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Scalability Evaluation of an Energy-Aware Resource Management System for Clusters of Web Servers

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SPECTS15

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Before we start …

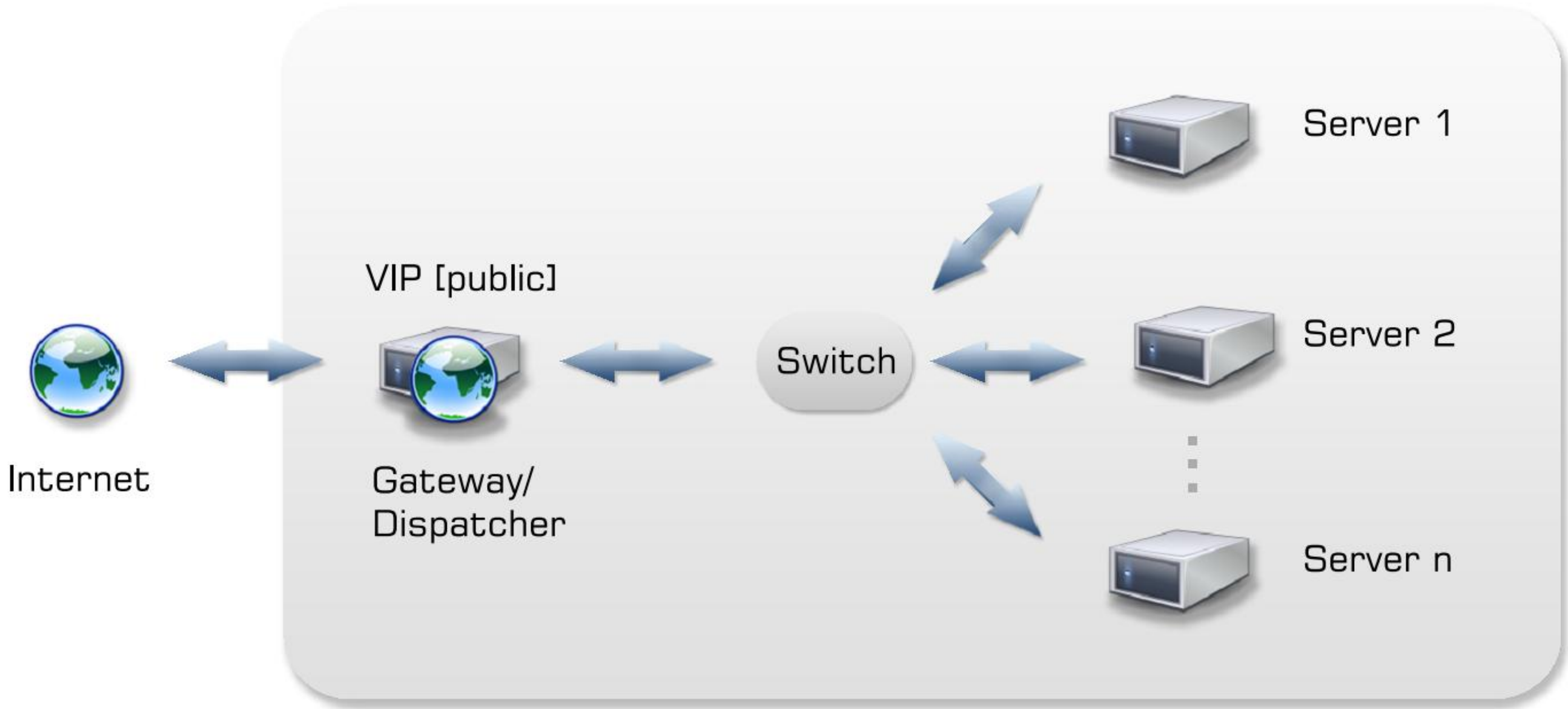
Outline

- Motivation
- Energy Saving Daemon (CHERUB)
- Scalability: Measurements
- Scalability: Simulation (ClusterSim)
- Conclusion & Future Work

Cluster Computing Basics

- High-Performance-Computing (HPC)
  - Few computationally intensive jobs which run for a long time (e.g. climate simulations, weather forecasting)
- **Web Server / Server-Load-Balancing (SLB)**
  - Thousands of small requests
  - Facebook as example:
    - 18.000 new comments per second
    - > 500 million user upload 100 million photos per day

Components of a SLB Cluster



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Motivation

- Energy has become a critical resource in cluster designs
- Demand of energy is still permanently rising
- Strategies for saving energy:
  1. **Switch off unused resources**
  2. Virtualization
  3. Effective cooling
     (e.g. build your cluster in north Sweden like Facebook did)

Motivation

- Stanford study [1] from 2015 with data from i.a. *Uptime Institute* supports Papers [2] position from 2008
- 30% of servers world-wide are *comatose*
- Corresponds to 4GW
  The most power full nuclear power plant block on earth generates 1.5GW

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Cherubs functionality

- Centralized approach - no clients on back-ends
- Daemon located at master node polls the system in fixed time intervals to analyze its state
  - Status of every node
  - Load situation
- Depending on the state and saved attributes and the load prediction, actions are performed for every node
- Online system - we don’t need any information about future load
- Cherub Publications: [3,4]

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Scalability: Measurements

- Test with 2 back-ends are not sufficient
- Aim: prove scalability up to 100+ nodes in terms of performance and strategy
- Methodology:
  - Measure key functions
  - Simulation

Key Functions

Key functions are either:

