The SCADS Director:
Scaling a Distributed Storage System Under Stringent Performance Requirements

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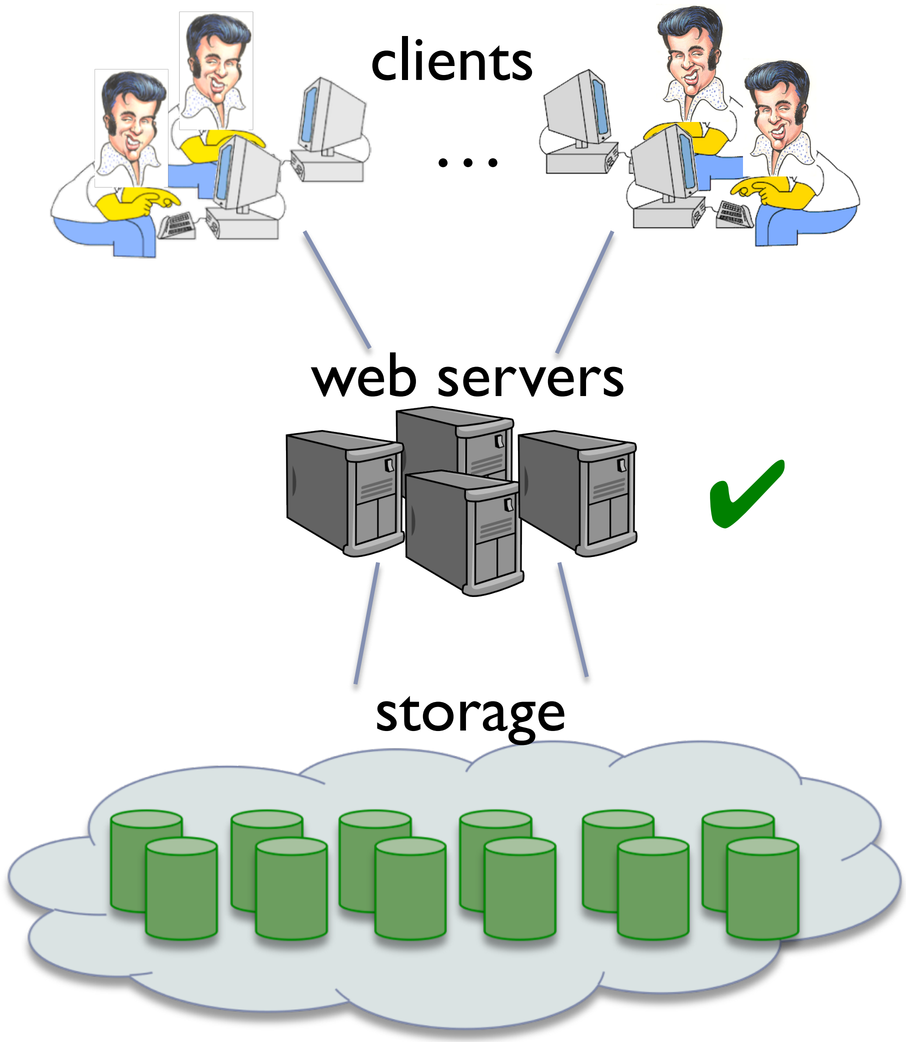
FAST 2011

