Predicting Bounds on Queuing Delay in Space-Shared Computing Environments

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Using HPC Machines

- Scientists previously had access to one or few HPC (High Performance Computing) machines
- Trends in commodity clusters has resulted in more HPC systems
- Grid computing efforts have led to higher degree of accessibility
  - Uniform software infrastructure
  - Easier to be granted access
- Modern HPC user has simultaneous access to many systems

Choices

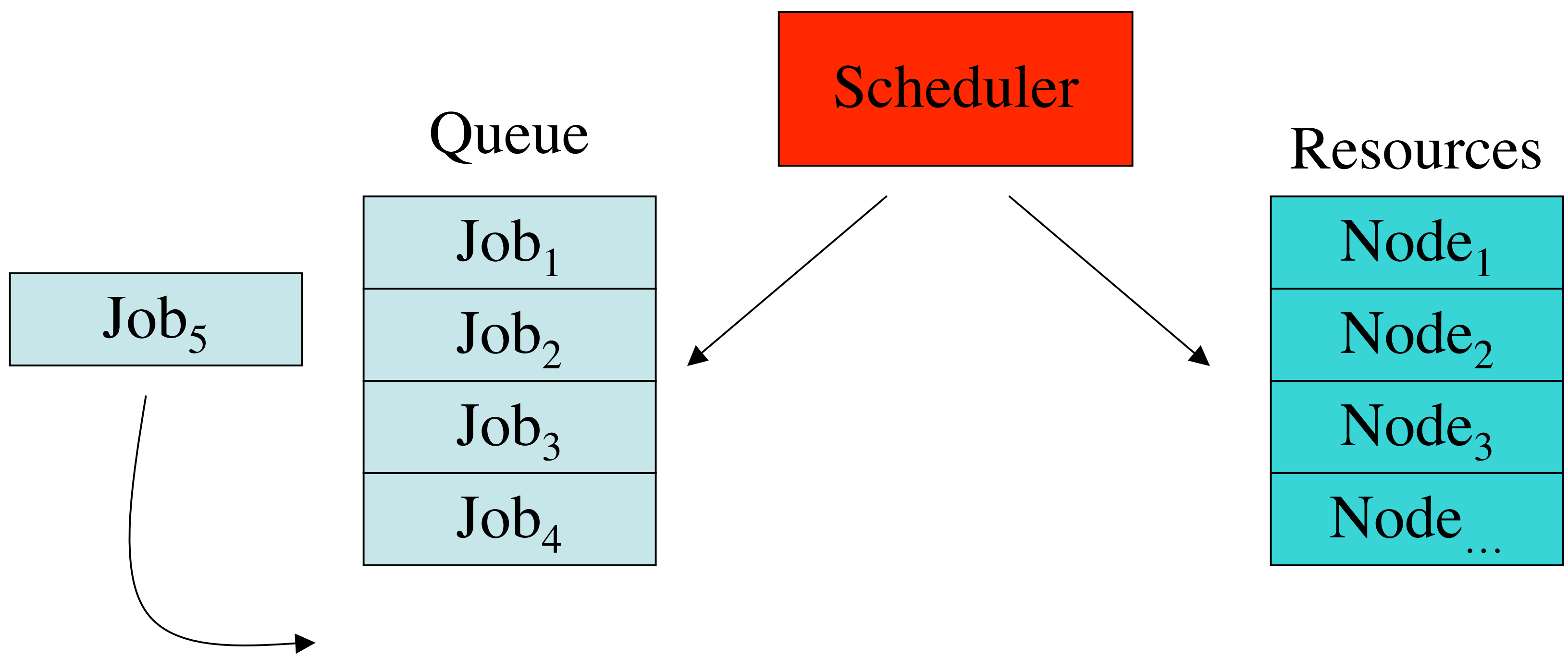
- Clusters, cycle-harvesting farms, parallel machines, SMP machines, etc
- Differ in significant ways
- Given an application and a pool of HPC systems, which do we choose to get fastest turnaround time?

