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Bandwidth Modeling in Large Distributed Systems for Big Data Applications

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OUTLINE

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- Introduction
- Background
- Modeling Methodology
- Bandwidth Modeling
- Model Validation
- Conclusions

INTRODUCTION

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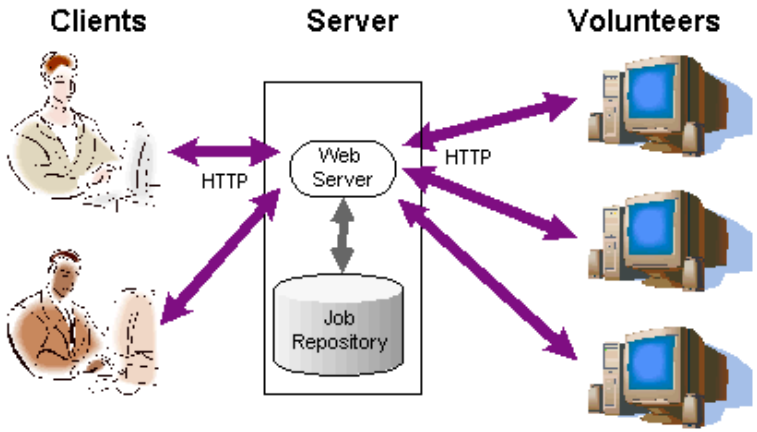
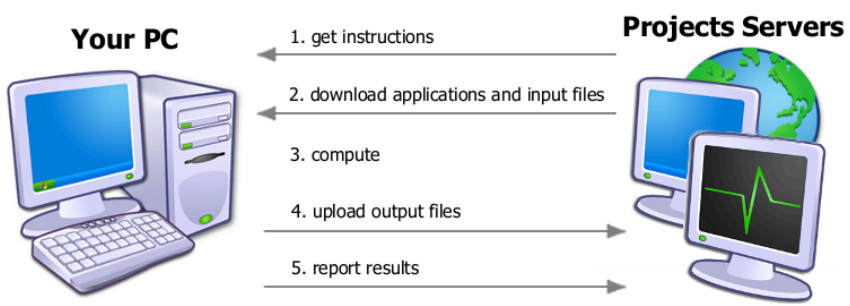
- Volunteer computing (VC)
  - large-scale distributed paradigm that harnesses the computing power and storage capacity of thousands or millions of hosts owned by the public for scientific applications.
  - Can fully support **Big Data** generation





INTRODUCTION

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- Analyzing of data communication and host bandwidth in VCs have not been address yet.

- Goal: a general methodology to model the network bandwidth (download and upload rates) of a volunteer computing project.

BACKGROUND

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- BOINC
  - Berkeley Open Infrastructure for Network Computing
  - Open-source system that harnesses the computing power and storage capacity of thousands or millions of hosts owned by the public for large-scale scientific projects
  - BOINC was originally developed to manage the SETI@home project.
  - It has been used for more than 70 scientific projects around the world.

BACKGROUND

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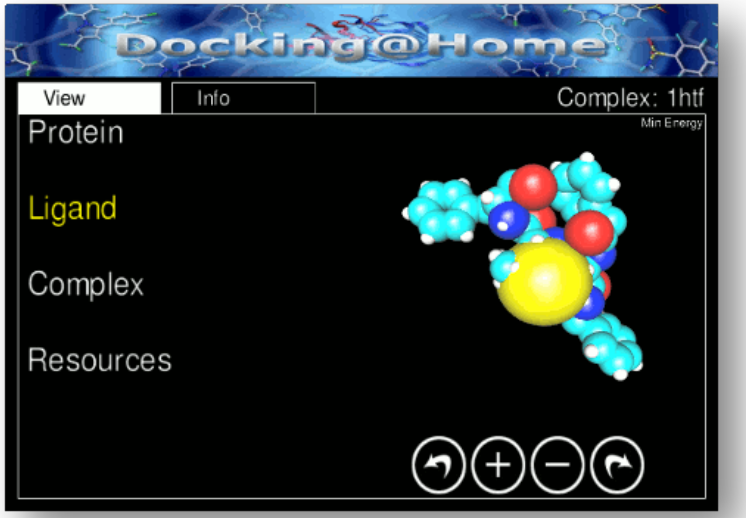
- Docking@home Project
  - Uses the BOINC Software
  - The Docking@Home project simulates the behavior of ligands when docking into the active site of a protein.
  - Job size: 1.2-1.9 MB
  - http://docking.cis.udel.edu/



