# Bringing BIG Systems to small Schools

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### **Course Overview**

- Goals
  - Introduce students to key design principles
  - Teach students skills necessary to build and evaluate distributed systems
  - Expose students to cutting-edge real-world technologies
  - Improve technical writing skills
- Components
  - Programming projects (x4)
  - Midterm and final exam
  - Research paper evaluations (x8-10)

### Student Profile

- Prerequisites
  - Data Structures
  - Computer Organization
- Non-prerequisites
  - Networks
  - Operating Systems
- First "project" course for many students
- Sample class breakdown
  - S08: 14 students: 2 sophomores, 4 juniors, 8 seniors
  - SI2: 15 students: 1 sophomore, 6 juniors, 9 seniors

### **Project Overview**

- Projects are 45% of overall grade
- Students work alone or with a partner
- Projects designed to emphasize techniques and technology from lecture topics and reading assignments
- Projects include a technical writing component
- Explored four different architectural models: client-server, multi-tier client-server, cluster computing, wide-area computing

# Project I: Web Server

- Assignment: Build a web server (in C)
  - Support GET requests in HTTPI.0 and HTTPI.1
  - Return valid response codes
- Goals
  - Explore simple client-server distributed computing paradigm
  - Gain experience with network/socket programming
  - Compare and contrast performance of HTTPI.0 and HTTPI.1 under varying conditions
- Student performance
  - All finished within 2.5 weeks; all projects worked
  - Quality of code varied significantly (some students had little prior experience with C)
  - Some write-ups were poorly written

### Project 2: Online Bookstore

- Assignment: Build a multi-tier online bookstore
  - Use Java and Python
  - Use Java RMI XML-RPC
  - Ensure proper synchronization
- Goals
  - Explore multi-tier distributed computing paradigm
  - Gain experience with RPCs and network programming in Java
  - Evaluate performance under varying levels of load
- Student performance
  - All easily finished within 2 weeks
  - Quality of code was good overall
  - Write-ups were slightly better



# Project 3 vI: Inverted Index

- Assignment: Build an inverted index using Hadoop
  - (Hadoop is open-source implementation of Google's MapReduce framework for large-scale data processing)
  - Return valid mapping of words to documents using eBooks from Project Gutenberg as input
- Setup
  - Created 60+ Xen virtual machines to host Hadoop miniclusters using 14 cluster machines
  - Students maintained/configured their own cluster
- Goals
  - Explore "cutting-edge" cluster computing paradigm
  - Gain experience with basic system administration
- Student performance
  - All finished within 3 weeks
  - Good write-ups



# Project 3 v1.5: Inverted Index

- Assignment: Build an inverted index using Hadoop
  - (Hadoop is open-source implementation of Google's MapReduce framework for large-scale data processing)
  - Return valid mapping of words to documents using eBooks from Project Gutenberg as input
- Setup
  - Awarded Amazon teaching grant
  - Created clusters on Amazon EC2 platform
  - Students maintained/configured their own cluster
- Goals
  - Explore "cutting-edge" cluster computing paradigm
  - Gain experience with basic system administration
- Student performance
  - All finished within 3 weeks
  - Good write-ups



# Project 3 v2: Contextual Advertising

- Assignment: Given an advertising context, predict which advertisement is most likely to be clicked
  - Designed by another student (my TA) during WI2
  - Compute click-through rate for ad id and page URL
- Setup
  - Awarded Amazon teaching grant
  - Created small clusters on Amazon EC2 platform
  - Dataset also comes from Amazon
  - Students maintained/configured their own cluster
- Goals
  - Explore "cutting-edge" cluster computing paradigm
  - Gain experience with basic system administration
- Student performance
  - All finished within 3 weeks
  - Good write-ups