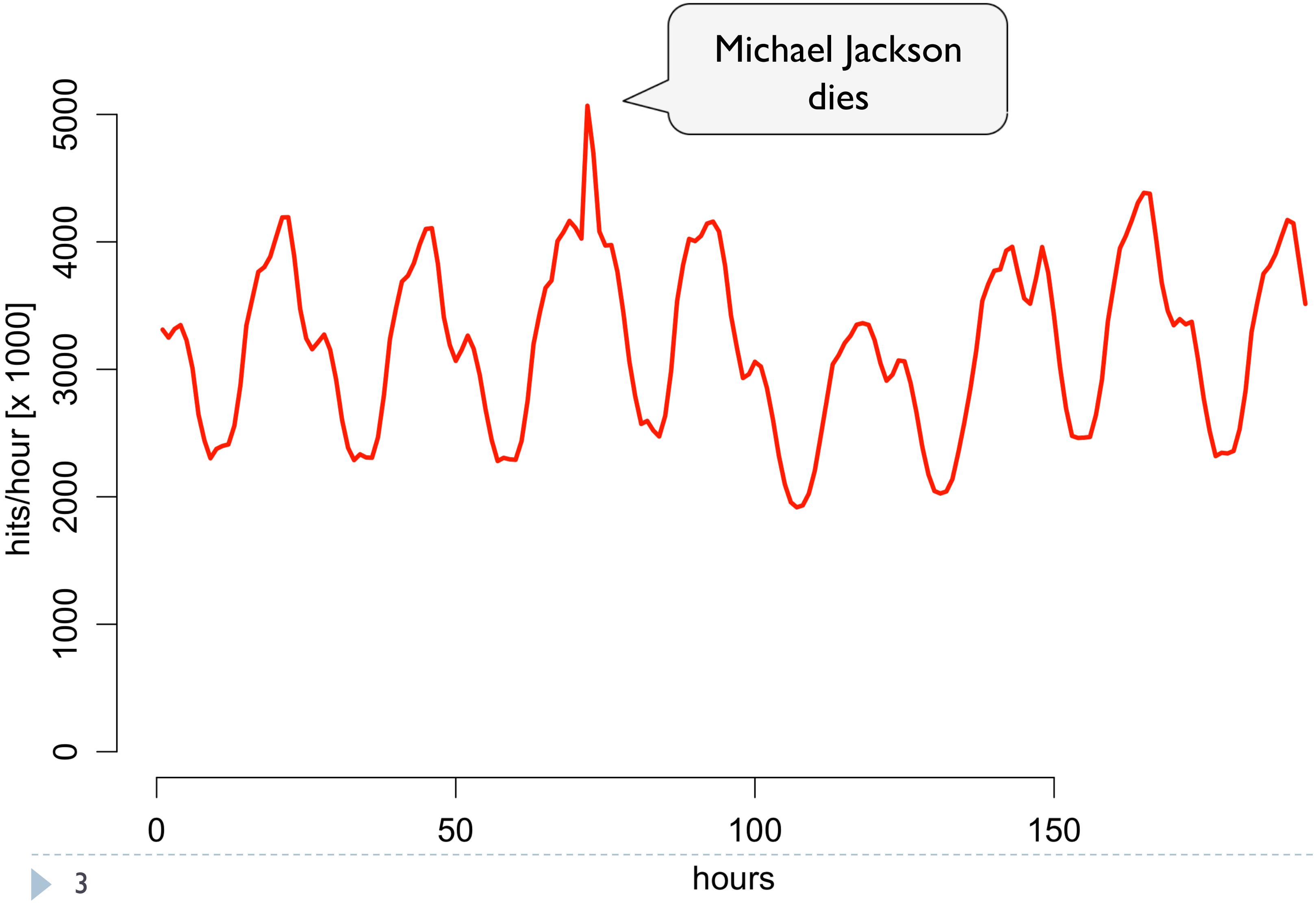
elasticity for interactive web apps



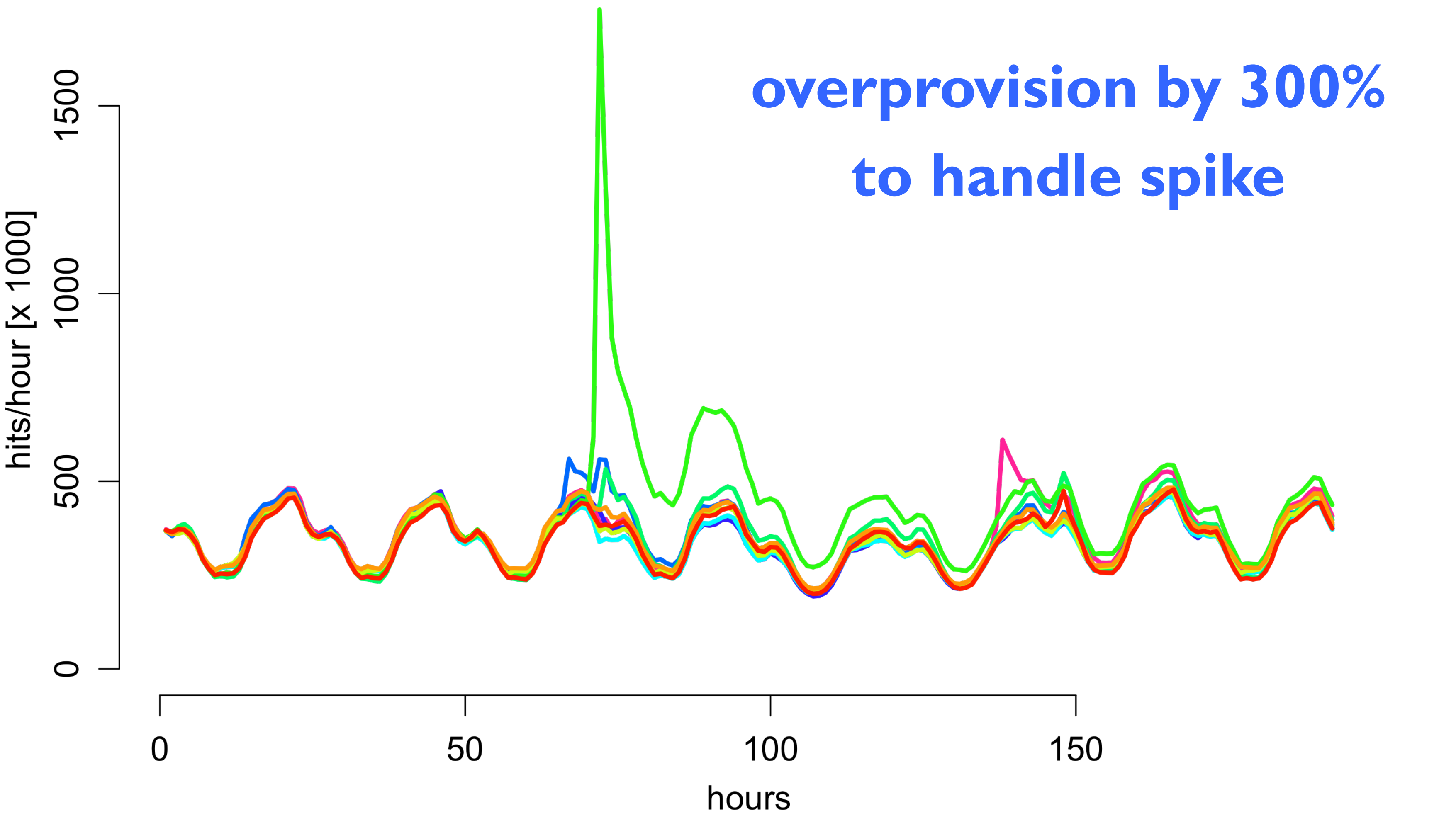
Interactivity Service-Level-Objective:
Over any 1-minute interval, 99% of requests are satisfied in less than 100ms

Targeted systems features:
- horizontally scalable
- API for data movement
- backend for interactive apps

wikipedia workload trace - June 2009



overprovisioning storage system



(assuming data stored on ten servers)

contributions

- Cloud computing is mechanism for storage elasticity
  - Scale up when needed
  - Scale down to save money
- We address the scaling policy
  - Challenges of latency-based scaling
  - Model-based approach for elasticity to deal with stringent SLO
  - Fine-grained workload monitoring aids in scaling up and down
  - Show elasticity for both a hotspot and a diurnal workload pattern

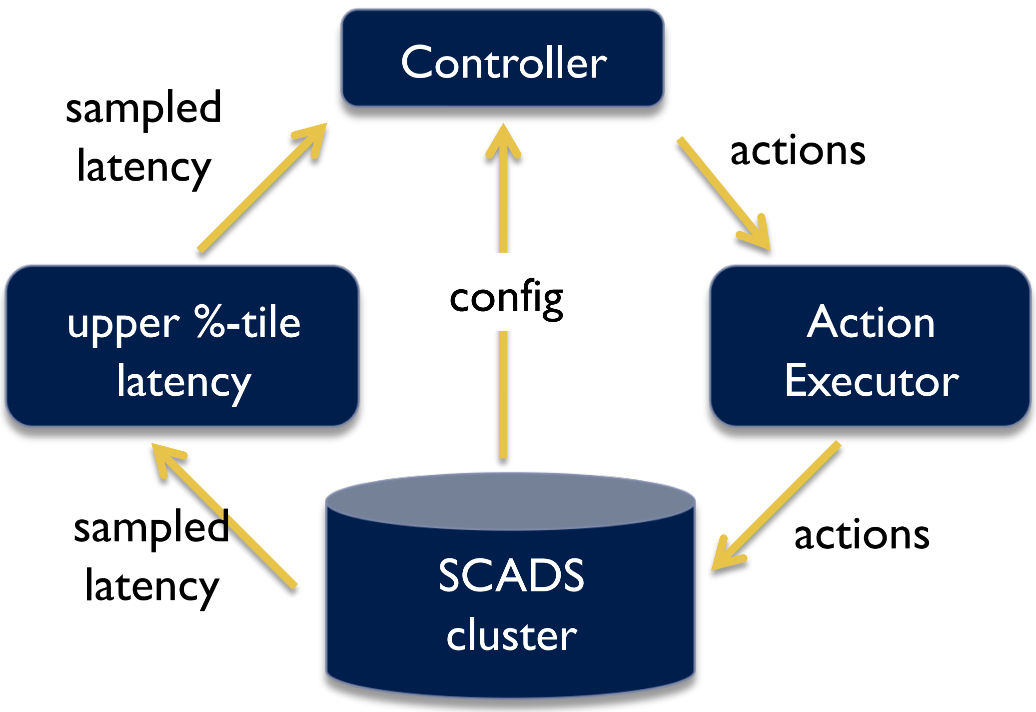
SCADS key/value store

- Features
  - Partitioning (until some minimum data size)
  - Replication
  - Add/remove servers