Modeling Methodology

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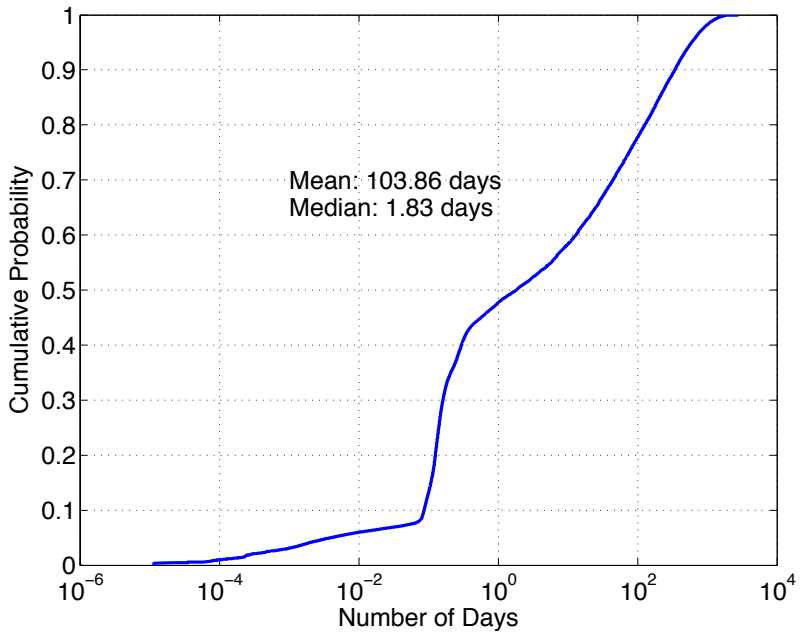
- Real trace from the Docking@home project
  - ~280,000 hosts
  - Period: September 11, 2006 to May 5, 2014
  - Available on FTA: http://fta.scem.uws.edu.au/
  - Host life time: 103 days on average



Server Analysis

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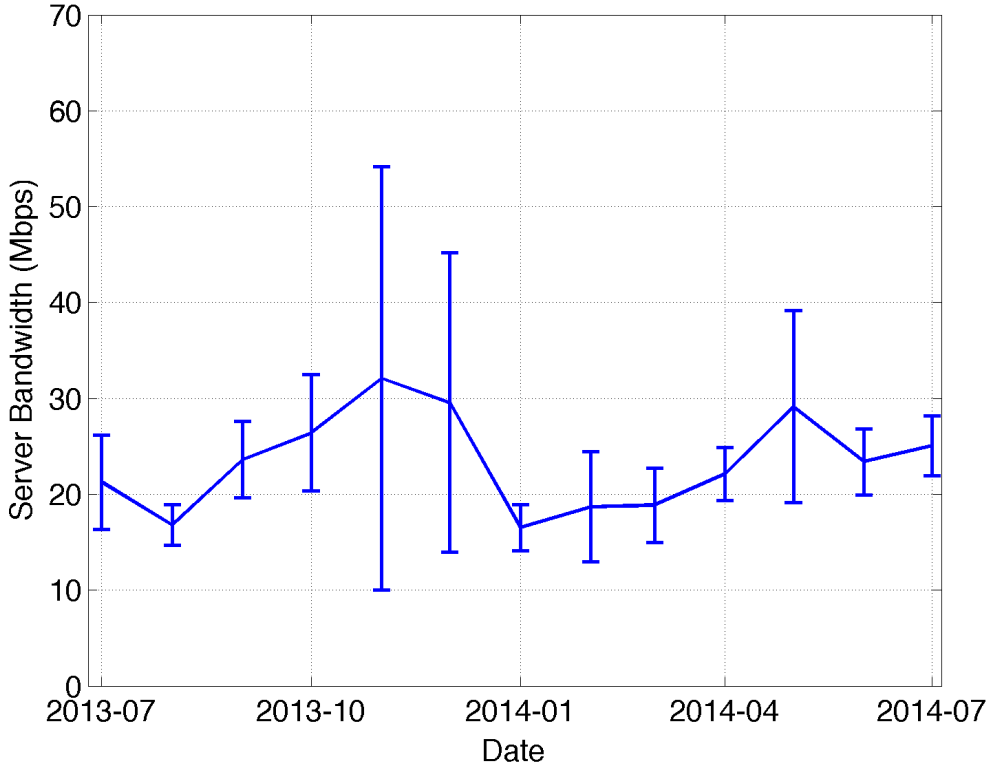
- Server Bandwidth could be a system bottleneck.
- Server Bandwidth: 1Gbps



