

Job structure

Co-allocation and parallelism

First Job arrival time

Job arrival distribution

Job language extensions

Combining four workloads into one

3. The GrenchMark Framework
3.4. Workload Submission

- Submission (mostly) decoupled from workload generation
- Submission engine architecture
  - Multiple threads (good for multi-core systems)
  - Hierarchical (when using ServMark)
- Open vs. Closed submission
  - Open = new jobs arrive independently of previous jobs' completion
  - Closed = use system feed-back to start jobs,
    e.g., chain of tasks, workflows
  - Also Partially-Open (only some jobs have feed-back)

3. The GrenchMark Framework
3.5. Data Collection and Analysis (1/2)

- Metrics of interest (sample)
  - Testing design adequacy
    - Ratio of jobs completed from started
    - Fairness
  - Testing performance
    - Time-related: wait time, run time, response time
    - Administrator: utilization, number of jobs completed, number of users served, middleware overhead
    - User: application makespan, number of results , middleware overhead, throughput
  - Testing reliability
    - MTTFailure, MTTRepair, hazard rate function (shape)

3. The GrenchMark Framework
3.5. Data Collection and Analysis (2/2)

- Reporting
  - Basic statistics
    - Mean, Min, Max, Std.Dev., Median, Quantiles
  - Higher moments
    - Kurtosis, Skewness
  - Distributions
    - Empirical distributions (histograms, CDF plot)
    - Curve fitting and goodness-of-fit for well-known distributions: Normal, Lognormal, Weibull, Exponential, etc.

3. The GrenchMark Framework
3.6. GrenchMark's Current Status

- Already done in Python [http://www.python.org]
  - Workload Generator
  - Generic Workload Submitter (Koala, Globus GRAM, Condor, option for JSDL, PBS, LSF, SGE, ...)
  - Results analyzer (crude)
  - Applications
    - Unitary, 3 types: sequential, MPI, Ibis (Java)
    - +35 applications
    - Composite applications: DAG-based
- Ongoing work
  - Automated results analyzer
  - **Experiments: test, test, test...**

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4. **Experiments with GrenchMark**
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4. Experiments with GrenchMark
4.1. Testing Design Adequacy

- **System functionality testing**: show the ability of the system to run various types of applications
  - Report failure rates
    [*10% job failure rate in a controlled system like the DAS!*]

Table 5: The results for system functionality testing.

Workload	Types of applications	# of CPUs	Component no.	Component size	Success Rate
gmark+	synthetic, seq. & MPI	1-128	1-15	1-32	85%
ibis+	various, Ibis	2-32	1-8	2-16	65%
unitary	gmark+ & ibis+	1-32	1-8	1-32	90%

- **Periodic system testing**: evaluate the current state of the grid
  - Replay workloads

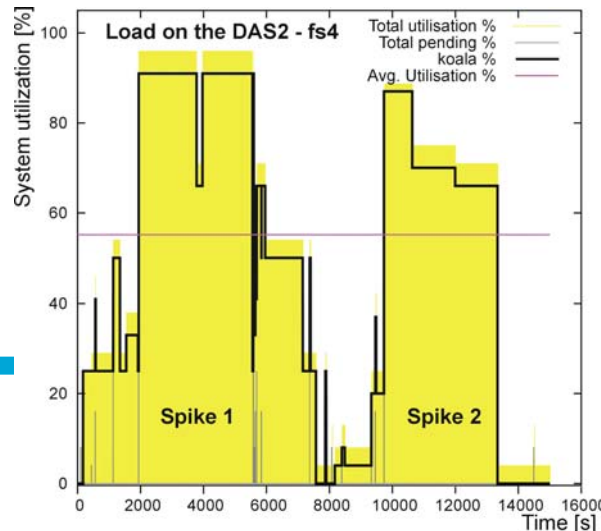
4. Experiments with GrenchMark
4.2. Testing Performance (1/2)

- **Testing application performance**: test the performance of an application (for sequential, MPI, Ibis applications)
  - Report runtimes, waiting times, grid middleware overhead
  - Automatic results analysis

Table 2: A summary of time and run/success percentages for different job types.