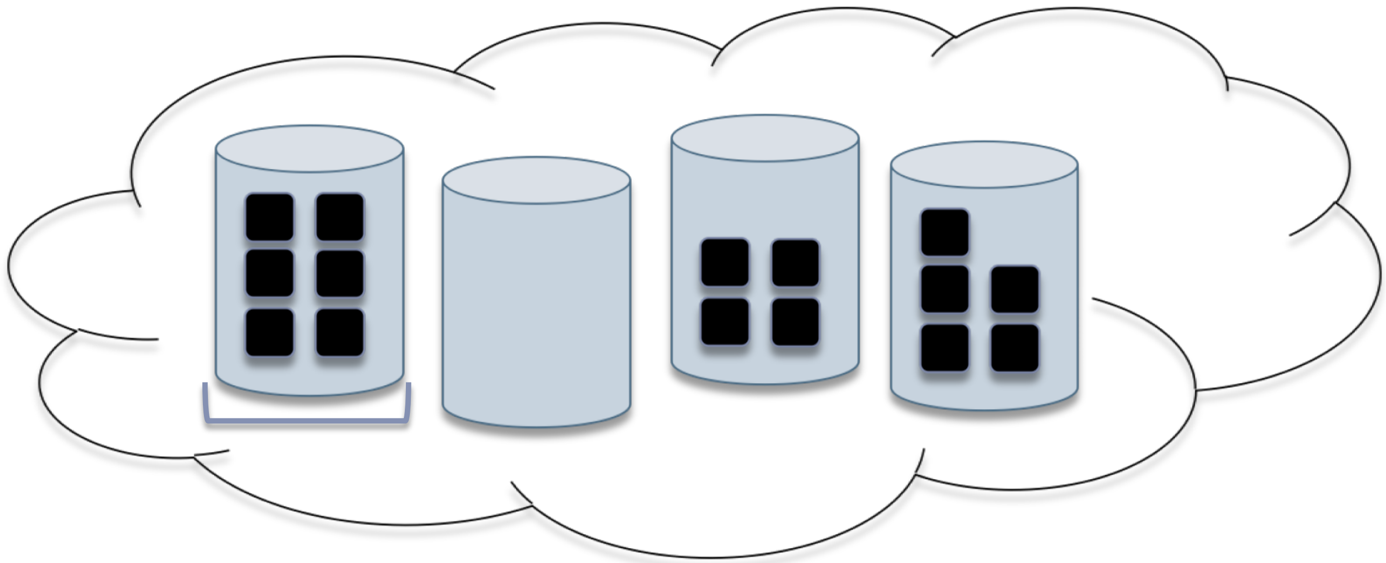
- Properties
  - Range-based partitioning
  - Data maintained in memory for performance
  - Eventually consistent

(see *SCADS: Scale-independent storage for social computing applications*, CIDR'09)

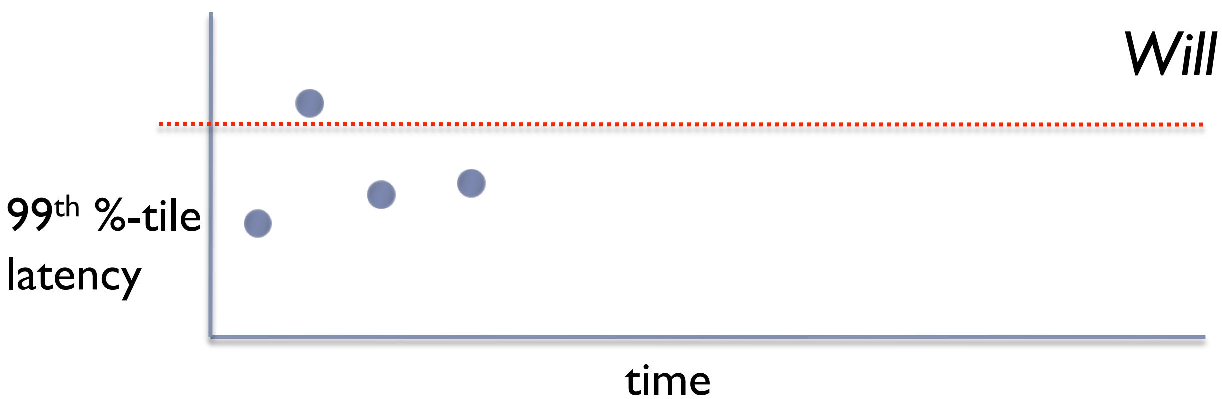
classical closed-loop control for elasticity?