Host Analysis

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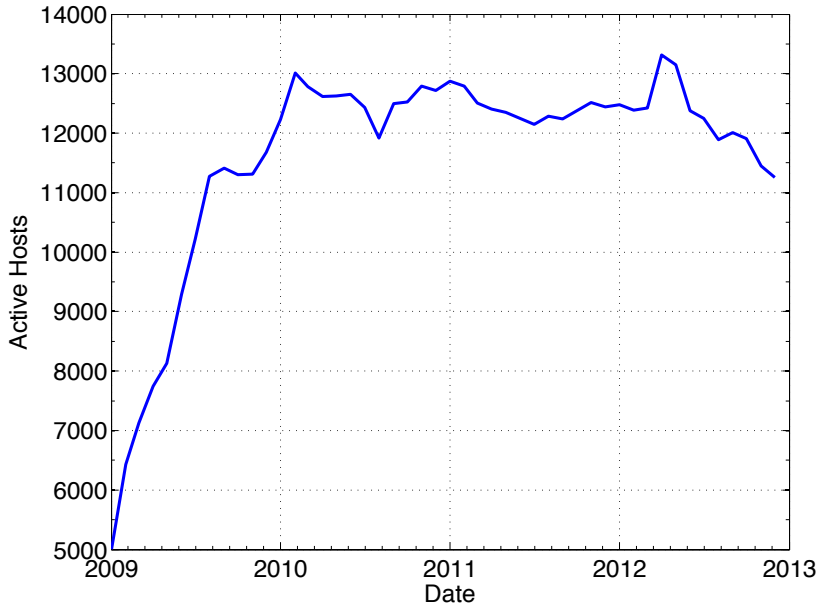
- Distribution of active hosts in Docking@Home from 2009 to 2012
  - An active host at time T is a host that had connected to the server before time T and whose last connection to the same server takes place after time T
  - ~10,000 hosts are active on average



Modeling: 2009-2012

Evaluation: 2013

BANDWIDTH ANALYSIS

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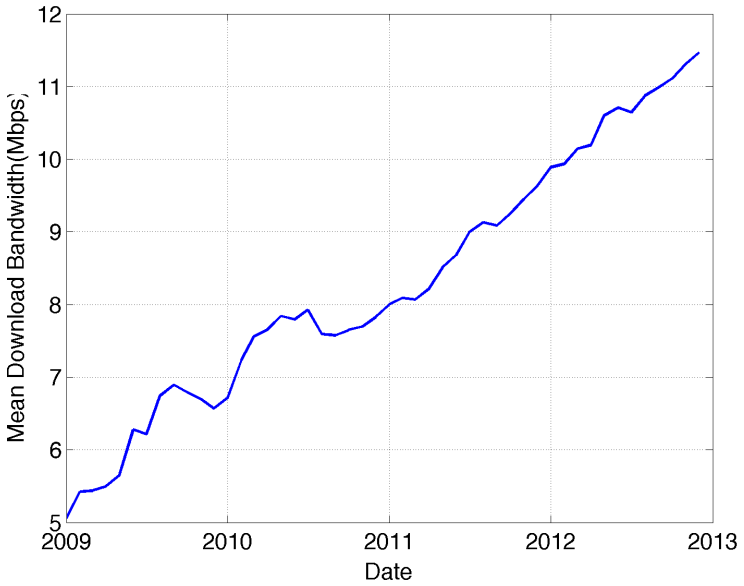
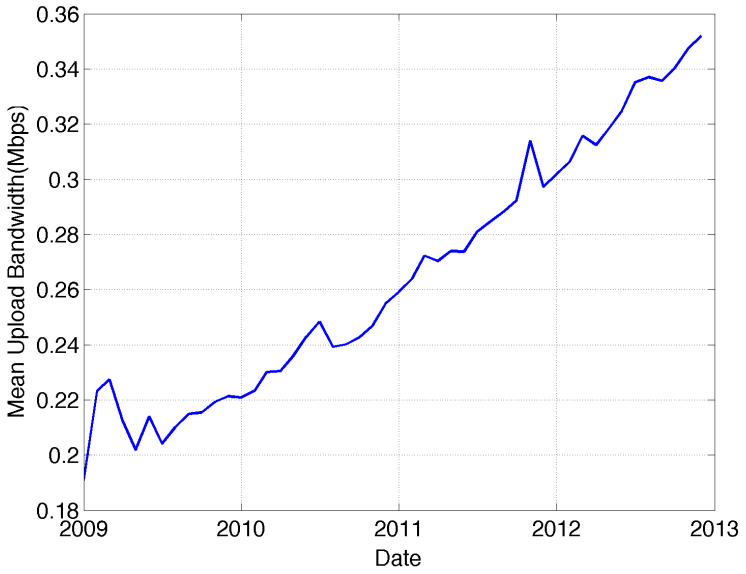
- Average download and upload bandwidth for active hosts in Docking@Home
  - The mean download bandwidth is about 30 times more than the mean upload bandwidth for each year.