Factors

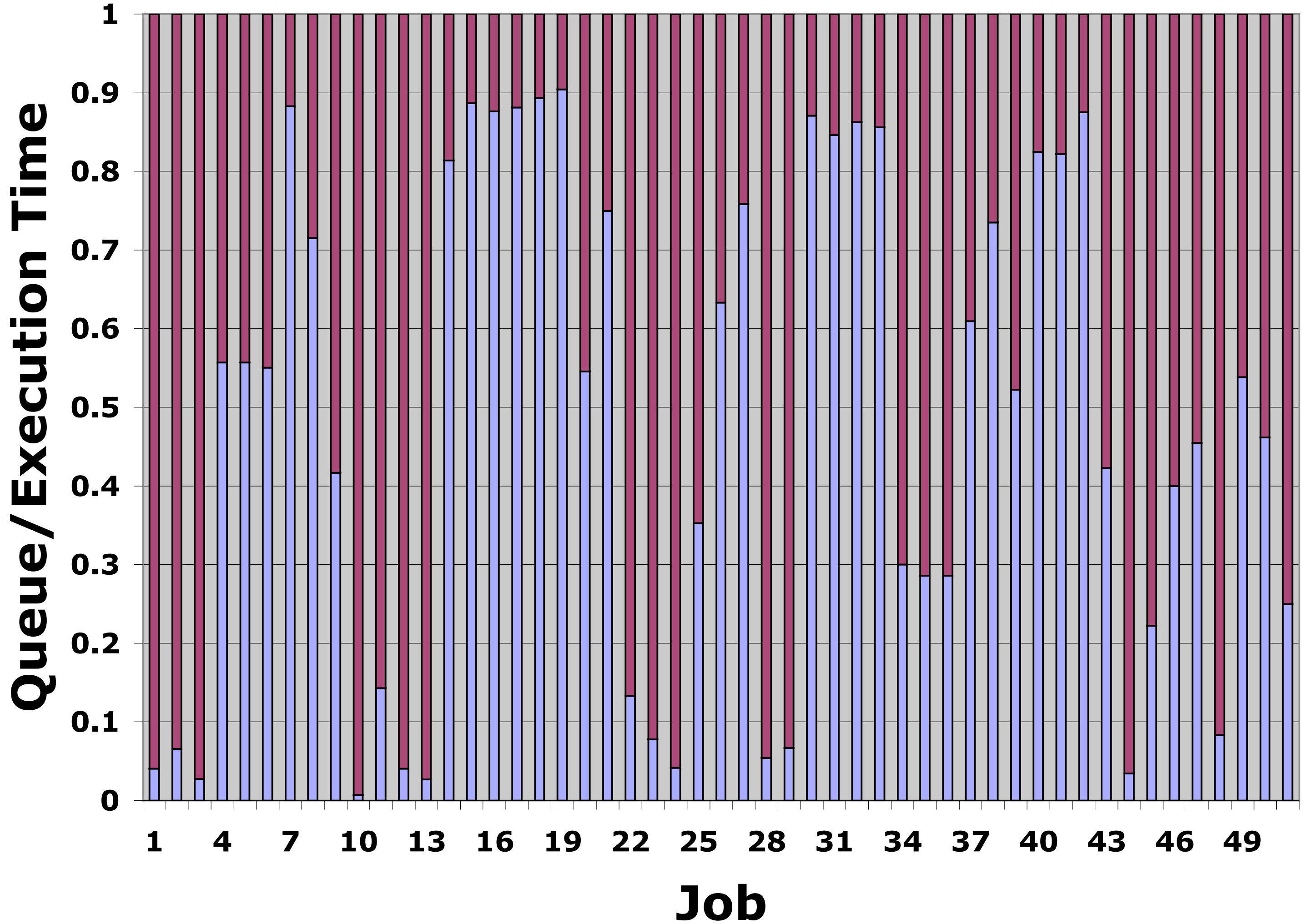
- Architecture
  - How well does my app perform on this architecture?
- Data locality
  - Is my data accessible, quickly, on this machine?
- Software/Environment
  - Are the tools my app requires available?
- Execution delay
  - What is the delay between when I decide to run my app and when the app actually executes?
  - **Batch Queue Wait Time**

Queuing Delay

- Most HPC sites employ space-sharing to manage workload
  - Batch queue system (PBS, Torque, LoadLeveler)
- Overall application turnaround time = queue delay + execution time



Queuing Delay



Mean = .48

Queuing Delay

- Modern batch queue software provides little if any batch queue wait time estimation
  - Requires perfect knowledge of scheduler, job execution time
  - Requires no cancellation or policy change
- Problem: can we provide **predictions** to help mitigate the effects of queuing delay overhead on overall turnaround time?