Job name	Job type	Turnaround [s] Avg	Turnaround [s] Range	Runtime [s] Avg	Runtime [s] Range	Run	Run+ Success
sser	seq	129	16–926	44	1–588	100%	97%
smpi1	MPI	332	21–1078	110	1–332	80%	81%
NQueens	Ibis	99	15–1835	31	1–201	70%	85%

- **What-if analysis**: evaluate potential situations
  - System change
  - Grid inter-operability
  - Special situations: spikes in demand



4. Experiments with GrenchMark
4.3. Testing Performance (2/2)

- **Single-site vs. co-allocated jobs**:
  compare the success rate of single-site and co-allocated jobs, in a system without reservation capabilities
  - Single-site jobs 20% better vs. small co-allocated jobs (<32 CPUs), 30% better vs. large co-allocated jobs
    [setting and workload-dependent **!**]

- **Unitary vs. composite jobs**:
  compare the success rate of unitary and composite jobs, with and without failure handling mechanisms
  - Both 100% with simple retry mechanism
    [setting and workload-dependent **!**]

4. Experiments with GrenchMark
4.4. Testing Reliability

- **Testing a 1500-processors Condor environment**: *what is the success rate of single-processor jobs when submitted in batches of various sizes?*
  - Workloads of 1000 jobs, grouped by 2, 10, 20, 50, 100, 200
  - Goal: finish jobs in at most 1h after the last submission
  - Results
    - >150,000 jobs submitted
    - >100,000 jobs successfully run, >2 yr CPU time in 1 week
    - **5% jobs failed (much less than other grids' average)**
    - 25% jobs did not start in time and where cancelled

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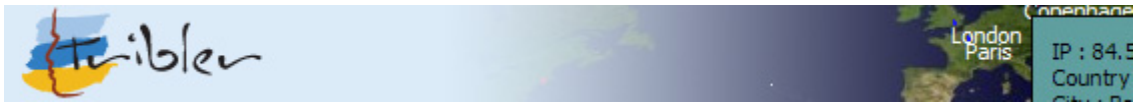
5. GrenchMark Success Stories
5.1. Releasing the Koala Grid Scheduler on the DAS

- **Koala [http://www.st.ewi.tudelft.nl/koala/]**
  - Grid Scheduler with co-allocation capabilities
- **DAS: The Dutch Grid, ~200 researchers**
- **Initially**
  - Koala, a tested (!) scheduler, pre-release version
- **Test specifics**
  - 3 different job submission modules
  - Workloads with different jobs requirements, inter-arrival rates, co-allocated v. single site jobs...
  - Evaluate: job success rate, Koala overhead and bottlenecks
- **Results**
  - **5,000+ jobs** successfully run (all workloads); functionality tests
  - 2 major bugs first day, **10+ bugs overall** (all fixed)
  - **KOALA is now officially released on the DAS**
    (full credit to KOALA developers, 10x for testing with GrenchMark)