BANDWIDTH MODELING

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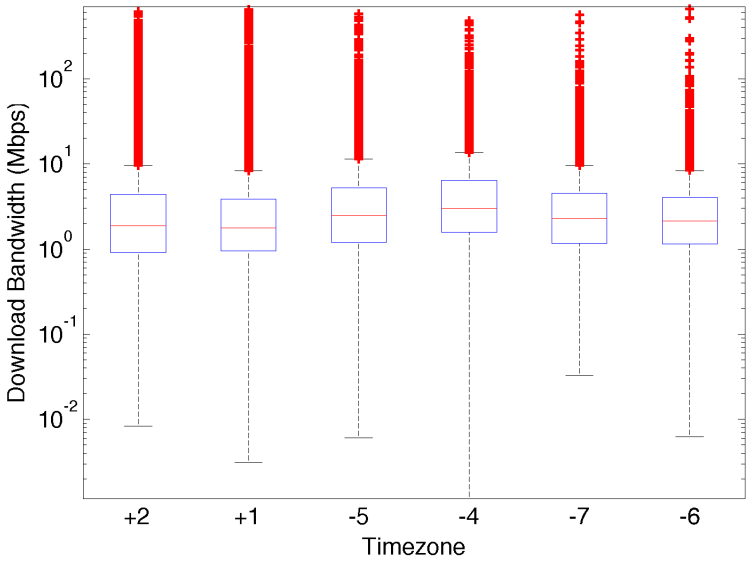
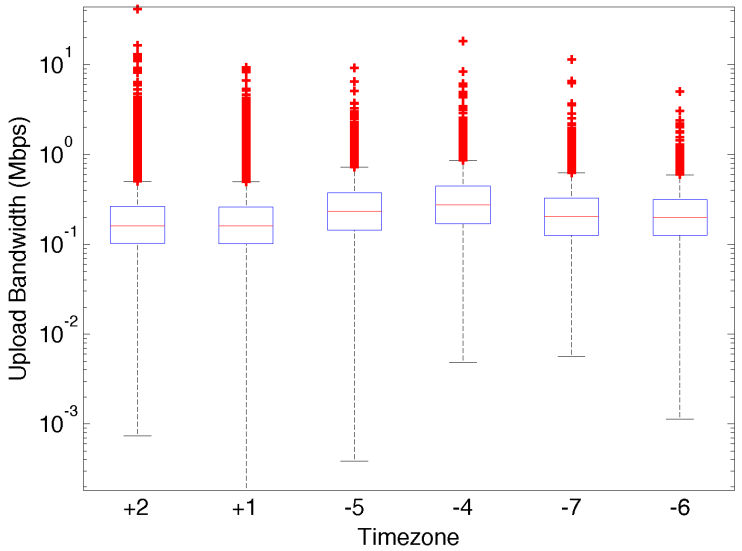
- Host Bandwidth Correlations
  - Test for host time zone





BANDWIDTH MODELING (CONT.)

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- Host Bandwidth Correlations
  - Test for host time zone
  - Test for upload and download
    - NO Obvious Correlation

- The absence of obvious correlations in the host bandwidth drives our modeling approach towards the design of an **independent** statistical model that predicts the download and upload rate for a given host and at a specific time.

BANDWIDTH MODELING (CONT.)

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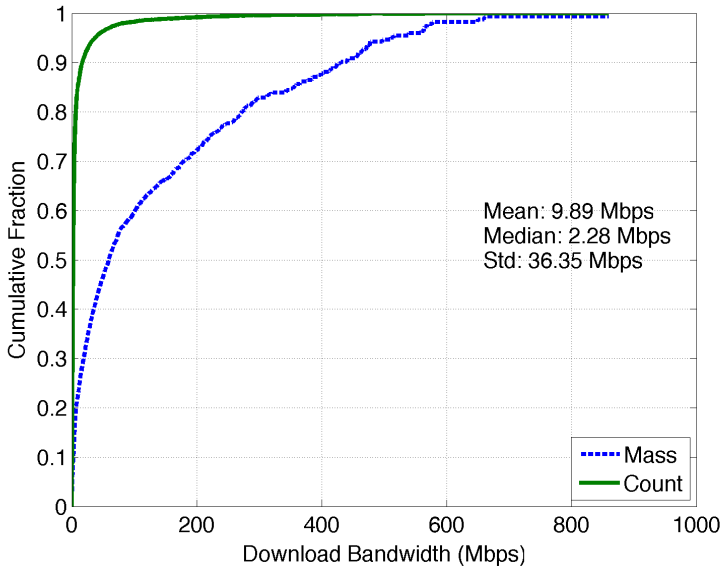
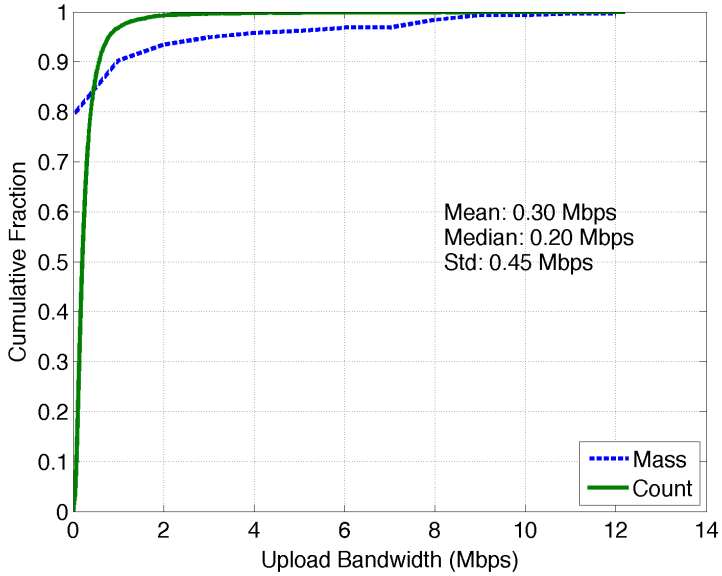
- Mass-Count Plot
  - For 2012