# Project 4 vI: P2P Computing

- Assignment: Build a P2P system (file sharing, game, distributed hash table, etc.)
  - Run system on PlanetLab
  - Be creative with design and implementation of system
- Setup
  - Created each group their own PlanetLab slice
  - Showed students how to use Plush for app management
- Goals
  - Explore P2P wide-area distributed computing paradigm
  - Allow students freedom to innovate
- Student performance
  - All finished and presented work within 3.5 weeks
  - Number of machines used ranged from 12 to 400+
  - Excellent write-ups

PLANETLAB

# Project 4 v2: Final Project

- Assignment: Open-ended final project
- "Default" project: Build a P2P file-sharing system
  - Run system on PlanetLab
  - Setup
    - Created each group their own PlanetLab slice
    - Many students used Plush/Gush for app management
  - Goals
    - Explore P2P wide-area distributed computing paradigm
    - Allow students freedom to innovate
- Student performance
  - All finished and presented work within 4 weeks
  - Excellent write-ups



### Plush/Gush User Interfaces

- Command-line interface used to interact with applications
- Nebula (GUI) allows users to describe, run, & visualize applications
- XML-RPC interface for managing applications programmatically

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<pre>NWWT-Xr-X 1 ucsd_plush slices 4764 May 6 20:41 bootstrap.pl TWWT-r-r-1 ucsd_plush slices 291 May 6 20:42 plush-logfile15415-1178484137.txt TWW-T-r-r-1 ucsd_plush slices 293 May 6 20:55 plush-logfile15415-11784840306.txt TWW-T-r-r-1 ucsd_plush slices 27634 May 6 20:55 plush-logfile15415-11784840306.txt TWW-T-r-r-1 ucsd_plush slices 280 May 7 05:06 plush-logfile15417-1178514401.txt TWW-T-r-r-1 ucsd_plush slices 280 May 7 05:06 plush-logfile15417-1178514401.txt TWW-T-r-r-1 ucsd_plush slices 280 May 7 05:06 plush-logfile15417-1178514401.txt TWW-T-r-r-1 ucsd_plush slices 32149 May 8 22:44 plush-logfile15175178664027.txt TWW-T-r-r-1 ucsd_plush slices 320 May 8 22:46 plush-logfile1515-1178664027.txt TWW-T-r-r-1 ucsd_plush slices 313 May 8 22:47 plush-logfile1515-1178664362.txt TWW-TWYTWX 1 ucsd_plush slices 313 May 8 22:47 plush-logfile15415-117866432.txt TWWTWYTWX 1 ucsd_plush slices 313 May 8 22:47 plush-logfile15415-1178664430.txt TWWTWYTWX 1 ucsd_plush slices 313 May 8 22:47 plush-logfile15415-1178664430.txt TWWTWYTWX 1 ucsd_plush slices 313 May 8 22:47 plush-logfile15415-1178664430.txt TWWTWYTWX 1 ucsd_plush slices 313 May 8 22:47 plush-logfile5415-1178664430.txt TWWTWYTWX 1 ucsd_plush slices 313 May 8 22:48 logfile-planet1ab1-15415-1178664430.txt TWWTWYTWX 1 ucsd_plush May 8 200 May 8 May 7 70 000 May 8 0</pre>		