Our Approach

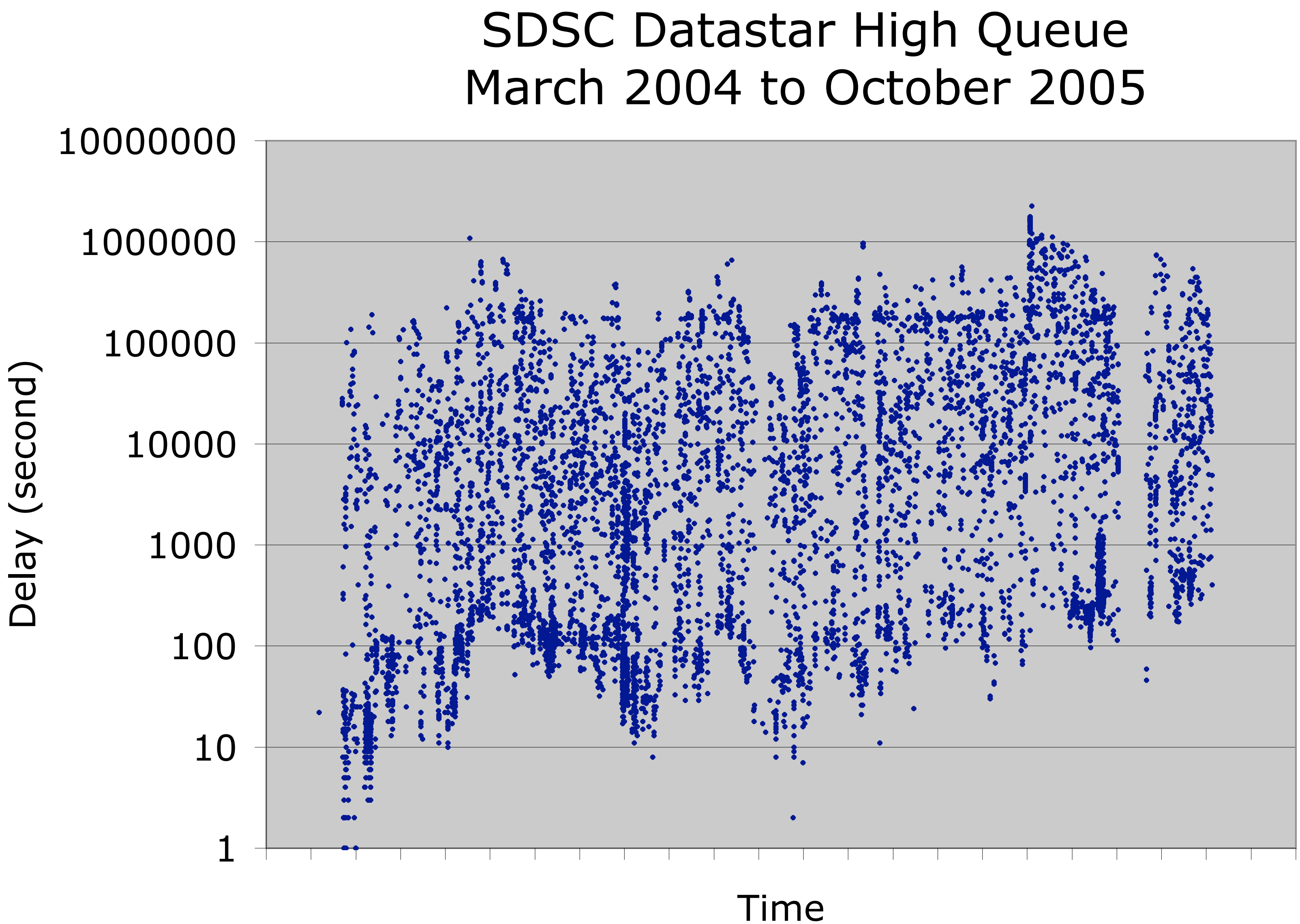
- Previous efforts focus on mean predictions
- Provide user with bound predictions, with quantifiable confidence, on queue wait time
  - Often real question is, “How long will my job wait at most?”
- Not an ‘expected wait time’ prediction
- Answer question, “At most, how long will my job wait 95% of the time?”

This Work

- Analyze Data
- Propose Prediction Methodology
- Perform Experiment
- Evaluate Results
- Future Work

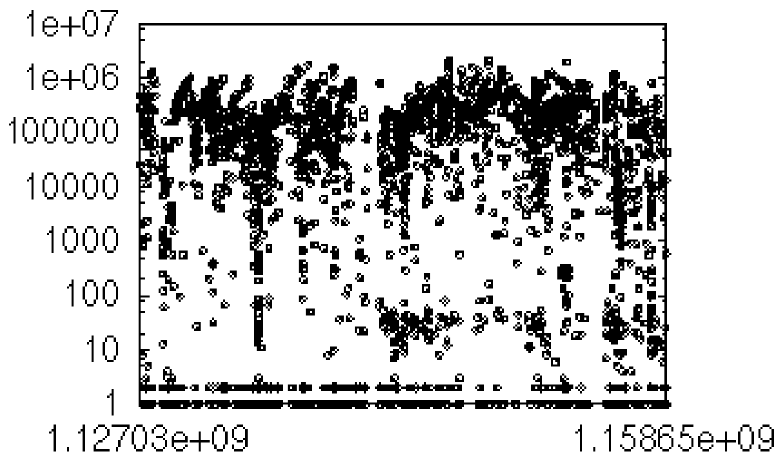
Batch Queue Data

- Collected job traces from 10 machines ranging 9 years of HPC (several million jobs)
  - Feitelson Parallel Workloads Archive
  - Current systems (TACC, Teragrid, etc)
- Real time monitoring system currently gathering job data from machines in operation