BANDWIDTH MODELING (CONT.)

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- Statistical Modeling
  - Model nomination: Weibull, Log-normal, Gamma and Exponential
  - Goodness of fit tests results (p-values): **Log-normal** is the best fit.

Model	Download	Upload
Exponential	0.026 0.003	0.403 0.255
Gamma	0.179 0.077	0.492 0.378
Log-normal	**0.548 0.391**	**0.608 0.477**
Weibull	0.323 0.188	0.442 0.311

BANDWIDTH MODELING (CONT.)

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- Embedding time into the model
  - Best Fit: Log-normal

$$\frac{1}{x\sigma\sqrt{2\pi}}\, e^{-\frac{(\ln x-\mu)^2}{2\sigma^2}}$$

  - Modeling Mean (μ) and Variance(σ^2) for the Log-normal distribution
  - Best model is following exponential function:
    - a,b: function metric
    - t: date (*t=date-Rdate*)
    - *date*: given date
    - *Rdate*: reference date (January 2009 for our traces)

$$f(t) = ae^{bt}$$

BANDWIDTH MODELING (CONT.)

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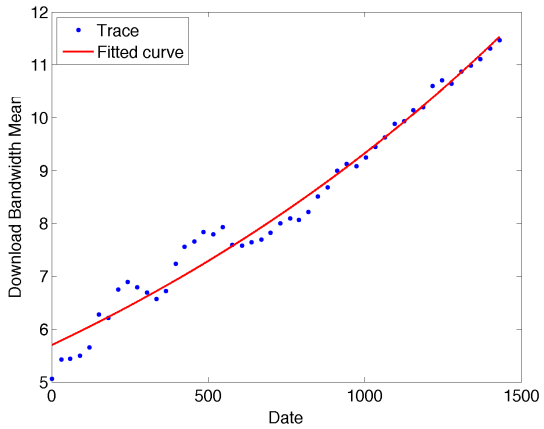
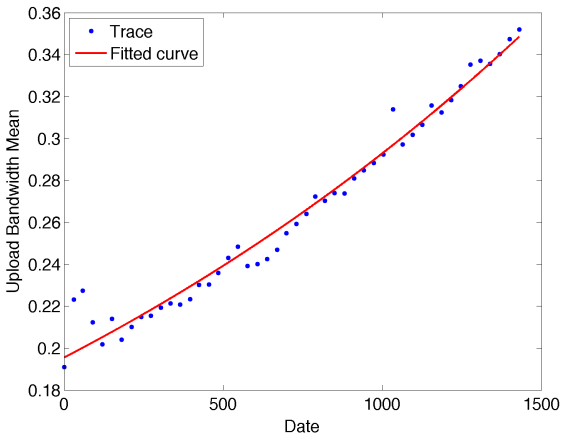
- Fitting Results for Mean Download bandwidth



- Fitting Results for Mean Upload bandwidth



BANDWIDTH MODELING (CONT.)