<pre>NW+Tr 1 ucsd_plush slites 291 May 6 20:42 plush-logfile15415-1178484137.txt NW+Tr 1 ucsd_plush slites 39787 May 6 20:53 plush-logfile15415-1178484096.txt NW+Tr 1 ucsd_plush slites 37634 May 6 20:55 plush-logfile15415-1178484096.txt NW+Tr 1 ucsd_plush slites 280 May 7 05:06 plush-logfile15415-1178484096.txt NW+Tr 1 ucsd_plush slites 38763 May 6 20:55 plush-logfile15415-1178484096.txt NW+Tr 1 ucsd_plush slites 380 Y 7 05:06 plush-logfile15415-117864400.txt NW+Tr 1 ucsd_plush slites 311 May 8 22:40 plush-logfile15415-1178664027.txt NW+Tr 1 ucsd_plush slites 311 May 8 22:44 logfile-planetlab1-15415-1178664302.txt NW+Tr 1 ucsd_plush slites 3273 May 8 22:44 logfile-planetlab1-15415-1178664302.txt NW+TW+Tr 1 ucsd_plush slites 32923 May 8 22:44 logfile-planetlab1-15415-117866430.txt NW+TW+TW+T ucsd_plush slites 38 May 8 22:47 plush-logfile15415-1178664430.txt NW+TW+TW+T ucsd_plush slites 38 May 8 22:47 plush-logfile15415-1178664430.txt NW+TW+TW+T ucsd_plush slites 38 May 8 22:47 plush-logfile15415-1178664430.txt NW+TW+TW+T ucsd_plush slites 188123 May 8 22:47 plush-logfile15415-1178664430.txt NW+TW+TW+T ucsd_plush slites 188123 May 8 22:47 plush-logfile15415-1178664430.txt NW+TW+TW+T ucsd_plush slites 188123 May 8 22:47 plush-logfile15415-1178664430.txt NW+TW+TW+T+-r 1 ucsd_plush slites 188123 May 8 22:48 logfile-planetlab1-15415-1178664430.txt NU=dusd_plush slites 168123 May 8 22:47 plush-logfile15415-1178664430.txt NU=dusd_plush slites 168123 May 8 22:48 logfile-planetlab1-15415-1178664430.txt NU=dus</pre>	maxi-xr-x 1 ucsd_plush slices 4764 May 6 20:41 hortstran.pl	
<pre>rw-r</pre>	rw-rr 1 ucsd plush slices 291 May 6 20:42 plush-loofile15415-1178484137.txt	
<pre>rw-rr- 1 ucsd_plush slices 293 May 6 20:55 plush-logfile15415-1178484906.txt rw-rr 1 ucsd_plush slices 37634 May 6 20:57 logfile_planetlab1-15415-1178484906.txt rw-rr 1 ucsd_plush slices 280 May 7 05:08 logfile_planetlab1-15415-117814401.txt rw-rr 1 ucsd_plush slices 311 May 8 22:40 plush-logfile15415-1178664027.txt rw-rr 1 ucsd_plush slices 311 May 8 22:44 logfile_planetlab1-15415-1178664027.txt rw-rr 1 ucsd_plush slices 3223 May 8 22:46 plush-logfile15415-1178664362.txt rw-rw-rr 1 ucsd_plush slices 3223 May 8 22:47 plush-logfile15415-1178664362.txt rw-rw-rr- 1 ucsd_plush slices 313 May 8 22:47 plush-logfile15415-1178664362.txt rw-rw-rr- 1 ucsd_plush slices 313 May 8 22:47 plush-logfile5415-1178664430.txt rw-rw-rw-rw 1 ucsd_plush slices 313 May 8 22:47 plush-logfile5415-1178664430.txt rw-rw-rr- 1 ucsd_plush slices 313 May 8 22:47 plush-logfile5415-1178664430.txt rw-rw-rr- 1 ucsd_plush slices 313 May 8 22:48 logfile-planetlab1-15415-1178664430.txt rw-rw-rr- 1 ucsd_plush slices 313 May 8 22:48 logfile-planetlab1-15415-1178664430.txt