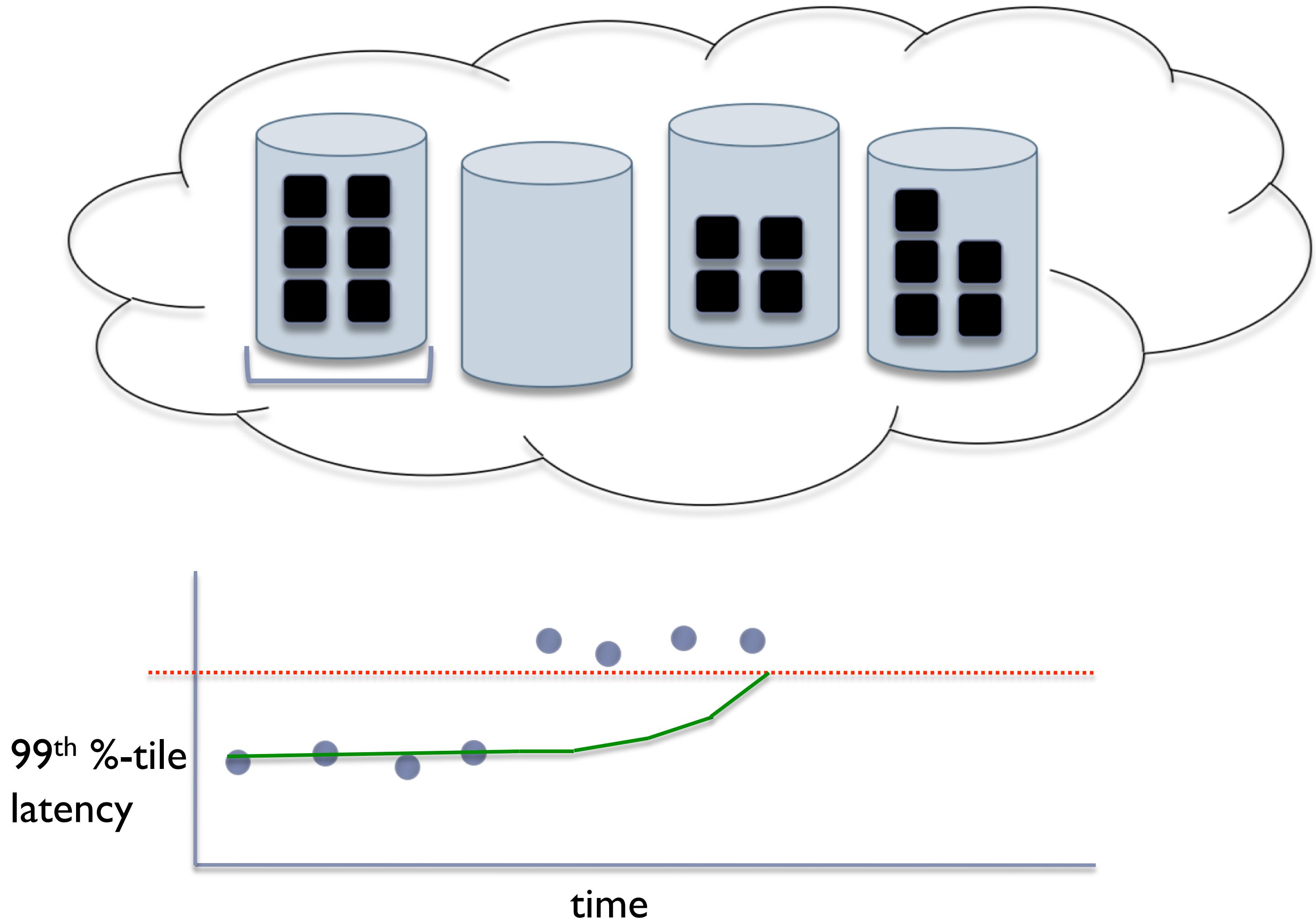
oscillations from a noisy signal



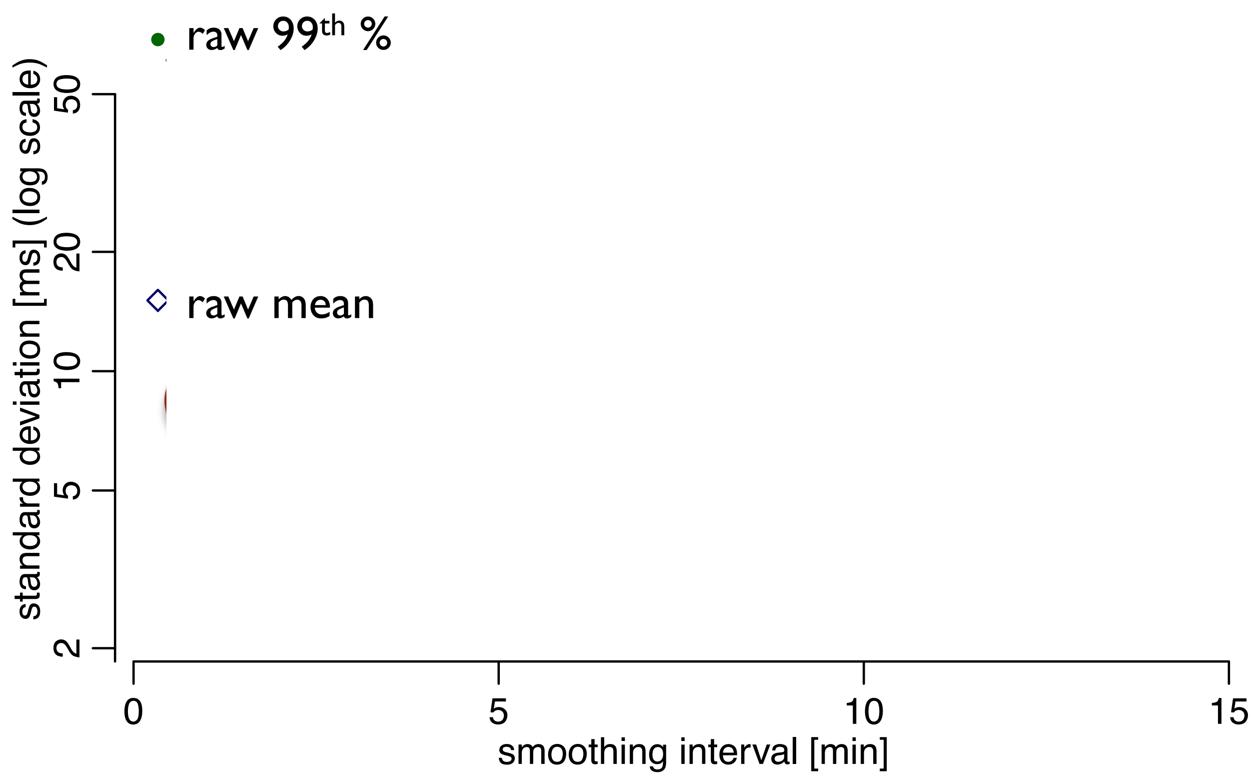
Noisy signal…
Will smoothing help?



too much smoothing masks spike



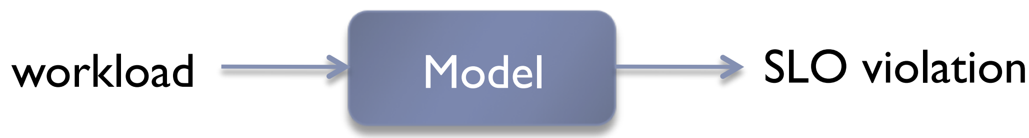
variation for smoothing intervals



(SCADS running on Amazon EC2)

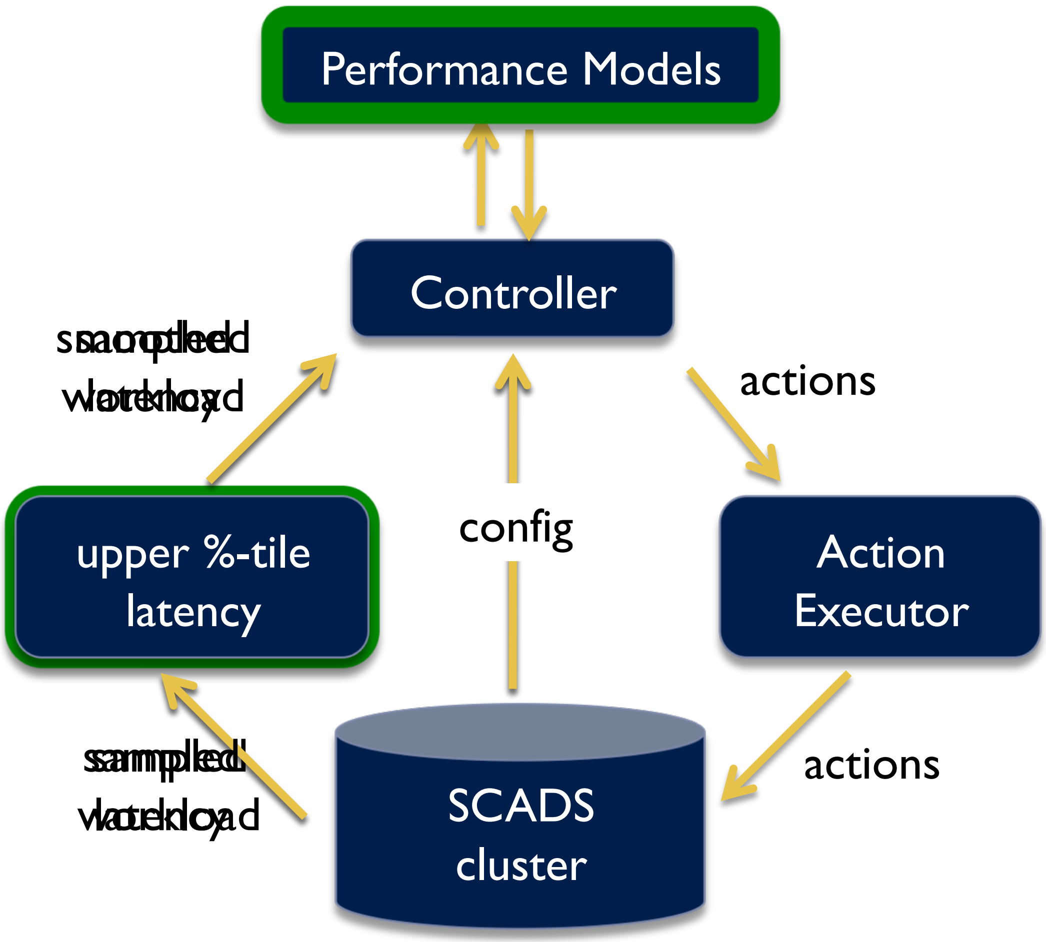
model-predictive control (MPC)

- MPC instead of classical closed-loop
  - Upper %-tile latency is a noisy signal
  - Use per-server workload as predictor of upper %-tile latency
  - Therefore need a model that predicts SLO violations based on observed workload