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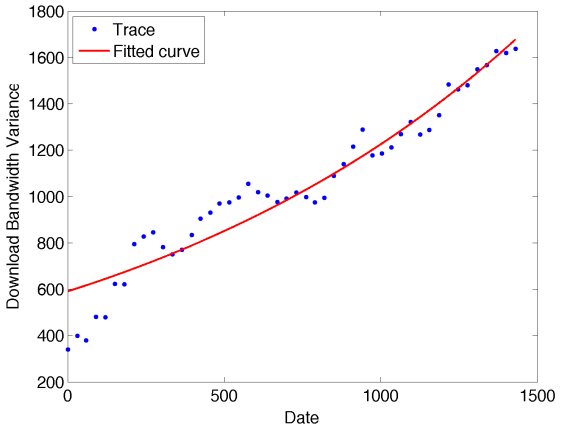
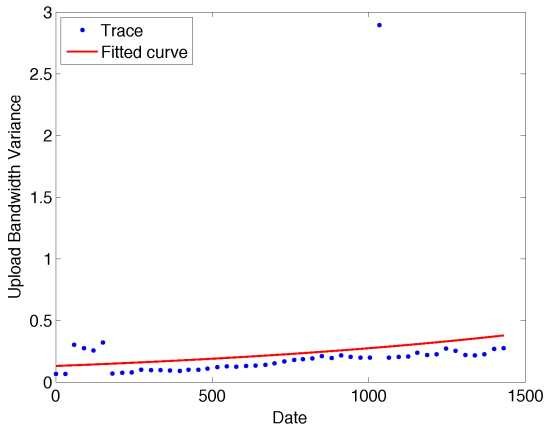
- Fitting Results for Variance Download bandwidth

Model	a	b	R^2
Mean download	5.698	$0.493e^{-3}$	0.9748
Variance download	590.7	$0.729e^{-3}$	0.9227
Mean upload	0.1955	$0.404e^{-3}$	0.9735
Variance upload	0.129	$0.745e^{-3}$	0.0376



- Fitting Results for Variance Upload bandwidth



Model Validation

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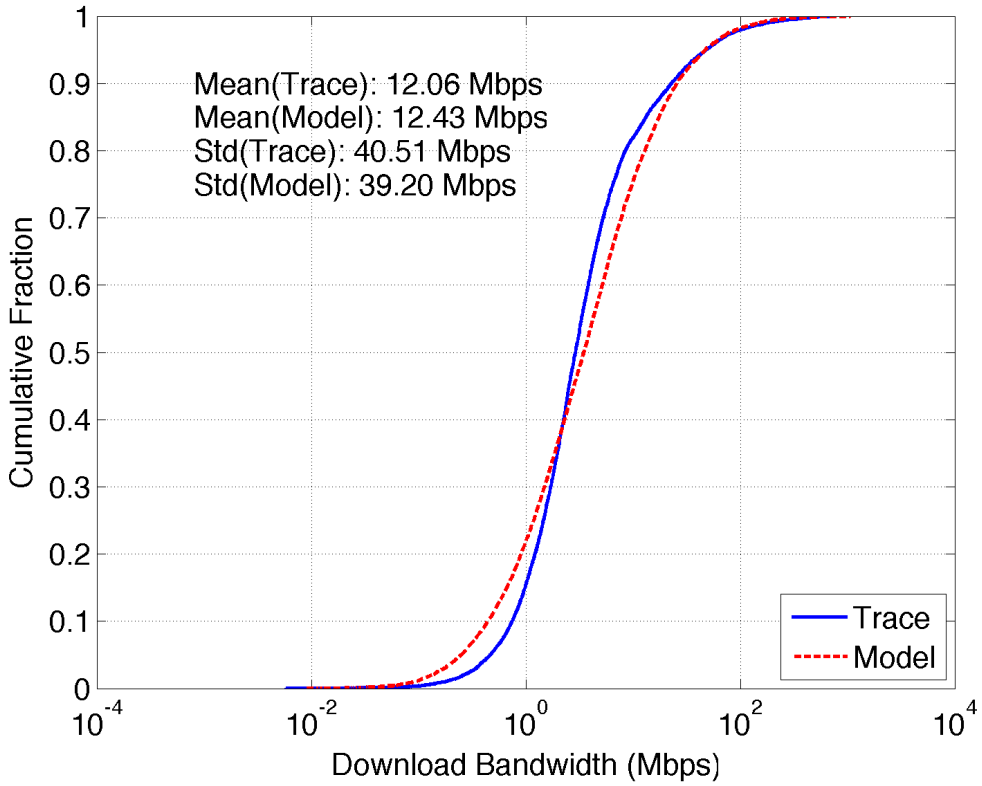
- Model-based validation
  - Download bandwidth for May 2013
  - 3% relative error



Model Validation (Cont.)