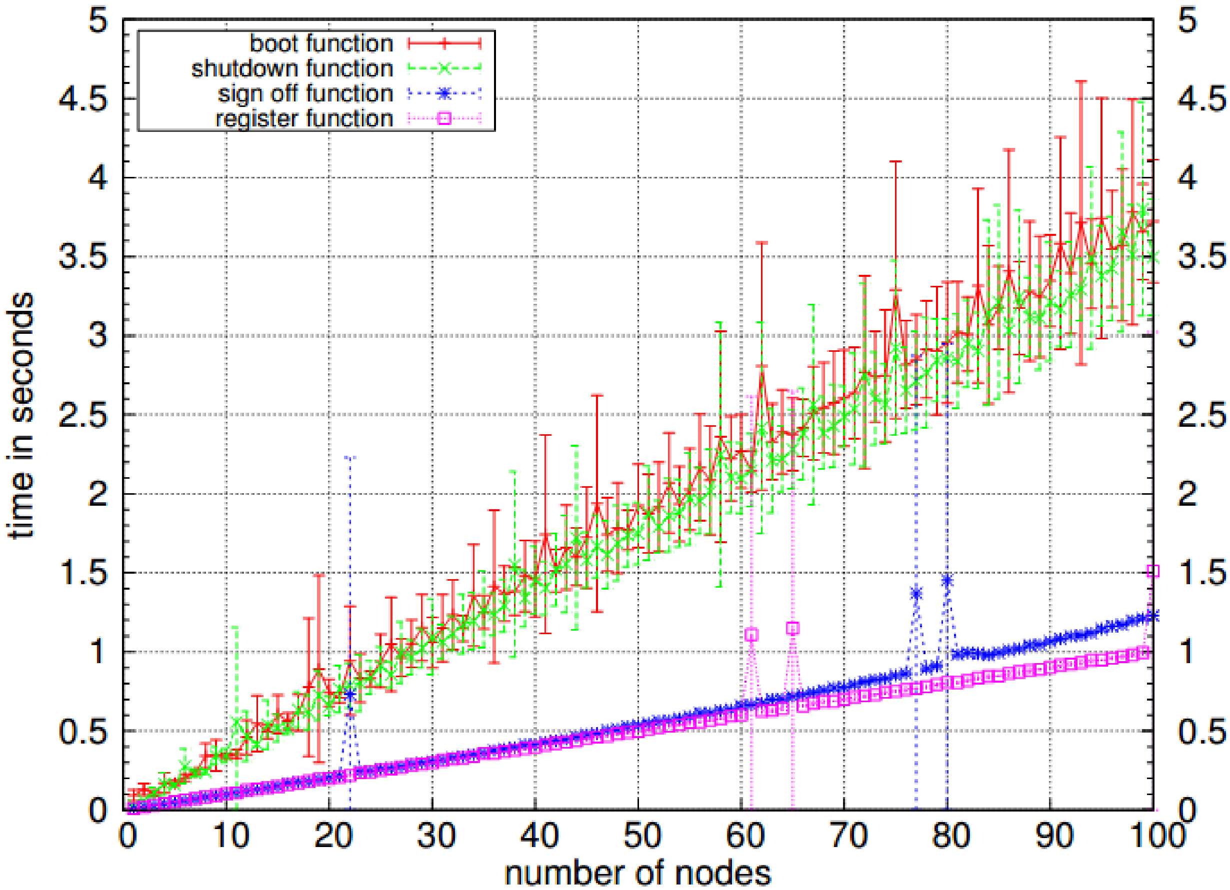
- Invocation rate depends on number of nodes
- Runtime depends directly on number of nodes

Two different types of key functions:

- State changing functions
- Information gathering functions

State Changing Functions

- Boot/Shutdown/Register/Sign Off
- All very equal in structure and invocation rate



Information Gathering Functions

- Status function:
  determines status of every node
- Load function:
  determines the load of the system

Information Gathering Functions

- **Status function:**
  determines status of every node
- Load function:
  determines the load of the system

Status Function - Prototype

Prototype:

Sequentially for every node:

- Query RMS for every node if registered
  Yes: Node is *Online* or *Busy* (load dependent)
  No: Test if physically on (via ping, http req., etc.)
    - Reachable: Node is *Offline*
    - Not reachable (1 sec timeout): Node is *Down*