- Reacting with MPC
  - Use model of the system to determine a sequence of actions to change state to meet constraint
  - Execute first steps, then re-evaluate

model-predictive control loop

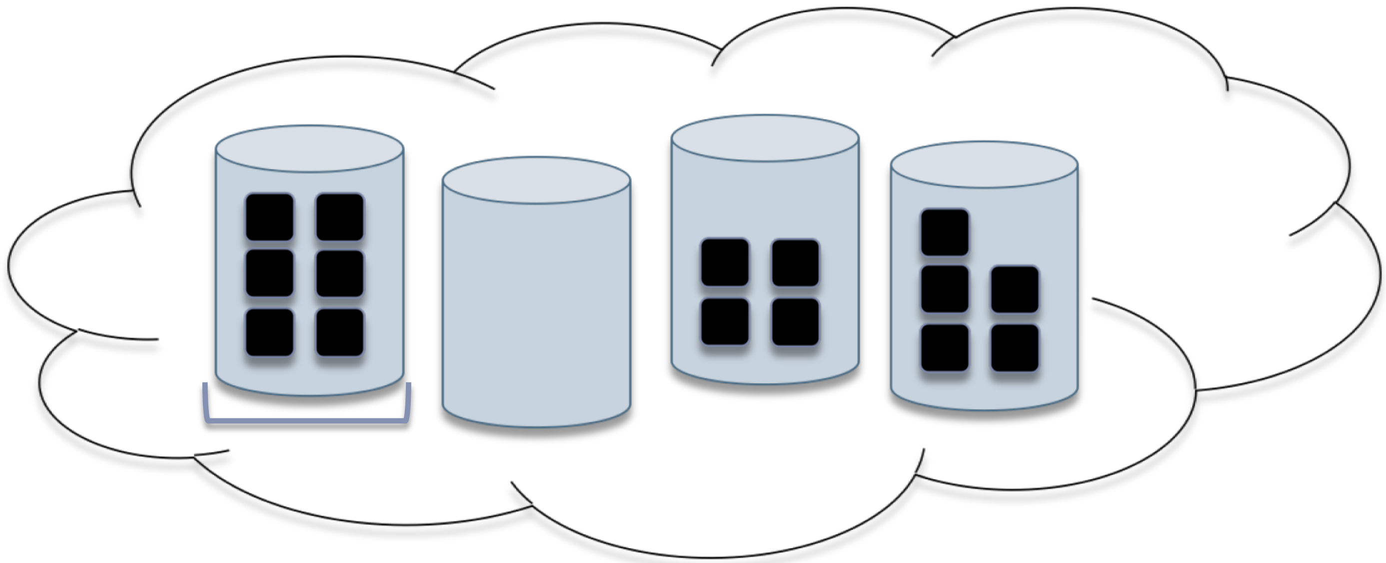


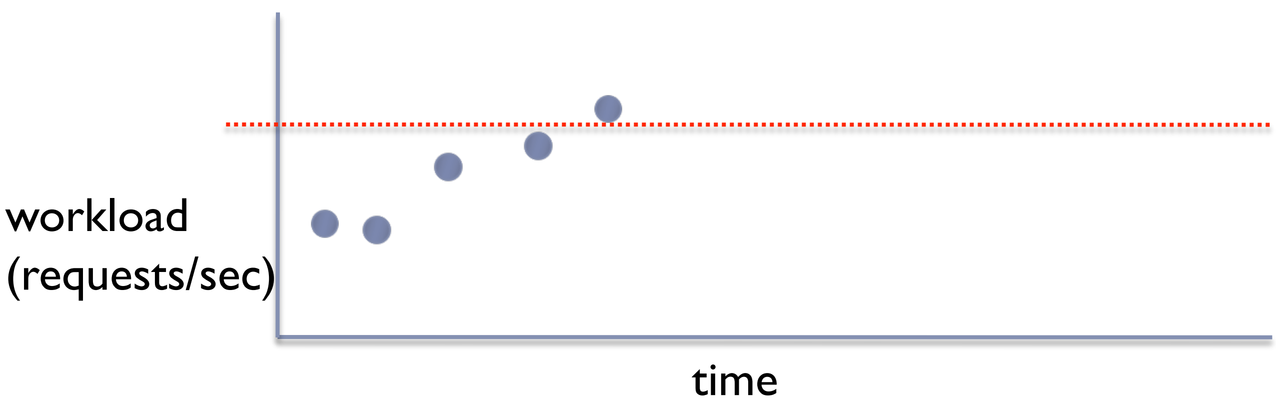
building a performance model

- Benchmark SCADS servers on Amazon's EC2

- Steady-state model
  - Single server capacity
  - Explore space of possible workload
  - Binary classifier: SLO violation or not

how much data to move?





finer-granularity workload monitoring

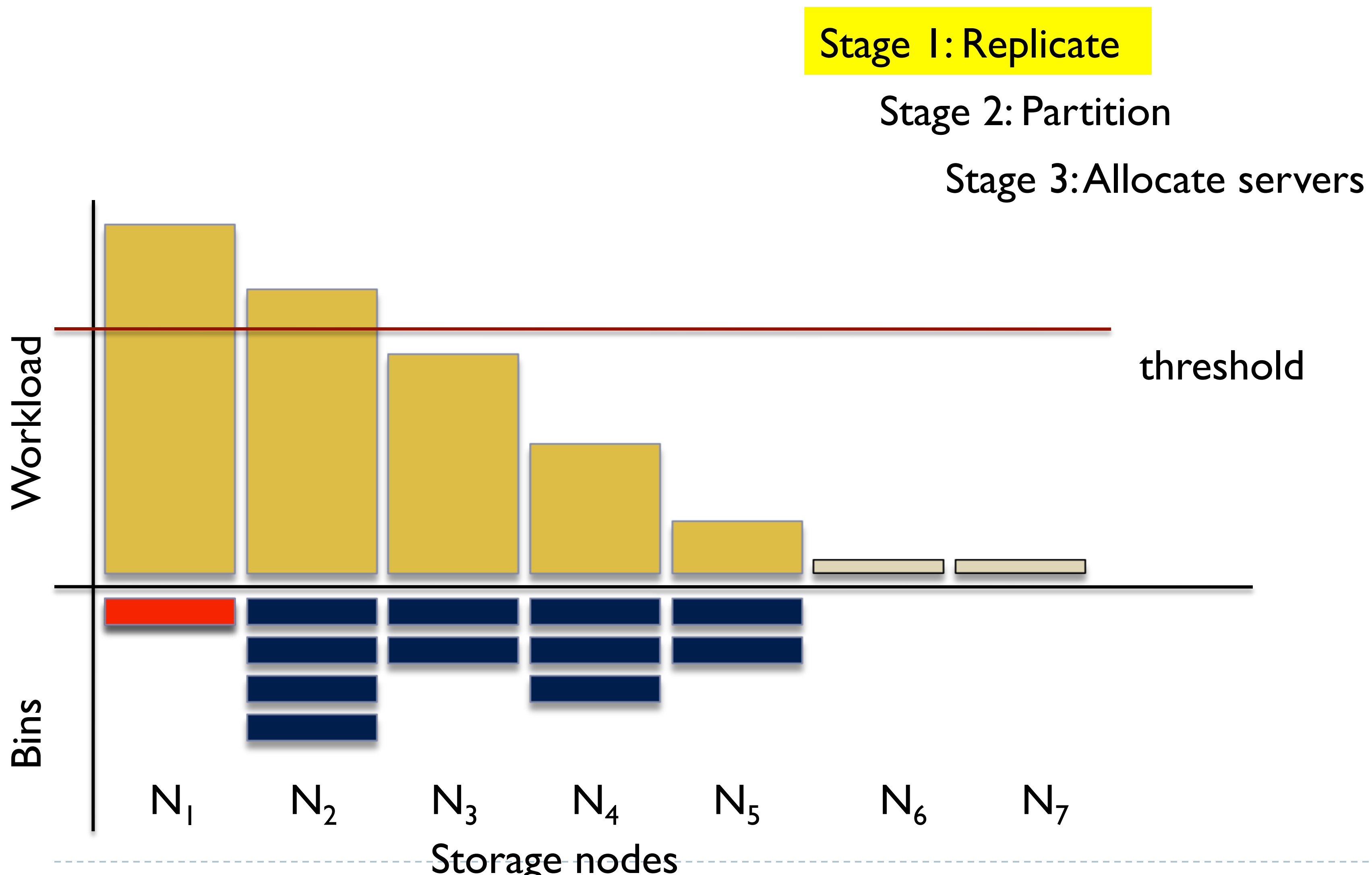
- Need fine-grained workload monitoring
  - Data movement especially impacts tail of latency distribution
  - Only move enough data to alleviate performance issues
  - Move data quickly
  - Better for scaling down later