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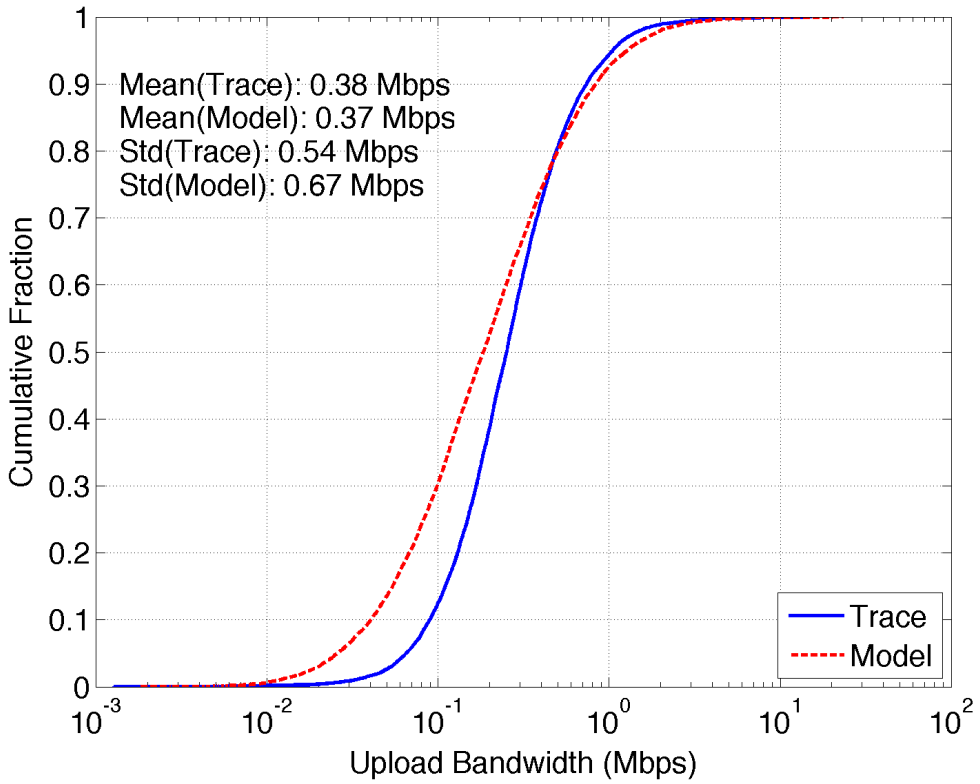
- Model-based validation
  - Upload bandwidth for May 2013
  - 15% relative error



Model Validation (Cont.)

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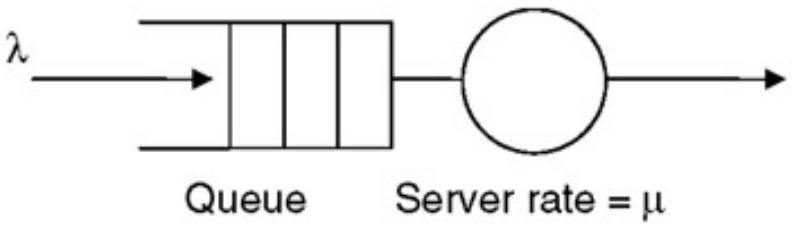
- Simulation-based validation
  - Simulating a queue with the variable service time
  - Using **model** and **trace** to generate the service time
    - M/Model/1
    - M/Trace/1



Input Parameters for the Simulation.

Parameter	Distribution
Download size	Uniform (12MB,18MB)
Upload size	Uniform (0.5MB,1.2MB)
Job runtime	Normal ($\mu = 1.2hrs$, $\sigma = 0.9hrs$)

Model Validation (Cont.)

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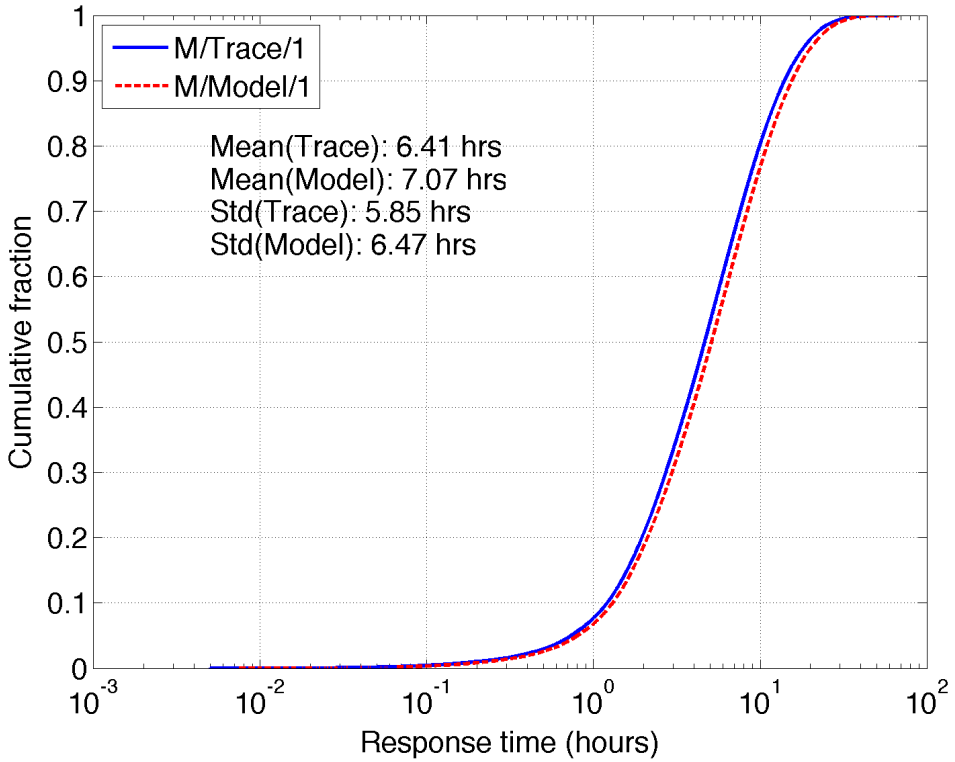
- Simulation-based validation
  - Queue response time (metric)
  - High accuracy of the model