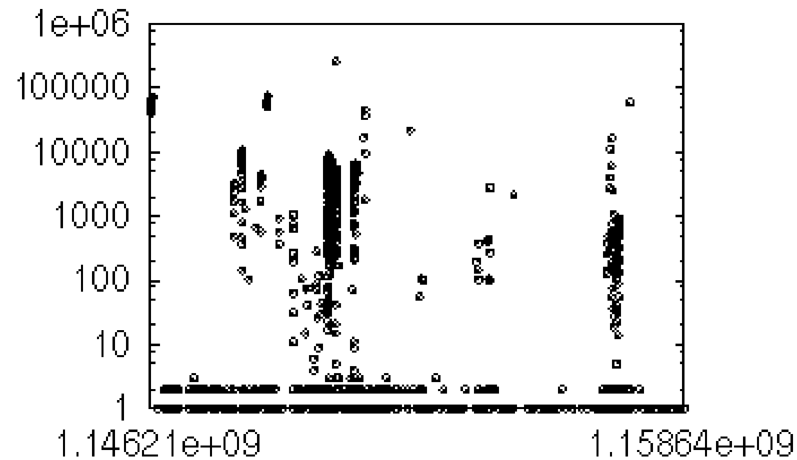

SDSC Datastar High Queue
March 2004 to October 2005
10000000
1000000
100000
10000
1000
100
10
1
Delay (second)
Time