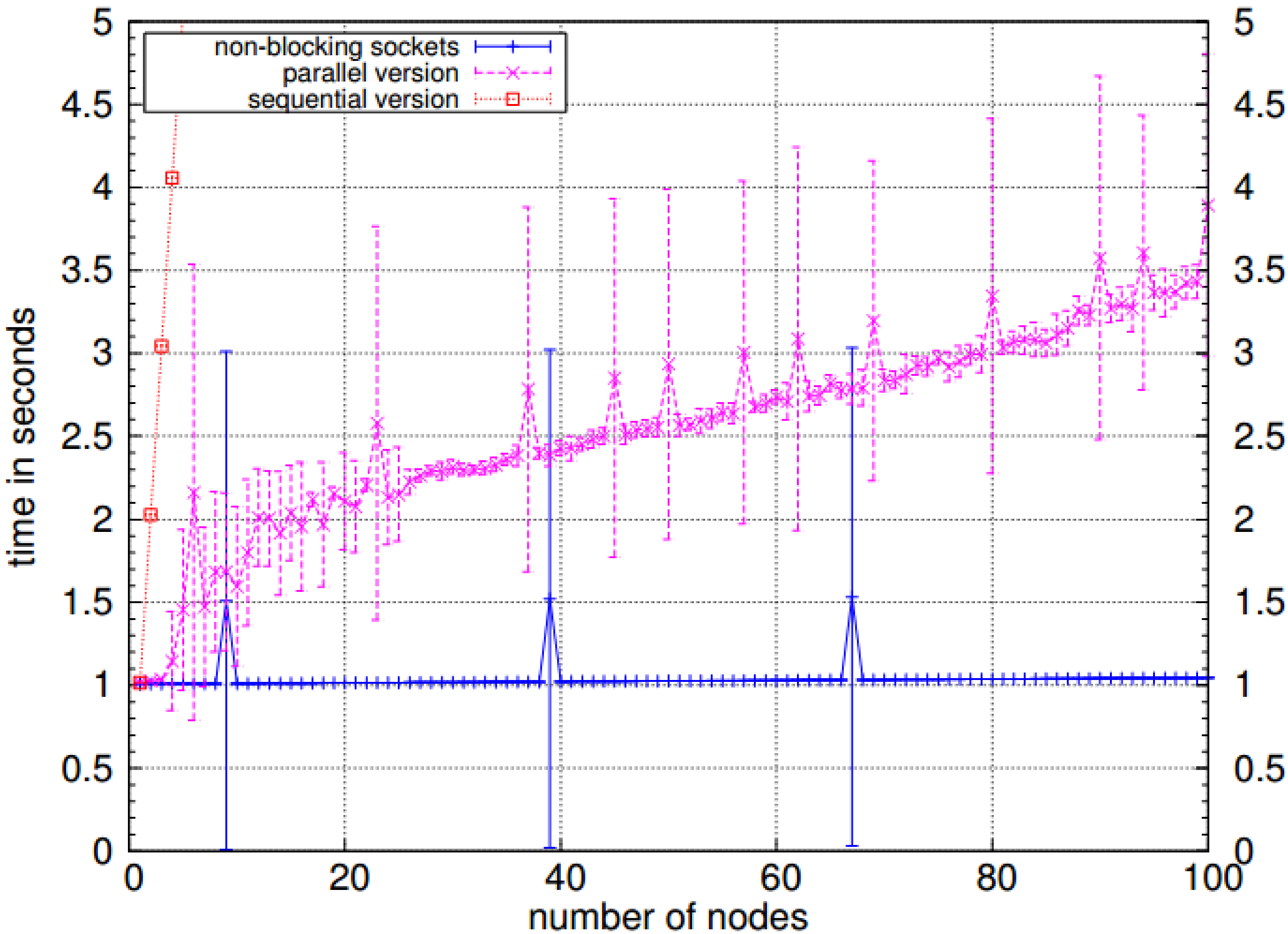
- Worst Case → all *N*-nodes *Down*
  → $T_{statusfun}(N) = N\ sec$

Status Function - Re-Implementation

2 different approaches:

- Simple: Prototype function for all nodes in a separate thread
- Complex: Non-blocking sockets and RMS query done for all nodes at once

Status Function - Results



Information Gathering Functions

- Status function:
  determines status of every node
- **Load function:**
  determines the load of the system

Load Function

Prototype:

- Every node is checked if the load forecast (2 minutes history) violates the overload threshold

→Linear regression computation for each node is far to expansive

→Drawback: No knowledge of the overall demand

Load Function

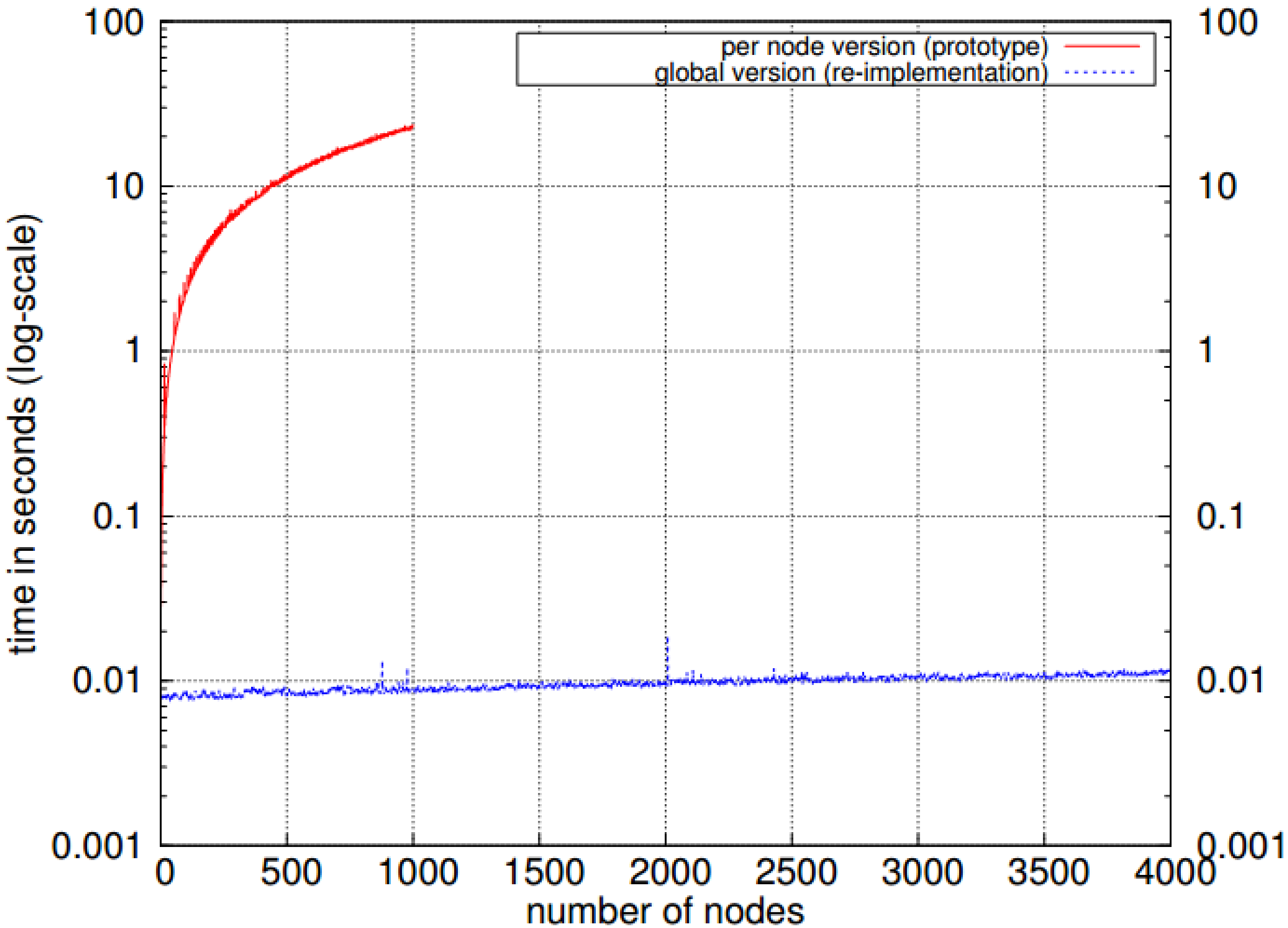
Re-Implementation:

- Checks load of the whole system
- Computes linear regression only once

→Benefit: knowledge about how many nodes must be booted

→Drawback: we now rely on a good schedule

Load Function - Results



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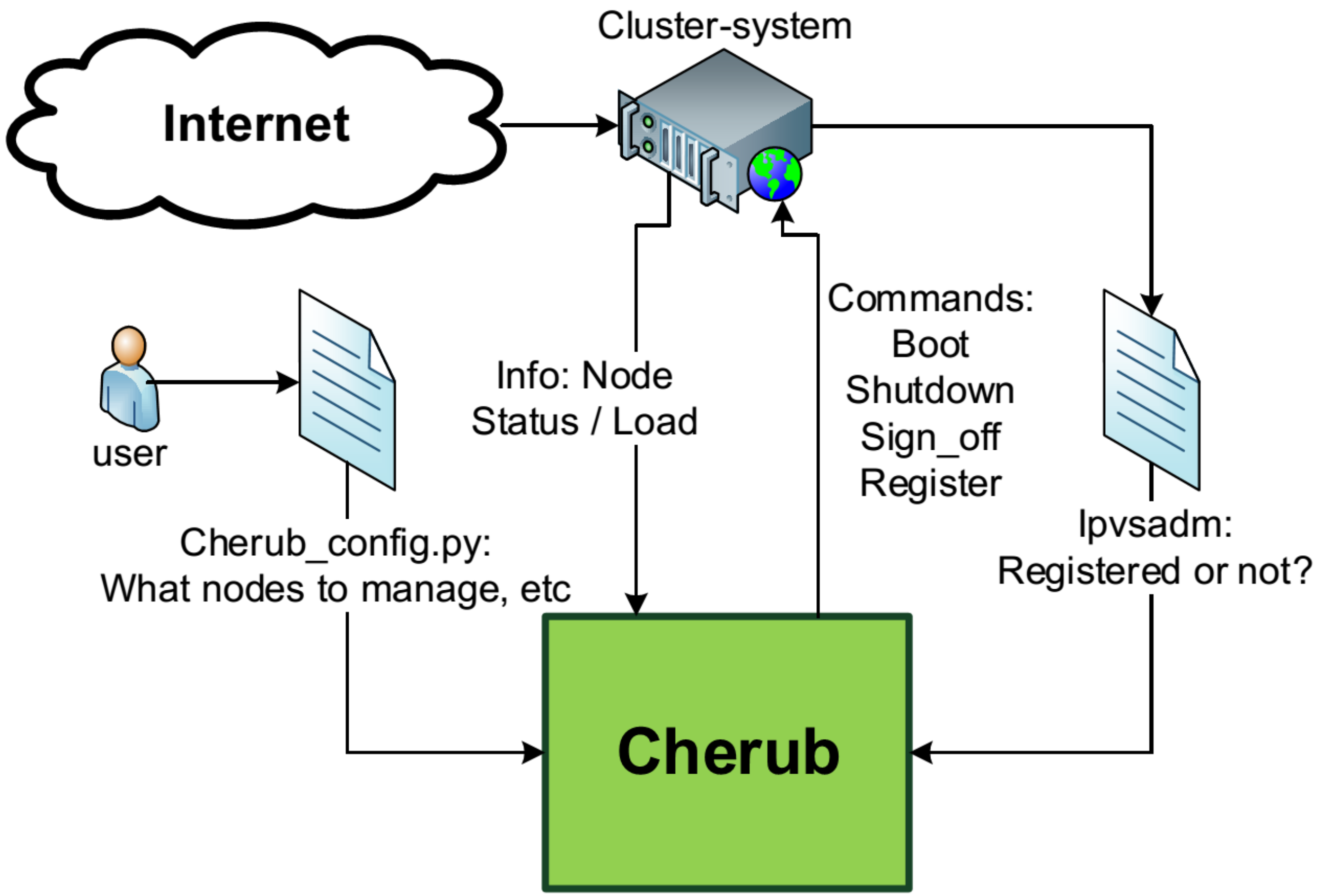
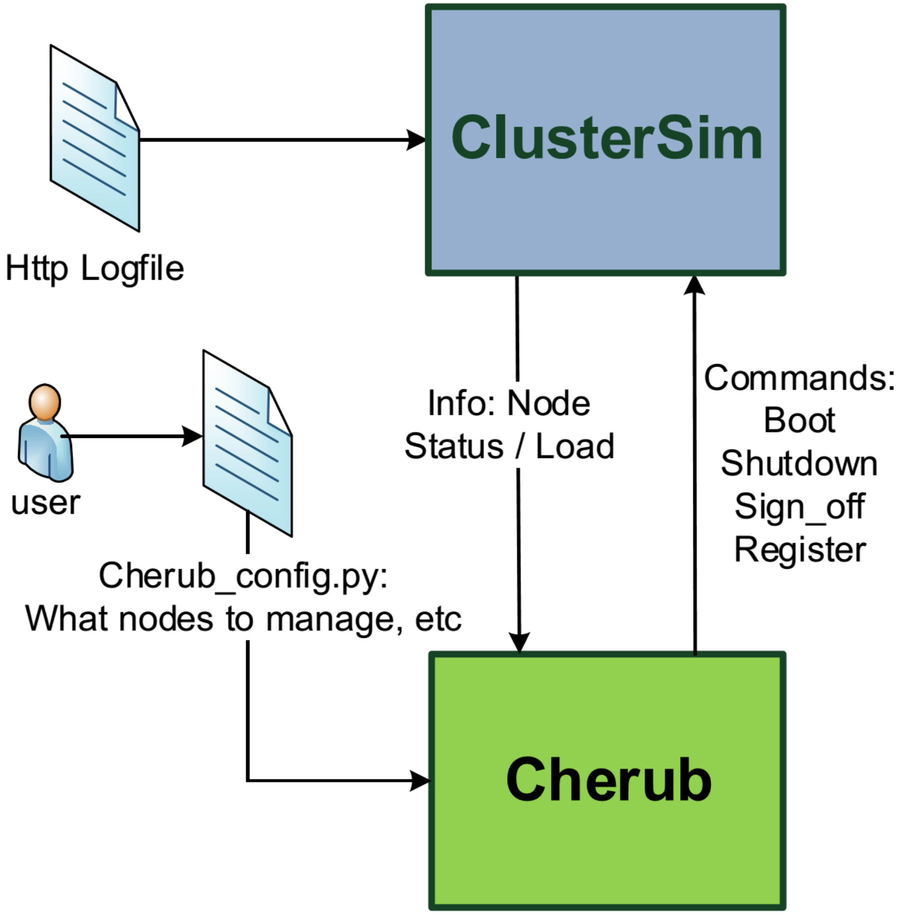
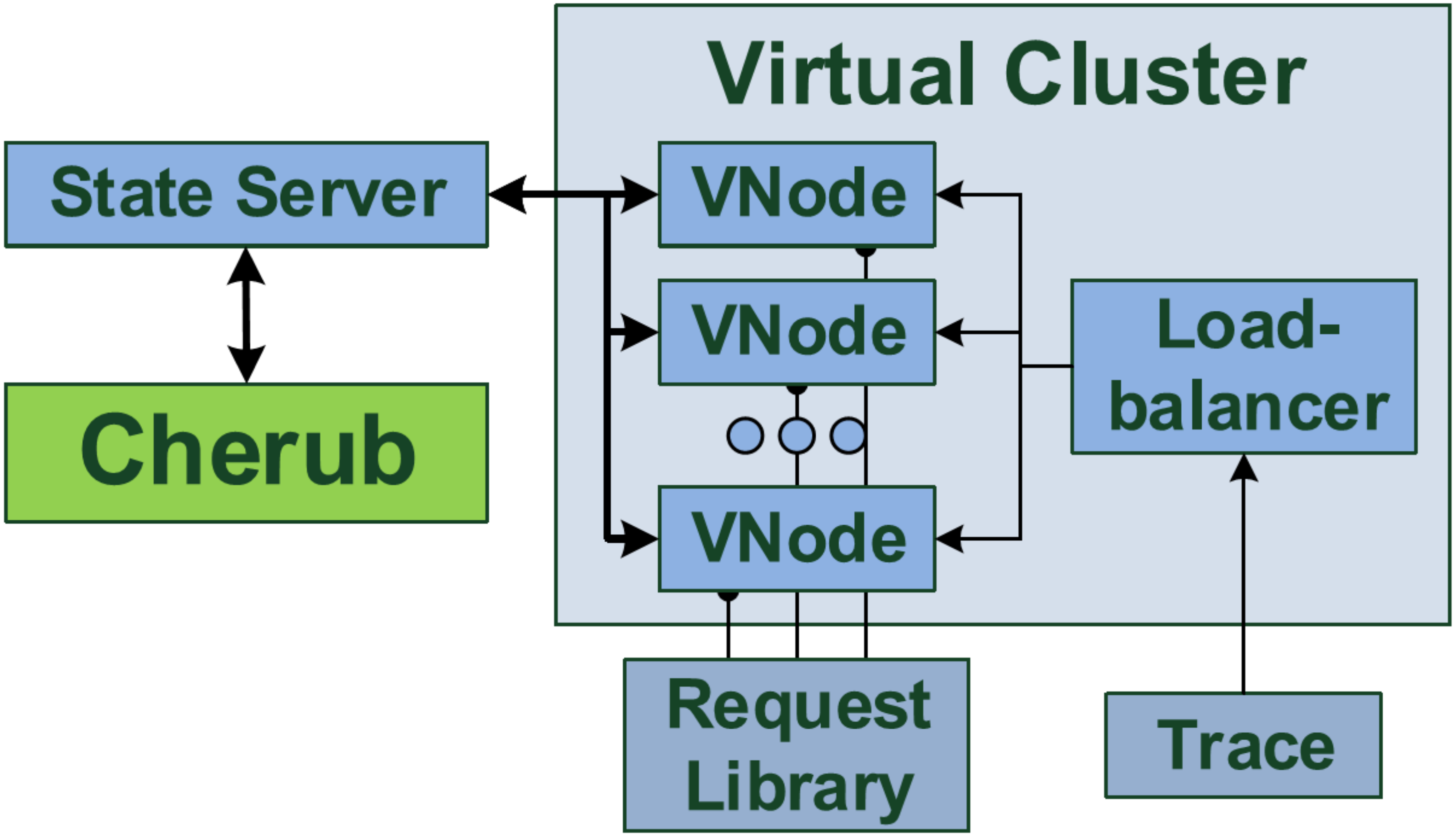
Simulation - Normal Setup