CONCLUSIONS

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- A new methodology to analyze and model the host bandwidths of volunteer computing projects
  - 5-year trace with 280,000 hosts
- Proposing a bandwidth model using the Log-normal distribution in combination of an exponential model to predict the mean and variance.
- Future Work
  - the study of scenarios in which our model is used for the prediction of in-situ and in-transit analysis of data generated in Docking@Home and other volunteer computing projects.

FAILURE TRACE ARCHIVE (FTA)

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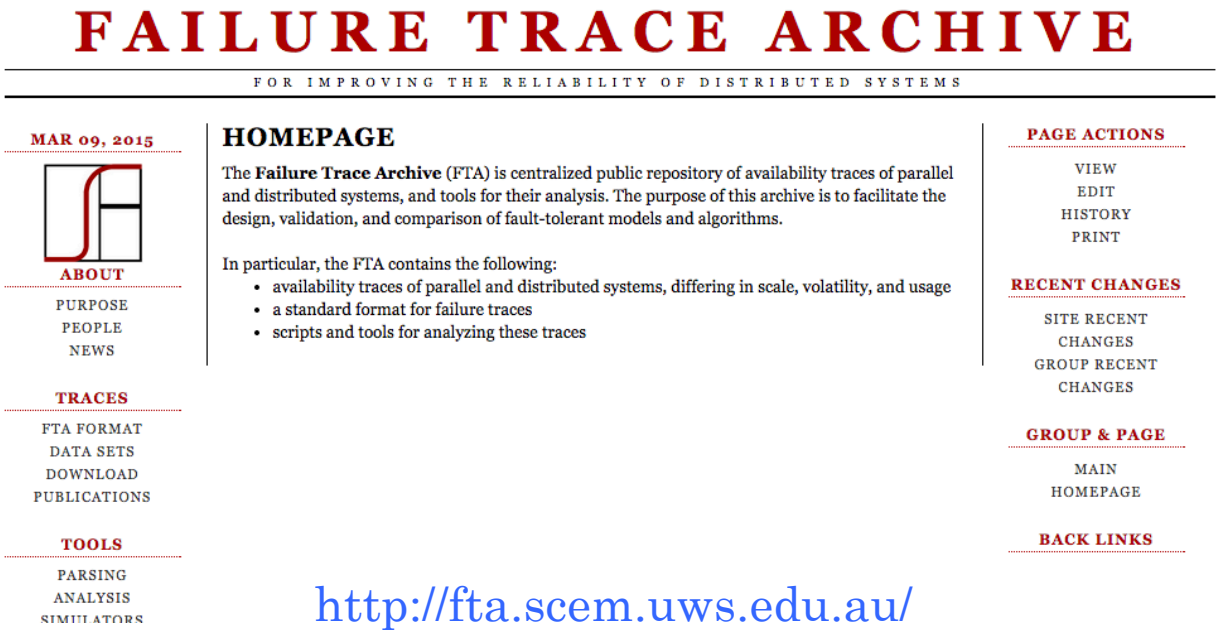
- 27 Failure Traces
  - Supercomputers, HPC, Grid, P2P
- FTA Format
- Simulator and Scripts



http://fta.scem.uws.edu.au/

Thank You

Open Position @ WSU

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- Assistant/Associate Professor
  - Level B,C,D
- School of Computing, Engineering and Mathematics
- Machine learning, cyber security, digital forensics, cloud and utility computing, internet of things, and mobile and service-oriented computing.
- Deadline: 15 Nov. 2015