More Data

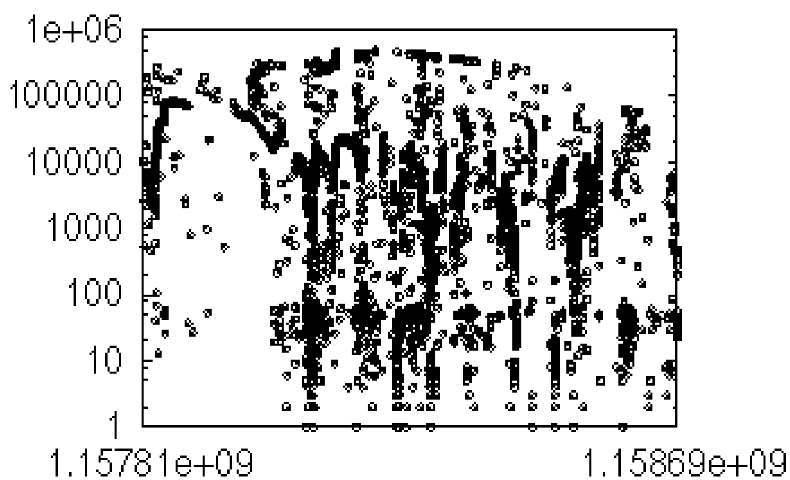
365 days cnsidell/ALL



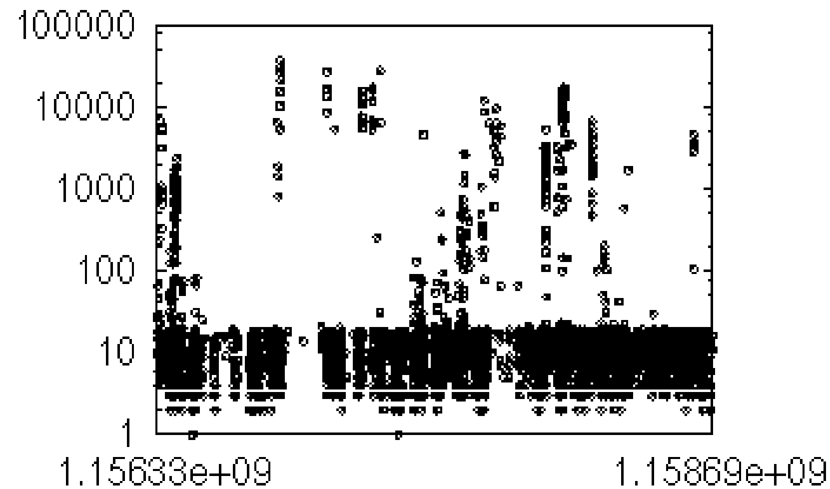
143 days dante/dque



10 days ncsateragrid/dque



27 days tsubame/default



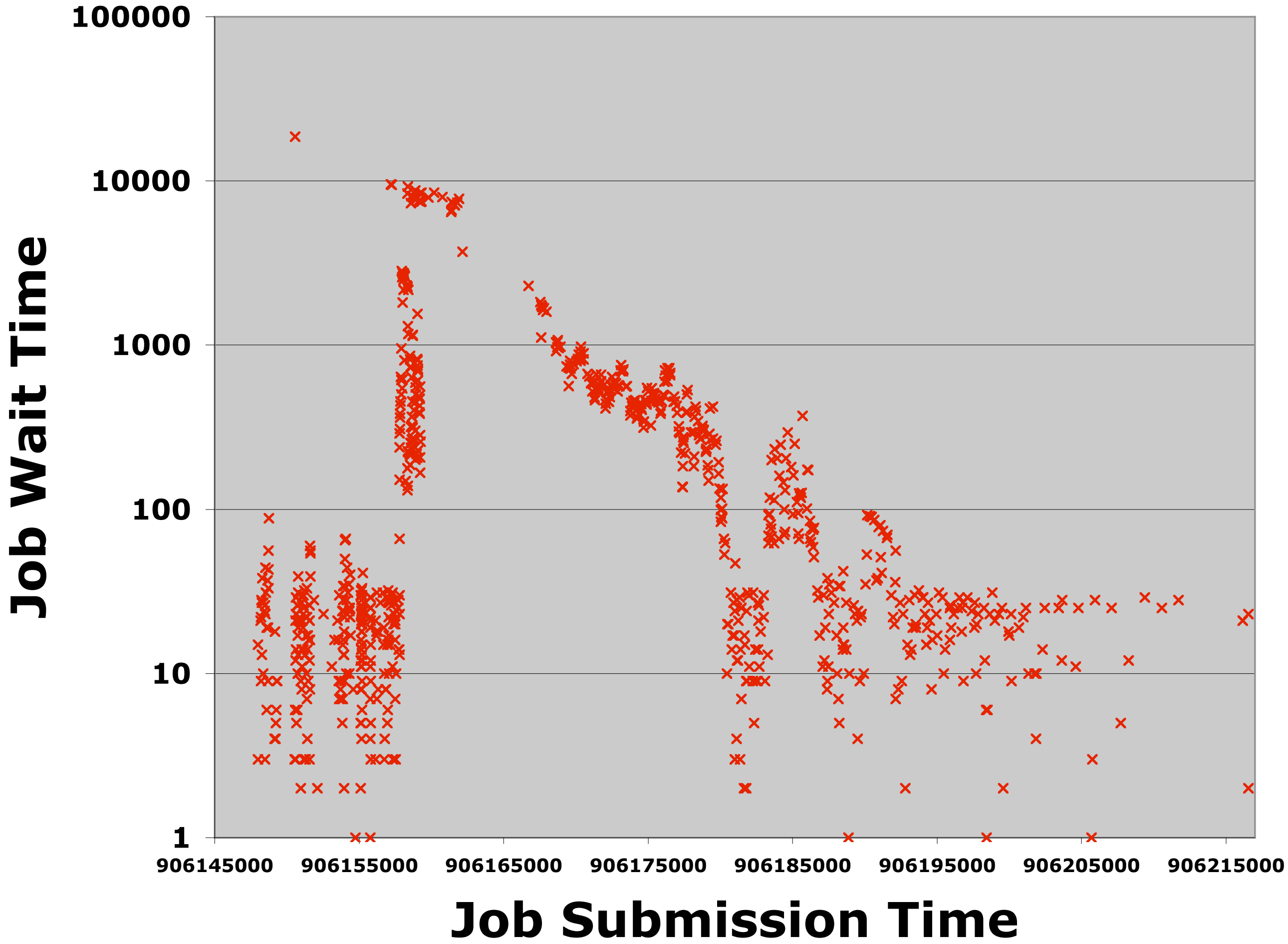
Prediction Methodology

- Questions of form, “At most, how long will the next job wait, Q percent of the time?”
  - Quantile prediction
  - Q_{th} Quantile - Value which Q percent of data points are less than or equal to
- Use our own non-parametric technique to make quantile predictions from historical values: Binomial Method (BM)

Prediction Methodology

- Simple application of BM results in inaccurate results
- Queuing delay fluctuates over time
  - Machine dynamism
  - Big events
- Jobs are not treated equally by scheduler
  - Job characteristics (nodes)
  - Backfilling