- Monitor workload on small units of data (bins)
  - Move/copy bins between servers

summary of approach

- Fine-grained monitoring and performance model
  - Determine amount of data to move from overloaded server
  - Estimate how much "extra room" an underloaded server has
  - Know when safe to coalesce servers
- Replication for predictability and robustness
  - See paper and/or tonight's poster session

controller stages

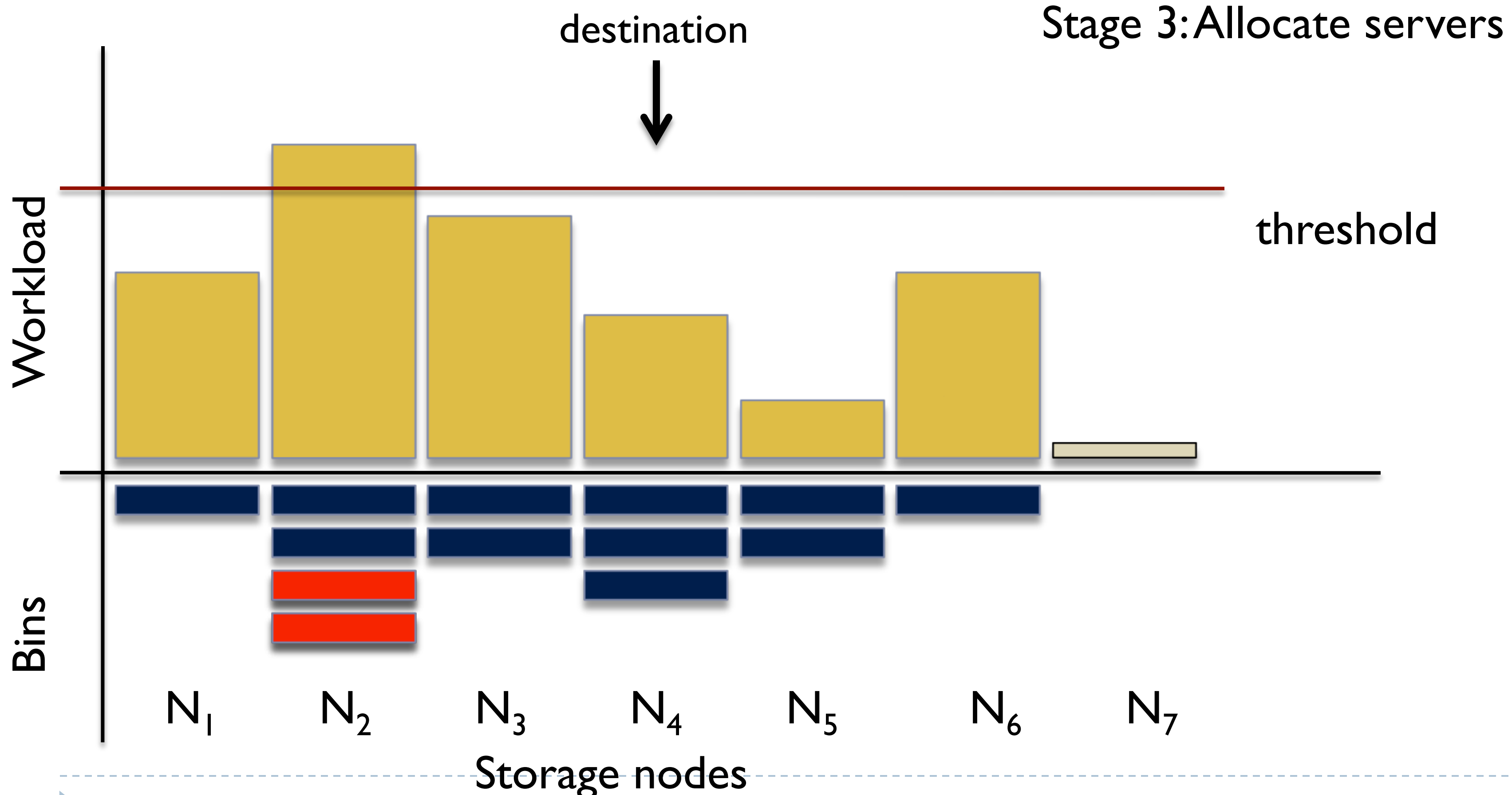


controller stages