Simulation - Simulation Setup



Simulation - ClusterSim Architecture



ClusterSim - Limitations

- No reimplementation of the *Completely Fair Scheduler*
- No typical discrete event driven simulation
  → Bulk arrivals and Backlog Queue (BLQ) checks
- No modeling of system noise
- No concurrent resource access

ClusterSim - Validation - Metrics of Interest

- Service Level Agreement (SLA) in %
  violated if a 5 sec timeout is hit

- Median duration in ms
  of all successfully served requests

ClusterSim - Validation - Bordercase

Measurement details:

- 1 node, 4 cores, 4 workers, BLQ 20
- 10 minutes steady load of 4 req/sec
- Border case scenarios:
  - Low load (req duration 0.8 msec)
  - Overload (req duration 3.6 sec)

ClusterSim - Validation - Bordercase Results

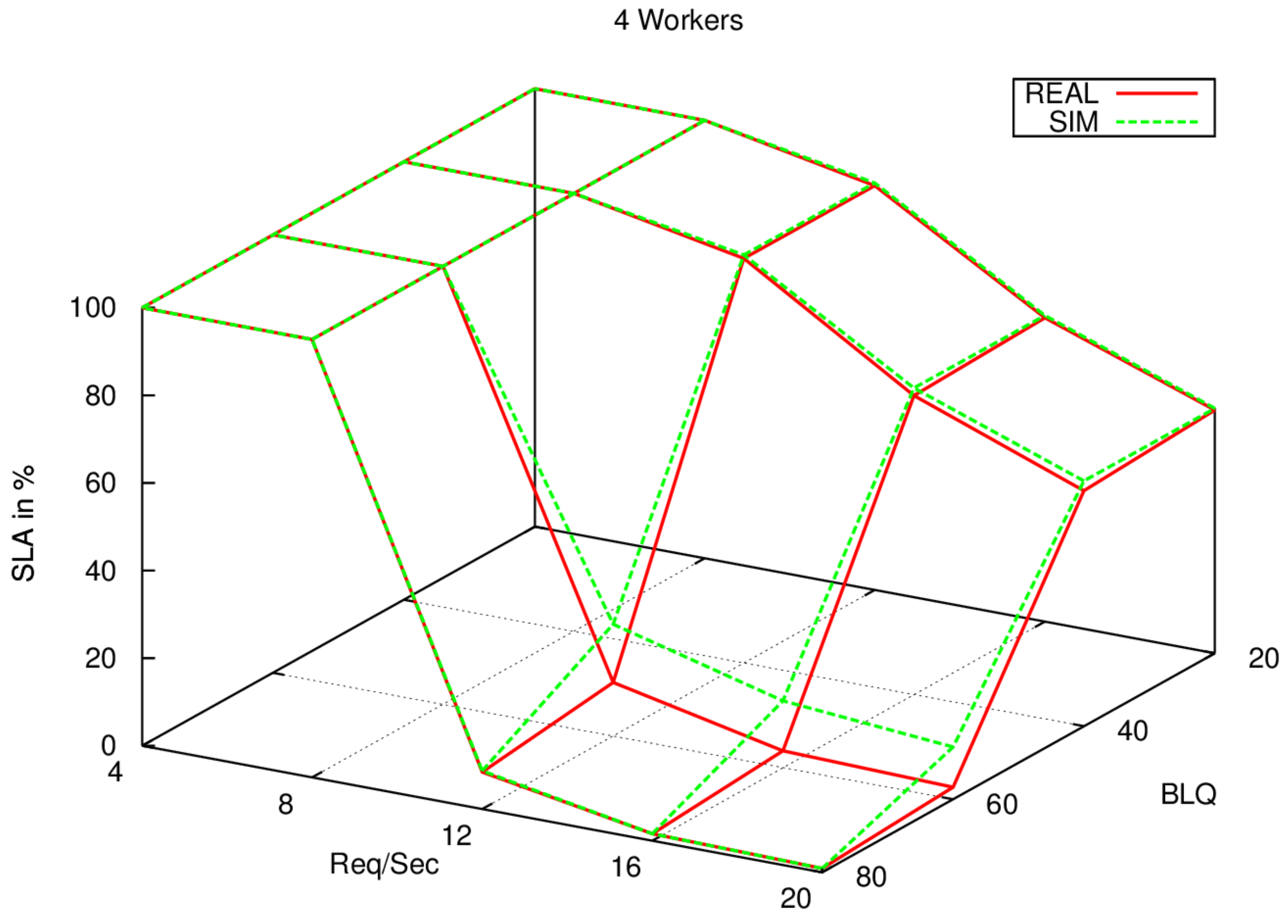
Request type	Metric	REAL	SIM
low load	SLA	100%	100%
	median duration	0.92 msec	0.802 msec
overload	SLA	0.166%	0.166%
	median duration	3.582 sec	3.578 sec