Changepoints



Day in the life - UofC Teragrid

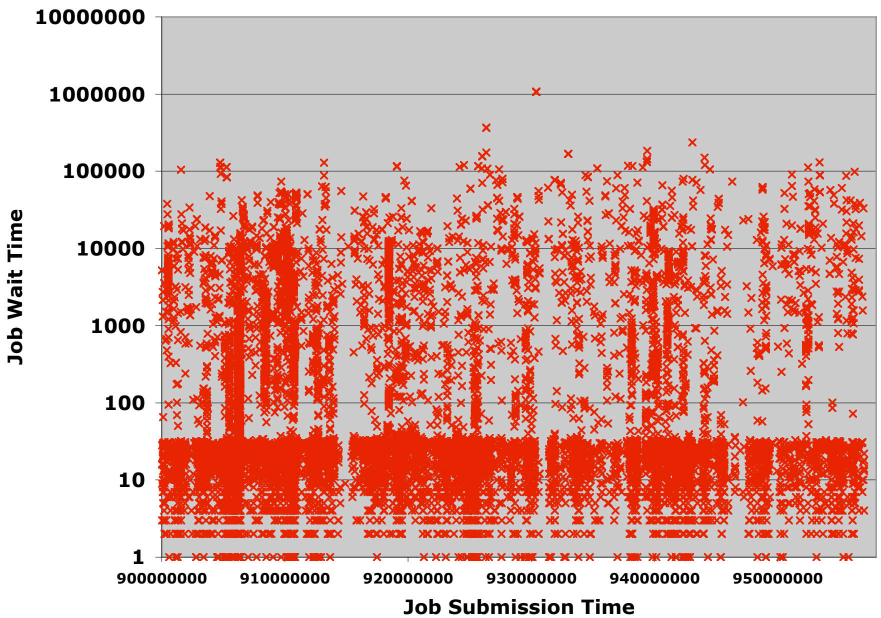
Changepoint Detection

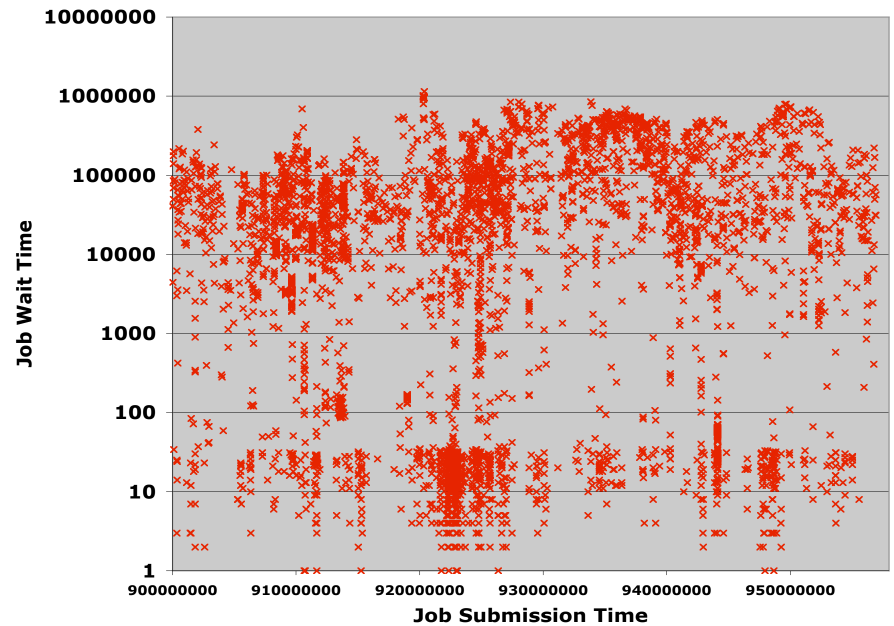
- Idea: Use only useful history for making predictions
- Assumption: Underlying distribution changes drastically and infrequently
- Rare event: Consecutive observations above .95 quantile
  - Find improbable number consecutive failures in synthetic data
  - Flag 'rare event' when we see same number of consecutive failures in real data
- If encounter rare event, trim history and continue

Grouping Jobs

- Have available more information than just submission time and queue wait time
  - Number of nodes requested
- Queried variety of system operators for ‘reasonable’ requested node ranges
- Settled on
  - 1 - 4
  - 5 - 16
  - 16 - 64
  - 65+

Grouping Jobs





Requested Nodes: 1 - 4

Requested Nodes: 17 - 64

Improved Predictor

- Use Binomial Method
  - Accurate non-parametric quantile predictor
- Introduce changepoint detector
  - Attempt to only use relevant history
- Introduce job clustering
  - Attempt to isolate like jobs
- Binomial Method Batch Predictor (BMBP)