rw-rw-rr- 1 ucsd_plush slices 313 May 8 22:48 logfile-planetlab1-15415-1178664430.txt rw-rw-rw-r 1 ucsd_plush slices 313 May 8 22:48 logfile-planetlab1-15415-1178664430.txt ucsd_plusheplanetlab1-3[\$ traceroute www.google.com raceroute warning: www.google.com has multiple addresses; using 72.14.205.99 raceroute warning: www.google.com //2.14.205.99), 30 hops max, 38 byte packets 1 152.3.138.61 (152.3.218.61) 0.330 ms 0.327 ms 0.329 ms 2 152.3.219.69 (152.3.219.69) 0.338 ms 0.300 ms 0.230 ms 3 tellsp-roti.netcom.duke.edu (152.3.219.54) 0.281 ms 0.333 ms 7.663 ms 8.402 ms 5 tel-2.tr01-sttrWa01.transitrail.net (137.164.131.173) 7.6131 ms 94.602 ms 5 tel-2.tr01-sttrWa01.transitrail.net (137.164.131.254) 99.644 ms 97.167 ms 93.723 ms 8 *** 9 209.85.130.4 (209.85.130.4) 95.293 ms 97.987 ms 94.702 ms 0 64.233.174.81 (64.233.174.81) 86.525 ms 86.340 ms 86.495 ms WPLS tabel=684000 (c5=0 TTL=1 S=1 1 72.14.232.113 (72.14.232.62) (72.14.232.62) 99.173</pre>	rw-rr 1 ucsd blush slices 39787 May 6 20:43 loofile-blanetlab1-15415-1178484137.txt	
<pre>rwr 1 ucsd_plush slices 37634 May 6 20:57 logfile-planetlabl-15415-117844906.txt rw-rr 1 ucsd_plush slices 18694 May 7 05:06 plush-logfile15417-1178514401.txt rw-rr 1 ucsd_plush slices 311 May 8 22:40 plush-logfile15415-1178664027.txt rw-rr 1 ucsd_plush slices 313 May 8 22:46 logfile-planetlabl-15415-1178664027.txt rw-rr 1 ucsd_plush slices 313 May 8 22:46 plush-logfile15415-1178664027.txt rw-rr 1 ucsd_plush slices 313 May 8 22:46 plush-logfile15415-1178664027.txt rw-rr 1 ucsd_plush slices 3292 May 8 22:46 logfile-planetlabl-15415-1178664362.txt rw-rwrwwrww 1 ucsd_plush slices 318 May 8 22:47 client.txt -&gt; ./push-logfile15415-1178664430.txt rw-rwrwwrww 1 ucsd_plush slices 138 May 8 22:47 client.txt -&gt; ./pofile-planetlabl-15415-1178664430.txt rw-rwrwrww 1 ucsd_plush slices 168123 May 8 22:47 client.txt -&gt; ./pofile-planetlabl-15415-1178664430.txt rw-rr 1 ucsd_plush slices 168123 May 8 22:48 logfile-planetlabl-15415-1178664430.txt rw-rr 1 ucsd_plush slices 168123 May 8 22:48 logfile-planetlabl-15415-1178664430.txt rw-rr 1 ucsd_plush slices 168123 May 8 22:48 logfile-planetlabl-15415-1178664430.txt rw-rr 1 ucsd_plush slices 168123 May 8 22:48 logfile-planetlabl-15415-117866430.txt rw-rr 1 ucsd_plush slices 168123 May 8 22:48 logfile-planetlabl-15415-117866430.txt rw-rr 1 ucsd_plush slices 168123 May 8 22:48 logfile-planetlabl-15415-117866430.txt rw-rr 1 ucsd_plush slices 168123 May 8 22:48 logfile-planetlabl-15415-117866430.txt rw-r 1 ucsd_plush slices 168123 May 8 22:49 logfile-planetlabl-15415-117866430.txt rw-r 1 ucsd_plush slices 168123 May 8 22:48 logfile-planetlabl-15415-117866430.txt rw-r 1 ucsd_plush slices 168123 May 8 22:49 logfile-planetlabl-15415-117866430.txt rw-r 1 ucsd_plush slices 168123 May 8 22:49 logfile-planetlabl-15415-117866430.txt rw-r 1 ucsd_plush slices 168123 May 8 22:49 logfile-planetlabl-15415-117866430.txt rw-r</pre>	rw-rr 1 ucsd_plush slices 293 May 6 20:55 plush-loqfile15415-1178484906.txt	