ClusterSim - Validation - Increasing Load

Measurement details:

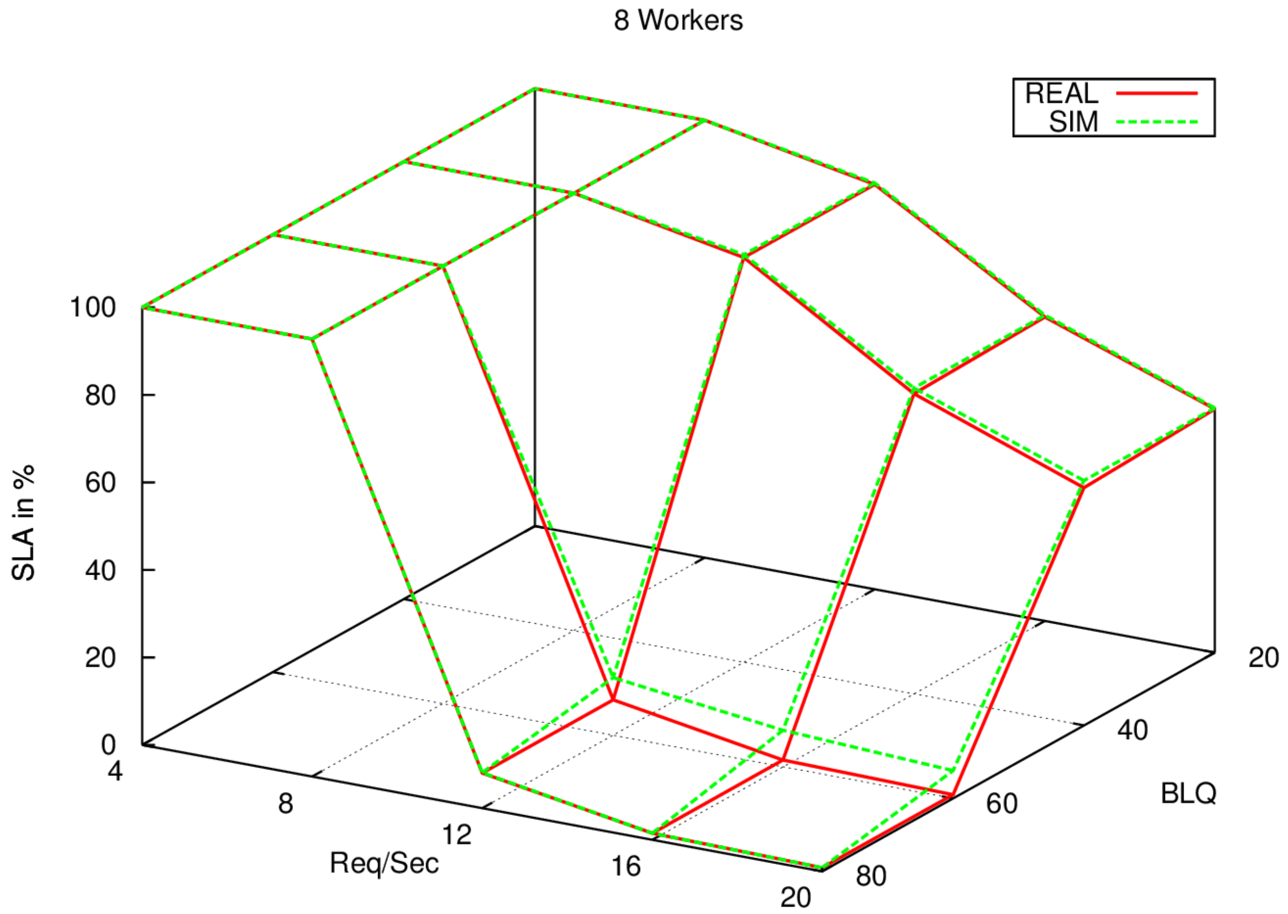
- 1 node, 4 cores
- 4/**8** workers
- BLQ 20/**40**/**60**/**80**
- 10 minutes steady load of 4/8/12/16/20 req/sec
- Req duration 0.36 sec