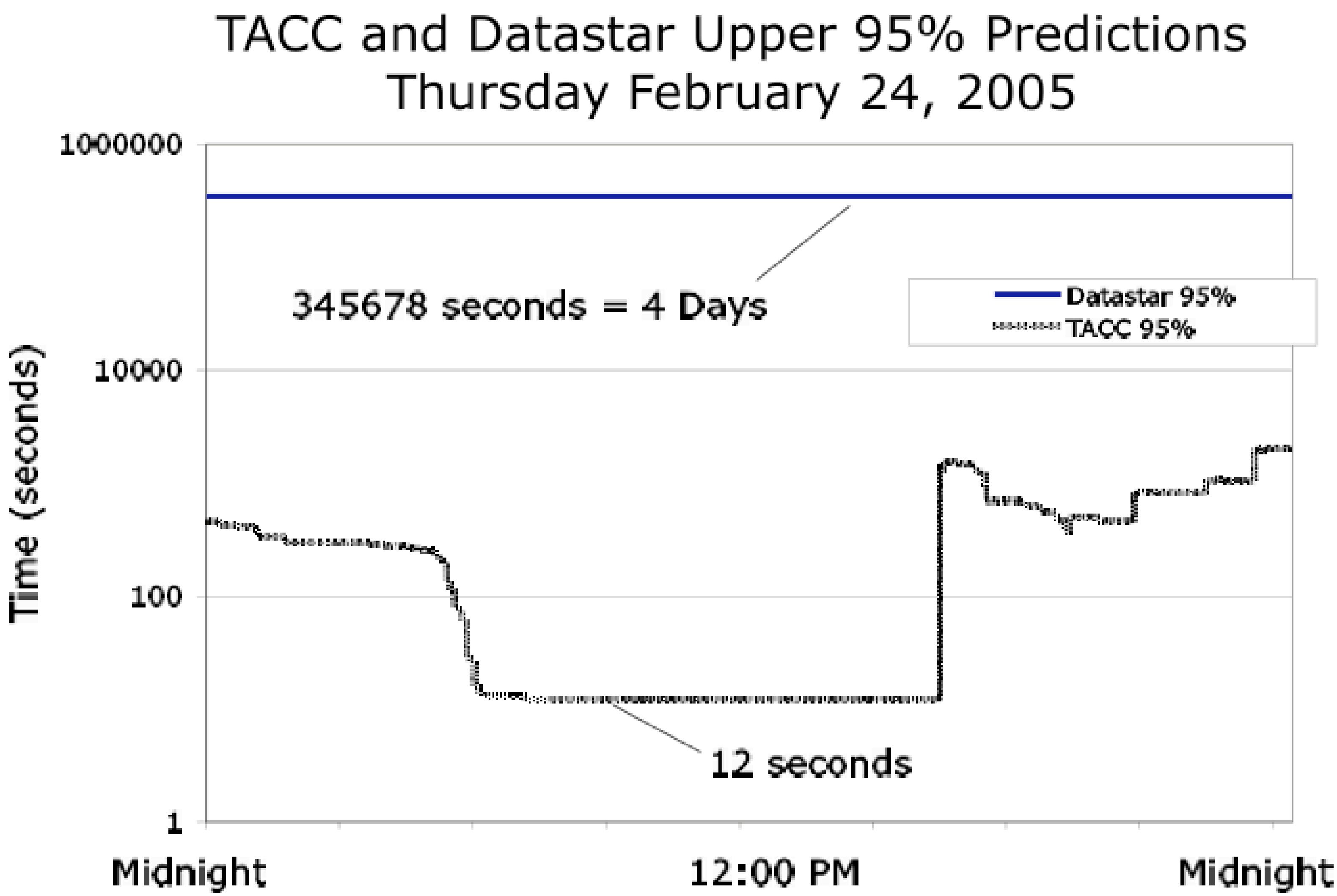
Experiment

- Choose quantile to predict: .95
  – Prediction of upper bound delay a job will experience 95% of the time
- Three methods
  – **BMBP**
  – Log-normal with history trimming
  – Log-normal without history trimming
- Examine both **correctness** and **accuracy** of each method
  – Correct: 95% or more predictions >= actual wait time
  – Accurate: median ratio of actual wait time over prediction