5. GrenchMark Success Stories
5.2. The LittleBird Peer-to-Peer protocol

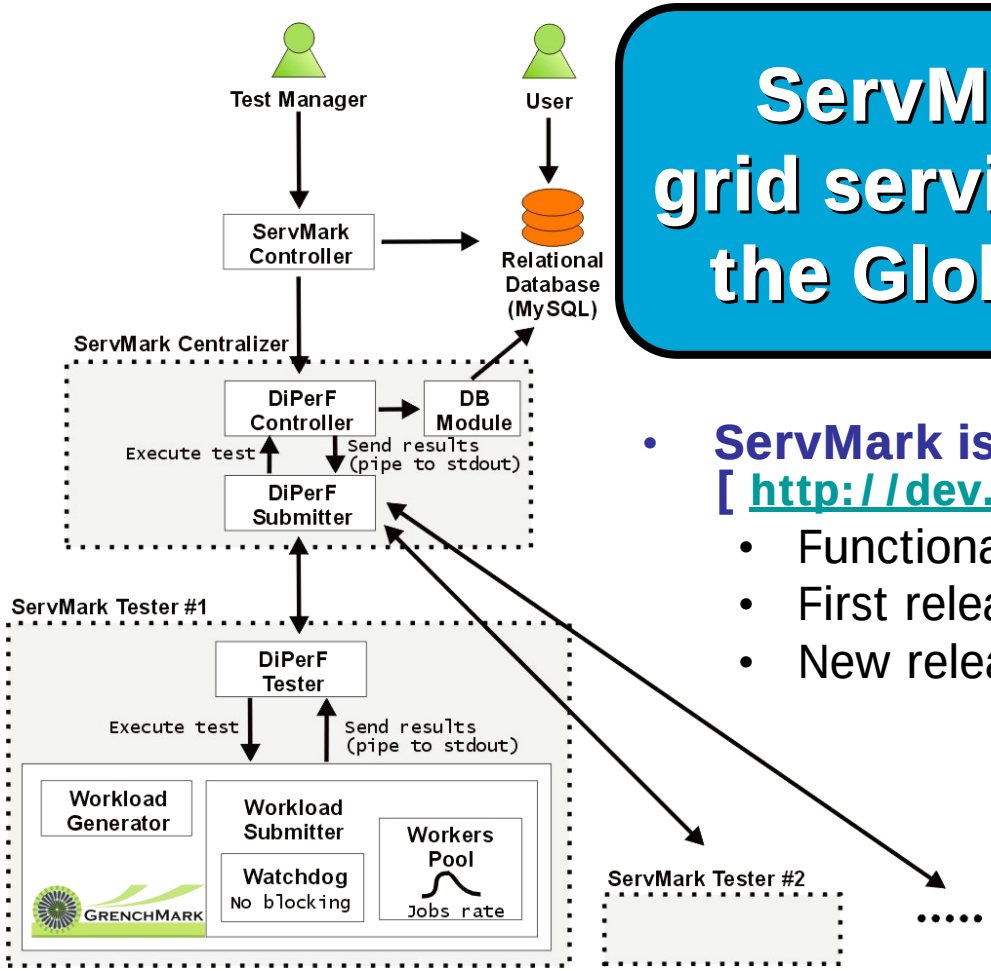
- **LittleBird, part of Tribler [http://www.tribler.org]**
  - Tribler – a Peer-to-Peer file-sharing system, >100,000 downloads/year
  - LittleBird – an epidemic protocol that exchanges swarm information between peers that are currently or were recently members of a swarm



- **Test specifics**
  - Large-scale test environment based on GrenchMark
  - Workload: peer arrival / departure
  - Evaluate: job success rate, Koala overhead and bottlenecks

- **Results (by Jelle Roozenburg)**
  - Functionality proof
  - Protocol is scalable, resilient against DoS and pollution attacks
  - **LittleBird is going to be integrated into Tribler**

5. GrenchMark Success Stories
5.3. The ServMark Grid Services Tester



ServMark is a hierarchical grid services tester, and part of the Globus Incubator Project

- **ServMark is a Globus Incubator Project**
  [http://dev.globus.org/wiki/Incubator/ServMark]
  - Functionality proof: test HTTP servers
  - First release in October 2006
  - New release scheduled for Q4 2007

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Conclusion

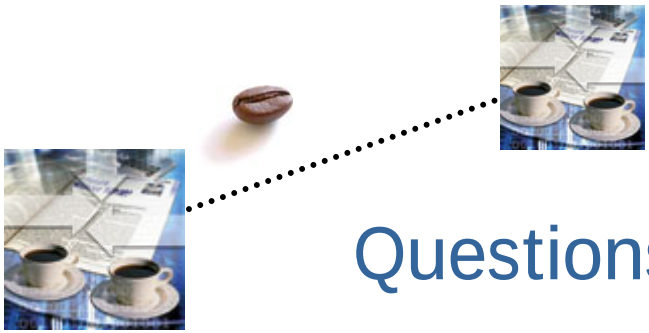
Today's grids are complex and error-prone

In today's grids, reliability is more important than performance, so: Test or perish!

GrenchMark can generate and run synthetic grid workloads

ServMark is a hierarchical grid services tester

Thank you!



Questions? Remarks? Observations?

GrenchMark

http://grenchmark.st.ewi.tudelft.nl/ **[10x Paulo]**

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