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<pre>rw-rr- 1 ucsd_plush slices 311 May 8 22:40 plush-logfile15415-1178664027.txt rw-rr- 1 ucsd_plush slices 32749 May 8 22:44 logfile-planetlab1-15415-1178664027.txt rw-rr- 1 ucsd_plush slices 32923 May 8 22:46 plush-logfile15415-1178664362.txt rww-rwxrwx 1 ucsd_plush slices 32923 May 8 22:47 plush-logfile15415-1178664362.txt rwxrwxrwx 1 ucsd_plush slices 35 May 8 22:47 plush-logfile15415-1178664362.txt rwxrwxrwx 1 ucsd_plush slices 313 May 8 22:47 plush-logfile15415-1178664430.txt rwwrrwxrwx 1 ucsd_plush slices 313 May 8 22:47 plush-logfile15415-1178664430.txt rwwrrwxrwx 1 ucsd_plush slices 168123 May 8 22:44 logfile-planetlab1-15415-1178664430.txt rwwrrwxruw 1 ucsd_plush slices 168123 May 8 22:44 logfile-planetlab1-15415-1178664430.txt ucsd_plush&amp;planetlab1 ~]\$ traceroute www.google.com raceroute: Warning: www.google.com has multiple addresses; using 72.14.205.99 raceroute to www.logogle.com has multiple addresses; using 72.14.205.99 raceroute to www.logogle.com 0.230 ms 0.275 ms 0.229 ms 1 152.3.219.69 (152.3.219.69) 0.350 ms 0.300 ms 0.230 ms 1 tellsp-roti.netcom.duke.edu (152.3.219.54) 0.281 ms 0.333 ms 0.245 ms 1 tellsp-roti.netcom.duke.edu (152.3.219.54) 0.281 ms 93.511 ms 93.597 ms 1 calren-trcust.plalca01.transitrail.net (137.164.131.254) 99.644 ms 97.167 ms 93.723 ms 1 * * * 1 20.85.130.4 (209.85.130.4) 95.293 ms 97.987 ms 94.702 ms 0 64.233.174.81 (64.233.17</pre>	rw-rr 1 ucsd_plush slices 18694 May 7 05:08 logfile-planetlab1-15417-1178514401.txt	
<pre>rw-rr- 1 ucsd_plush slices 32749 May 8 22:44 logfile-planetlab1-15415-1178664027.txt rw-rr- 1 ucsd_plush slices 313 May 8 22:46 logfile-planetlab1-15415-1178664362.txt rwkrwwrrwx 1 ucsd_plush slices 35 May 8 22:47 plush-logfile_txt -&gt; ./plush-logfile15415-1178664430.txt rwkrwkrwx 1 ucsd_plush slices 313 May 8 22:47 plush-logfile_txt -&gt; ./plush-logfile15415-1178664430.txt rwkrwkrwx 1 ucsd_plush slices 313 May 8 22:47 plush-logfile_txt -&gt; ./plush-logfile15415-1178664430.txt rwkrwkrwx 1 ucsd_plush slices 168123 May 8 22:47 plush-logfile15415-1178664430.txt rw+rr 1 ucsd_plush slices 168123 May 8 22:48 logfile-planetlab1-15415-1178664430.txt rwk-rwkrwx is usd_plush slices 168123 May 8 22:48 logfile-planetlab1-15415-1178664430.txt ucsd_plush@planetlab1 ~] \$ traceroute www.google.com raceroute: Warning: www.google.com (72.14.205.99), 30 hops max, 38 byte packets 1 152.3.138.61 (152.3.138.61) 0.330 ms 0.275 ms 0.229 ms 2 152.3.219.69 (152.3.219.69) 0.353 ms 0.300 ms 0.229 ms 3 tellsp-roti.netcom.duke.edu (152.3.219.54) 0.281 ms 0.333 ms 0.245 ms 4 te2-1581.tr01-asbnva01.transitrail.net (137.164.129.37) 76.141 ms 84.463 ms 76.121 ms 6 te4-1160.tr01-plalca01.transitrail.net (137.164.129.37) 76.141 ms 84.463 ms 76.121 ms 6 te4-1160.tr01-plalca01.transitrail.net (137.164.131.254) 99.634 ms 97.167 ms 93.723 ms 8 *** 9 209.85.130.4 (209.85.130.4) 95.293 ms 97.987 ms 94.702 ms 0 64.233.174.81 (64.233.174.81) 86.525 ms 86.340 ms 86.495 ms MPLS Label=684000 Co50- TTL=1 5=1 1 72.14.236.20 (72.14.236.20) 93.077 ms 110.785 ms 93.037 ms 2 72.14.232.113 (72.14.232.113) 100.908 ms 96.452 ms 98.807 ms 3 72.14.232.62 (72.14.232.66) 99.173 ms 72.14.232.142 (14.236.142) 99.5319 ms 72.14.232.66 (72.14.232.66) 100.434 ms</pre>	rw-rr- 1 ucsd_plush slices 311 May 8 22:40 plush-logfile15415-1178664027.txt	
<pre>rww-r-r 1 ucsd_plush slices 313 May &amp; 22:46 plush-logfile15415-1178664362.txt rww-rwxrwx 1 ucsd_plush slices 32923 May &amp; 22:46 logfile-planetlab1-15415-1178664362.txt 7wwrwxrwx 1 ucsd_plush slices 35 May &amp; 22:47 plush-logfile.txt -&gt; ./plush-logfile15415-1178664430.txt rwxrwxrwx 1 ucsd_plush slices 313 May &amp; 22:47 plush-logfile.txt -&gt; ./plush-logfile15415-1178664430.txt rwwr-r-r 1 ucsd_plush slices 168123 May &amp; 22:47 plush-logfile.planetlab1-15415-1178664430.txt rwwr-rwr-r 1 ucsd_plush slices 168123 May &amp; 22:48 logfile-planetlab1-15415-1178664430.txt ucsd_plush@planetlab1 ~] \$ traceroute www.google.com raceroute: Warning: www.google.com (72.14.205.99), 30 hops max, 38 byte packets 1 152.3.138.61 (152.3.138.61) 0.330 ms 0.275 ms 0.229 ms 2 152.3.138.61 (152.3.219.69) (152.3.219.54) 0.281 ms 0.333 ms 0.245 ms 3 tellsp-roti.netcom.duke.edu (152.3.219.54) 0.281 ms 0.333 ms 0.245 ms 4 te2-1581.tr01-ashnva01.transitrail.net (137.164.129.37) 76.141 ms 84.463 ms 76.121 ms 6 te4-1160.tr01-plalca01.transitrail.net (137.164.129.34) 93.630 ms 93.511 ms 93.597 ms 7 calren-trcust.plalca01.transitrail.net (137.164.131.254) 99.644 ms 97.167 ms 93.723 ms 8 * * * 9 209.85.130.4 (209.85.130.4) 95.293 ms 97.987 ms 94.702 ms 0 64.233.174.81 (64.233.174.81) 86.525 ms 86.340 ms 86.495 ms MPLS Label=684000 co50= TTL=1 5=1 1 72.14.236.20 (72.14.236.20) 93.077 ms 110.785 ms 93.037 ms 2 72.14.232.113 (77.14.232.113) 100.908 ms 96.452 ms 98.807 ms 3 72.14.232.66 (72.14.232.66) 99.173 ms 72.14.236.142 (72.14.236.142) 95.319 ms 72.14.232.66 (72.14.232.66) 100.434 ms</pre>	rw-rr- 1 ucsd_plush slices 32749 May 8 22:44 logfile-planetlab1-15415-1178664027.txt	