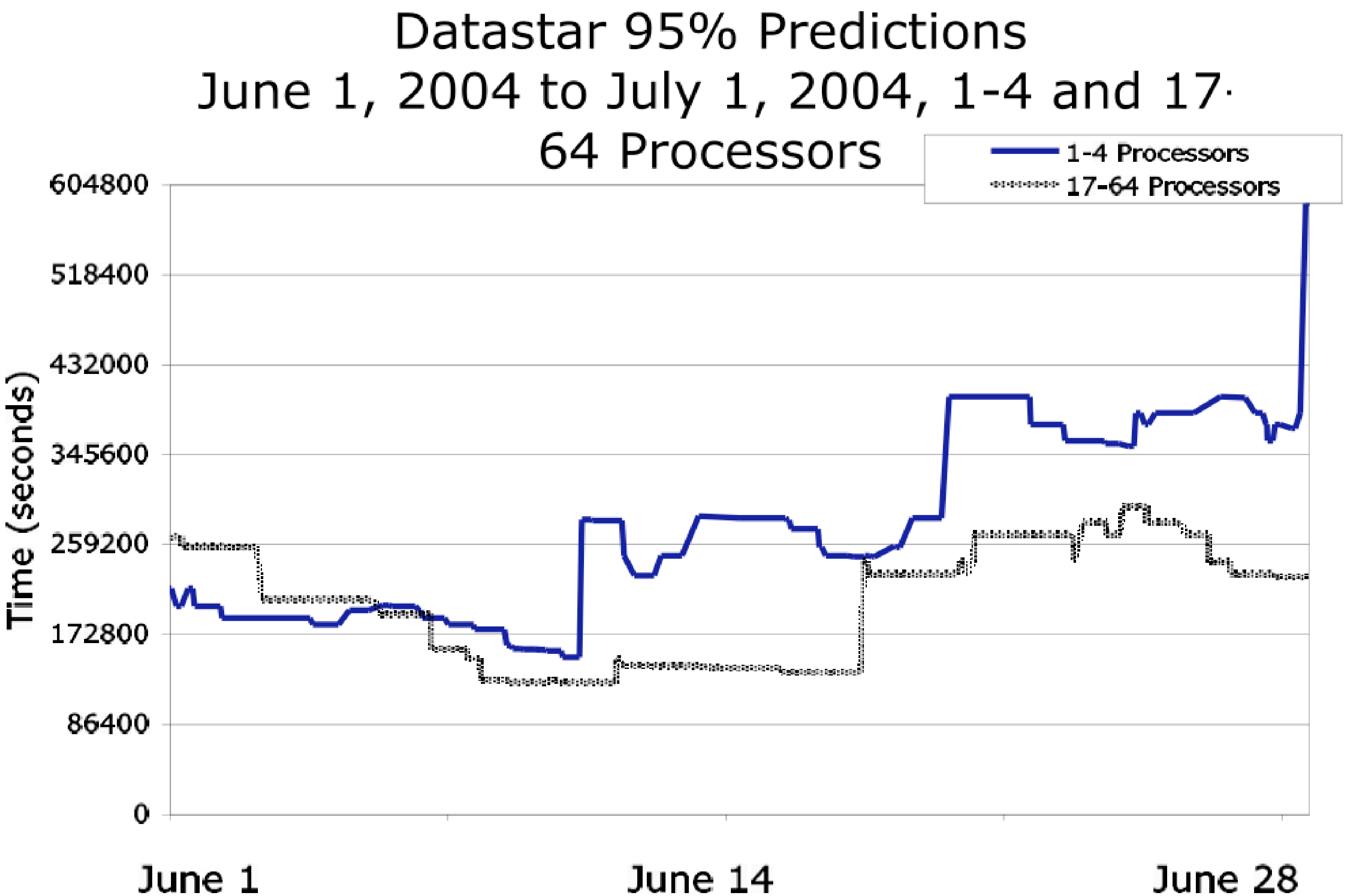
Results

- Correctness
  - 40/68 Log-normal no-trim
  - 59/68 Log-normal with-trim
  - **68/68** BMBP
- Correct and more accurate
  - 6/68 Log-normal no-trim
  - 15/68 Log-normal with-trim
  - **46/68** BMBP
- BMBP correct for all data sets, significantly more accurate than log-normal based methods

Interesting Observations



Interesting Observations



Current Status/Future Work

- Compare against other parametric quantile predictors
  - Weibull, hyper-exponential
- We have added automatic job grouping
  - Model based clustering
  - Improves accuracy
- Use batch queue wait time predictions for workflow task resource selection
  - SC'06 paper
- Online batch queue prediction tools
  - http://nws.cs.ucsb.edu/batchq

Thanks

- Next Generation Software (NGS) program
- VGrADS project
- San Diego Supercomputer Center
- http://nws.cs.ucsb.edu/batchq