Stage 1: Replicate

Stage 2: Partition

Stage 3: Allocate servers



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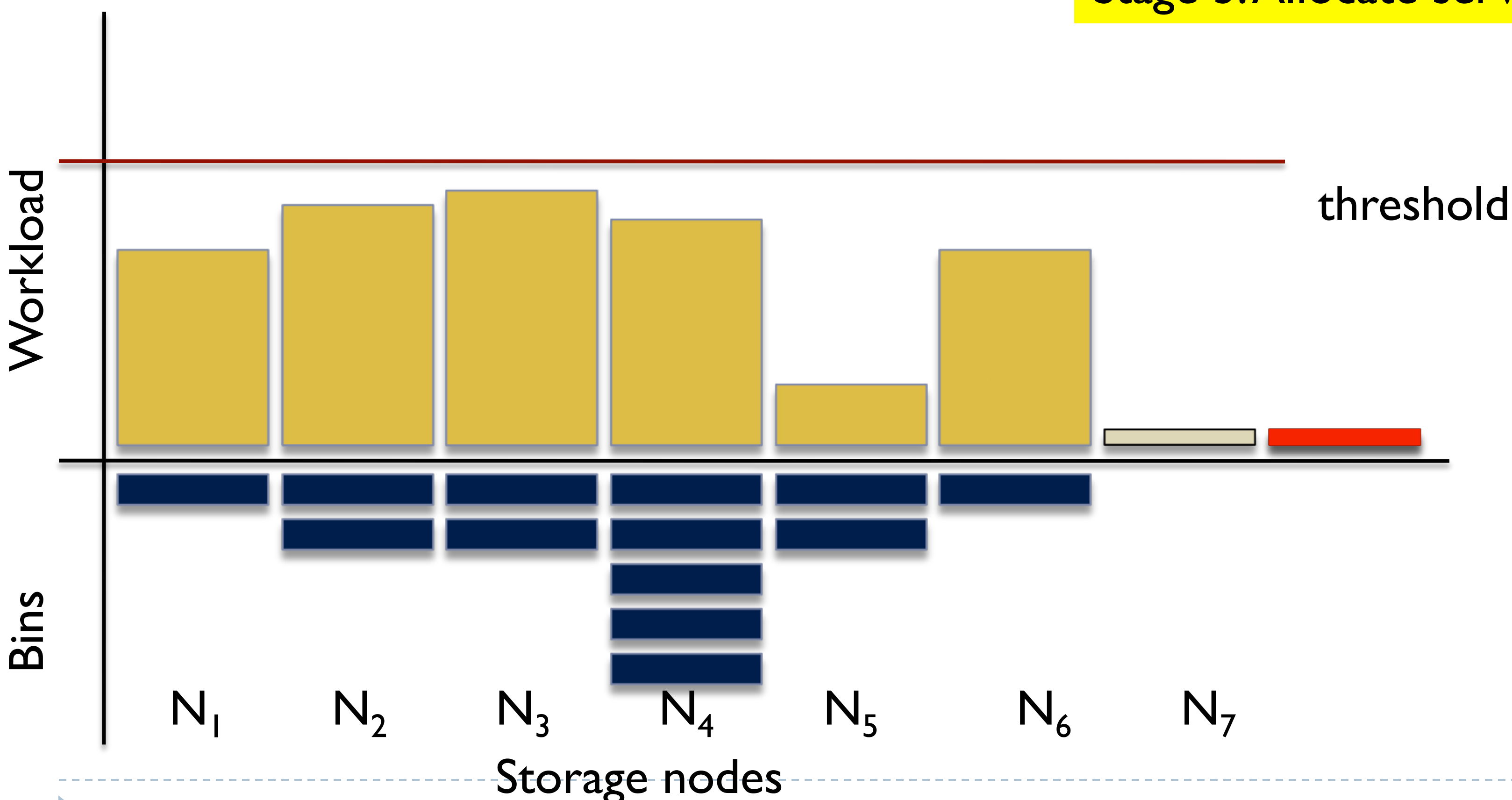
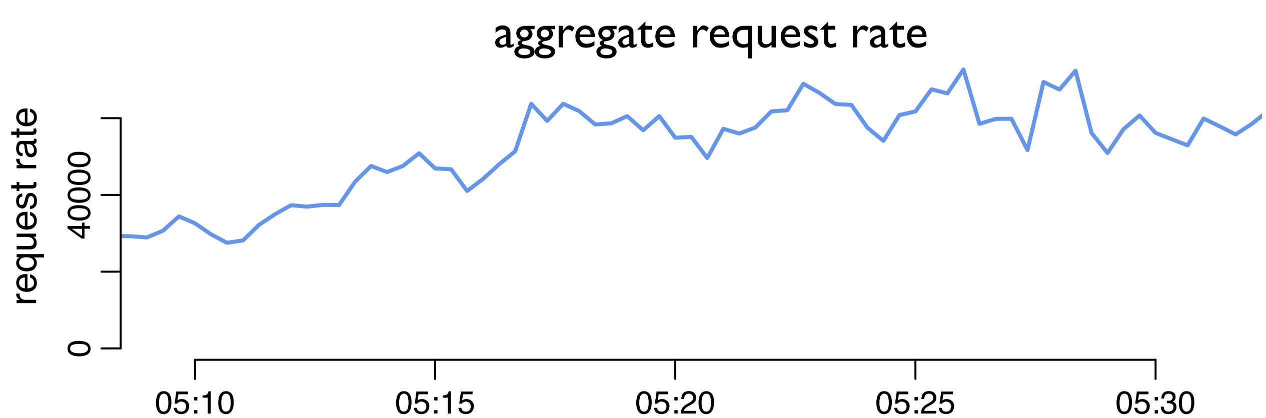


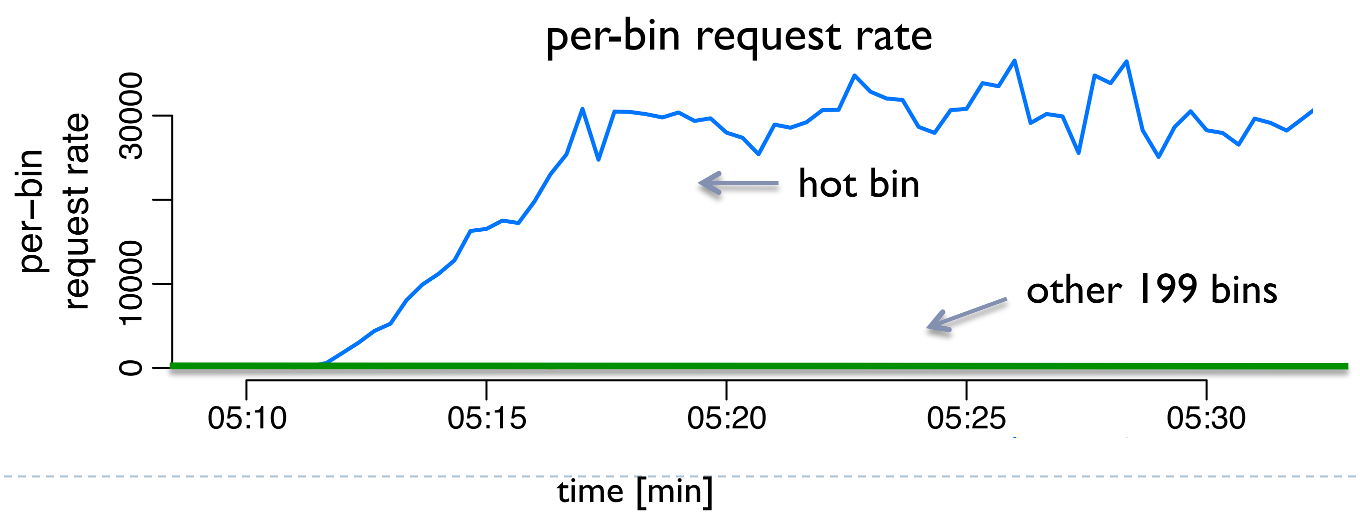
experimental results

- Experiment setup
  - Up to 20 SCADS servers run on m1.small instances on Amazon EC2
  - Server capacity: 800MB, due to in-memory restriction
  - 5-10 data bins per server
  - 100ms SLO on read latency