SLA



4 Workers
REAL
SIM
SLA in %
100
80
60
40
20
0
4
8
12
16
20
Req/Sec
20
40
60
80
BLQ

SLA


8 Workers
REAL
SIM
SLA in %
100
80
60
40
20
0
4
8
12
16
20
Req/Sec
20
40
60
80
BLQ

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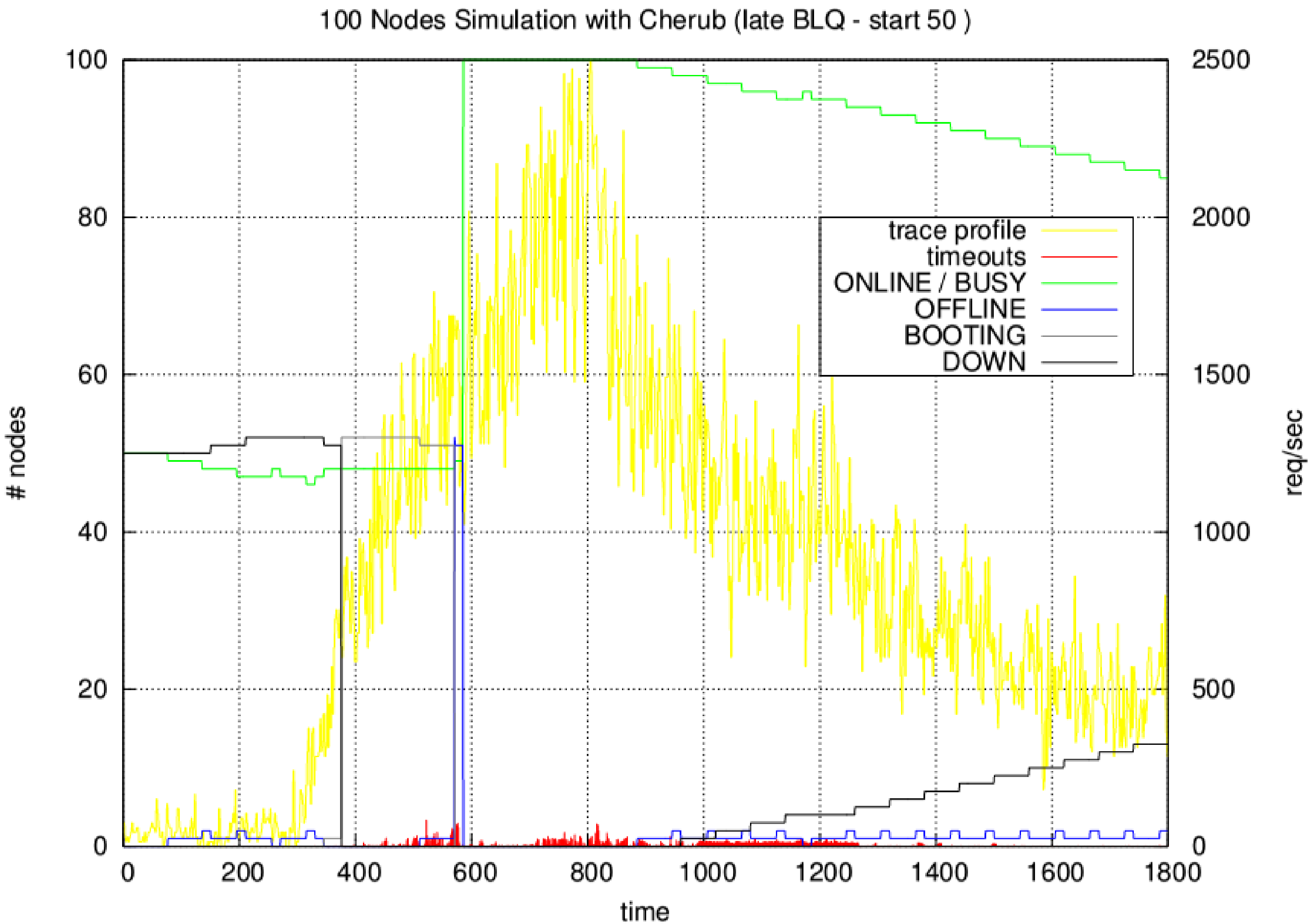
First Results

- Cherub + ClusterSim with 100 vnodes configured
- 30 minutes Trace with load peak
- 180 sec boottime
- Initial number of started nodes 10/50
- Results:
  95.6% / 99.45% SLA
  20.8% / 13.8% energy savings
- 42.5% theoretical optimum

100 Nodes Simulation With 50 Initial Started



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Conclusion & Future Work

- All key functions are fast enough to handle bigger clusters, proved with measurements
- ClusterSim mimics our real setup in a convincing way, proved with a border case study
- CHERUB scales up to 100+ nodes

- Deeper investigations on CHERUB + ClusterSim situations, tuning CHERUB parameters!

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Thank you for your attention!
Any Questions?

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Sources

[1] “New data supports finding that 30 percent of servers are ‘Comatose’, indicating that nearly a third of capital in enterprise data centers is wasted” by Jonathan Koomey and Jon Taylor, 2015

[2] “Revolutionizing Data Center Energy Efficiency” by James Kaplan, William Forrest, Noah Kindler, 2008

[3] “Energy aware resource management for clusters of web servers” by Simon Kiertscher and Bettina Schnor In IEEE International Conference on Green Computing and Communications (GreenCom), IEEE Computer Society (Beijing, China, 2013).

[4] “Cherub: power consumption aware cluster resource management” by Simon Kiertscher, Jörg Zinke and Bettina Schnor. In Journal of Cluster Computing (2011).