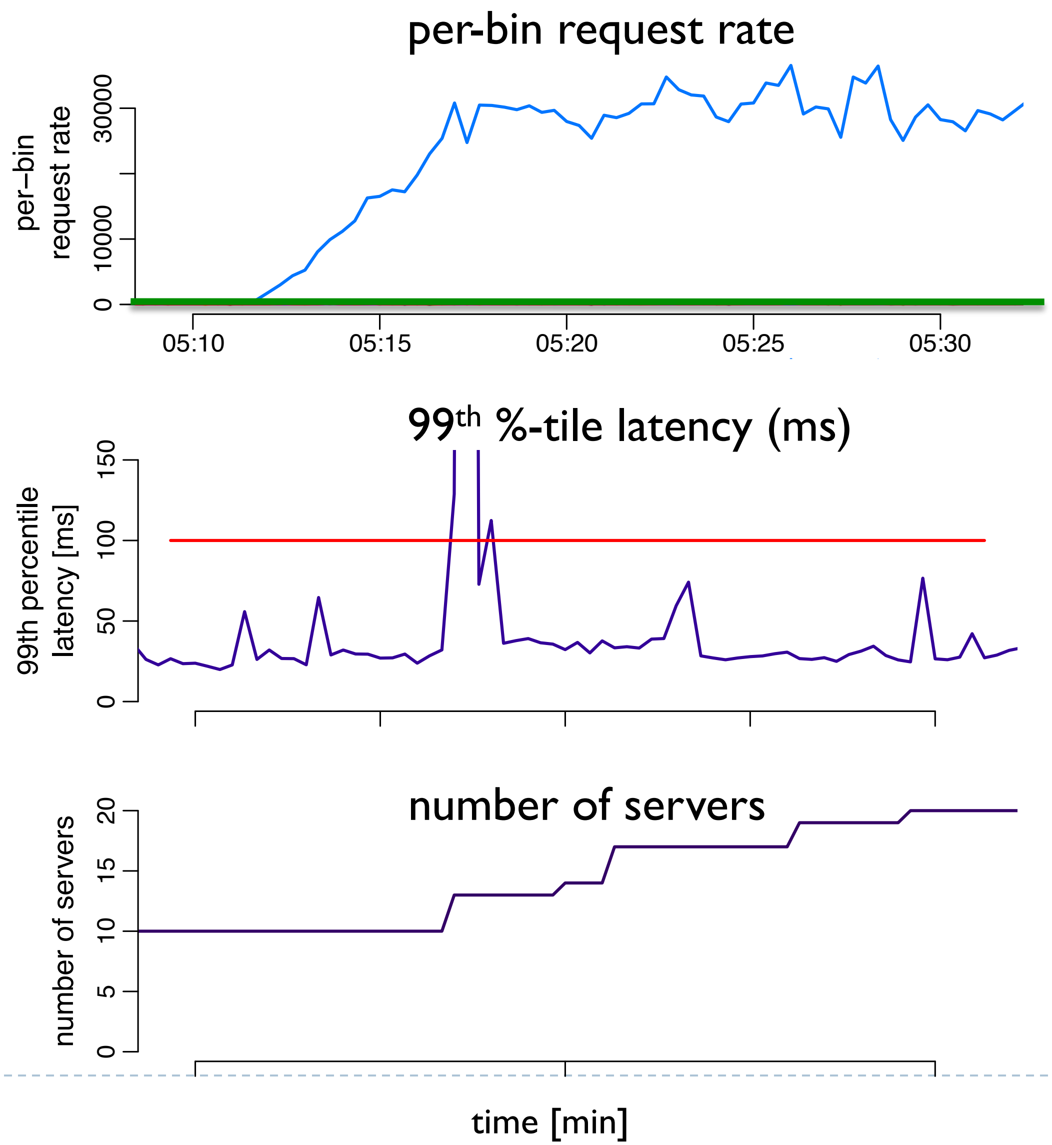
- Workload profiles
  - Hotspot
    - 100% workload increase in five minutes on a single data item
    - Based on spike experienced by CNN.com on 9/11
  - Diurnal
    - Workload increases during the day, decreases at night
    - Replayed trace at 12x speedup

extra workload directed to single data item



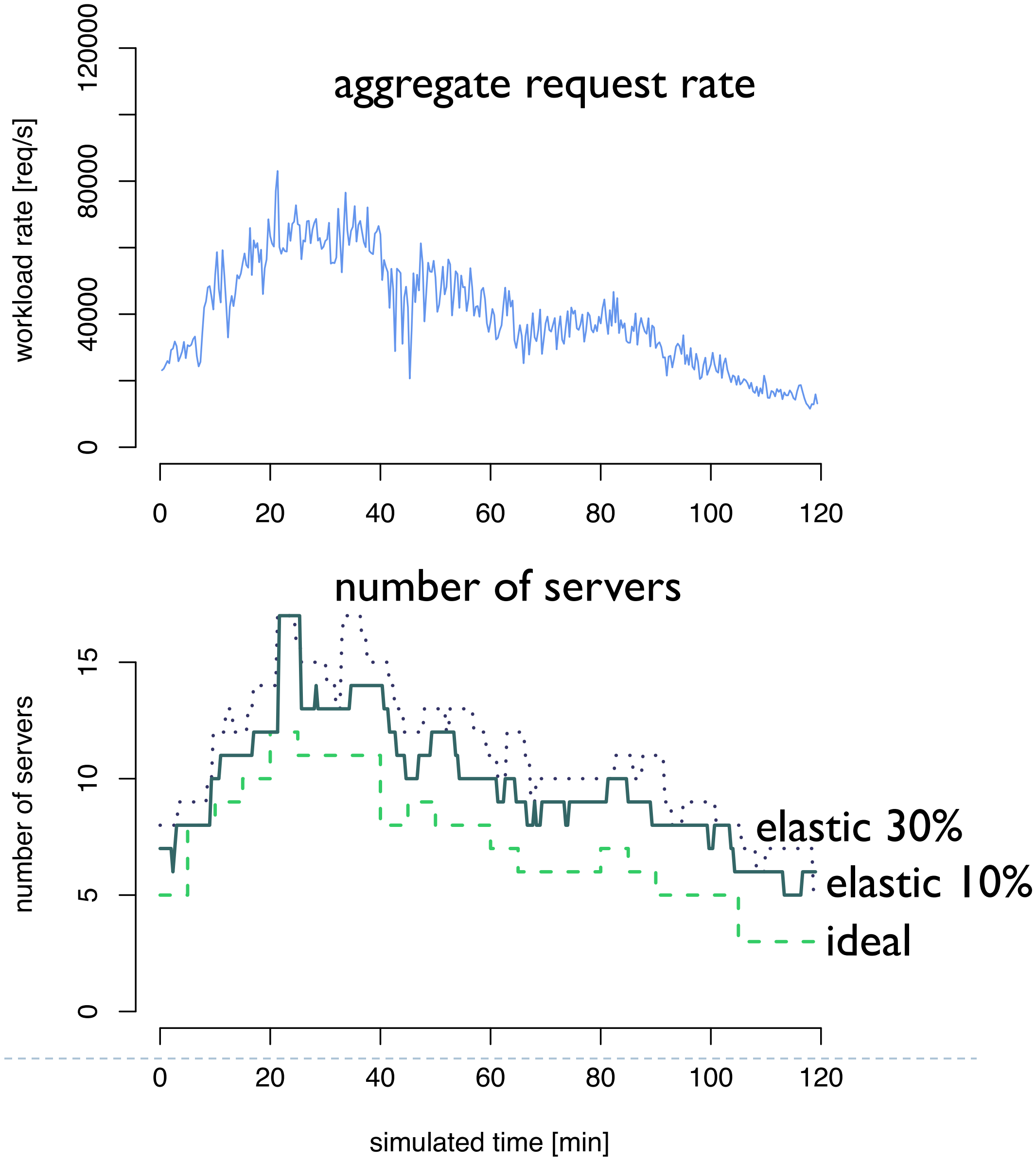


replicating hot data



scaling up and down

- Number of servers
  - two experiments close to "ideal"
- Over-provisioning tradeoff
  - Amplify workload by 10%, 30%
- Savings
  - Known peak: 16%
  - 30% headroom: 41%



cost-risk tradeoff

- Over-provisioning
  - Allows more time before violation occurs
  - Cost-risk tradeoff
- Comparing over-provisioning for diurnal experiment
  - Recall SLO parameters: *threshold*, *percentile*, *interval*
  - Over-provisioning factor of 30% vs 10%

Interval	**Max percentile achieved**	
	30%	**10%**
5 min	99.5	99
1 min	99	95
20 sec	95	90

conclusion

- Elasticity for storage servers possible by leveraging cloud computing
- Upper percentile too noisy
  - Model-based approach to build control framework for elasticity subject to stringent performance SLO
- Finer-grained workload monitoring
  - Minimize impact of data movement on performance
  - Quickly responding to workload fluctuations
- Evaluated on EC2 with hotspot and diurnal workloads

increasing replication