<pre>rww-r-r 1 ucsd_plush slices 32923 May 8 22:46 logfile-planet1ab1-15415-1178664362.txt rwwrwxrwx 1 ucsd_plush slices 35 May 8 22:47 plush-logfile.txt -&gt; ./plush-logfile15415-1178664430.txt rww-rwrwxrwx 1 ucsd_plush slices 313 May 8 22:47 plush-logfile15415-1178664430.txt rww-rr 1 ucsd_plush slices 168123 May 8 22:47 plush-logfile15415-1178664430.txt rww-rr 1 ucsd_plush slices 168123 May 8 22:47 plush-logfile15415-1178664430.txt rww-rumxrwx.nws.google.com has multiple addresses; using 72.14.205.99 raceroute: Warning: www.google.com (72.14.205.99), 30 hops max, 38 byte packets 1 152.3.138.61 (152.3.138.61) 0.330 ms 0.275 ms 0.229 ms 2 152.3.219.69 (152.3.219.69) 0.353 ms 0.300 ms 0.230 ms 3 tellsp-roti.netcom.duke.edu (152.3.219.54) 0.281 ms 0.333 ms 0.245 ms 4 te2-1581.tr01-asbnva01.transitrail.net (137.164.129.37) 76.141 ms 84.463 ms 76.121 ms 6 te4-1160.tr01-plalca01.transitrail.net (137.164.129.34) 93.630 ms 93.511 ms 93.597 ms 7 calren-trcust.plalca01.transitrail.net (137.164.129.34) 99.644 ms 97.167 ms 93.723 ms 8 ** * 9 209.85.130.4 (209.85.130.4) 95.293 ms 97.987 ms 94.702 ms 0 64.233.174.81 (64.233.174.81) 86.525 ms 86.340 ms 86.495 ms MPLS Label=684000 Co5=0 TTL=1 5=1 1 72.14.236.20 (72.14.236.20) 93.077 ms 110.785 ms 93.037 ms 2 72.14.232.113 (72.14.232.113) 100.908 ms 96.452 ms 98.807 ms 3 72.14.232.62 (72.14.232.62) 99.174 ms 72.14.232.142 (12.14.236.142) 99.531 ms 72.14.232.66 (72.14.232.66) 100.434 ms</pre>	rw-rr- 1 ucsd_plush slices 313 May 8 22:46 plush-logfile15415-1178664362.txt	
<pre>rwwrwwrwwx 1 ucsd_plush slices 35 May 8 22:47 plush-logfile.txt -&gt; ./plush-logfile15415-1178664430.txt rwwrrwwr 1 ucsd_plush slices 41 May 8 22:47 plush-logfile15415-1178664430.txt rwwr-r-r- 1 ucsd_plush slices 168123 May 8 22:47 plush-logfile15415-1178664430.txt ucsd_plush@planetlab1]\$ traceroute www.google.com ks multiple addresses; using 72.14.205.99 rraceroute: Warning: www.google.com (72.14.205.99), 30 hops max, 38 byte packets 1 152.3.138.61 (152.3.138.61) (152.3.219.69) (0.353 ms 0.229 ms 2 152.3.219.69 (152.3.219.69) 0.353 ms 0.300 ms 0.229 ms 3 tellsp-roti.netcom.duke.edu (152.3.219.54) 0.281 ms 0.333 ms 0.245 ms 4 te2-1581.tr01-astbra01.transitrail.net (137.164.129.37) 76.141 ms 84.463 ms 76.121 ms 6 te4-1160.tr01-plalca01.transitrail.net (137.164.129.34) 93.630 ms 93.511 ms 93.723 ms 8 ** * 9 209.85.130.4 (209.85.130.4) 95.293 ms 97.987 ms 94.702 ms 0 64.233.174.81 (64.233.174.81) 86.525 ms 86.340 ms 86.495 ms MPLS Label=684000 Co5=0 TTL=1 5=1 1 72.14.236.20 (72.14.236.20) 93.077 ms 110.785 ms 93.037 ms 2 72.14.232.113 (72.14.232.113) 100.908 ms 96.452 ms 98.807 ms 3 72.14.232.62 (72.14.232.612) 99.173 ms 72.14.205.142 (152.3.219.54) 100.943 ms 3 72.14.232.62 (72.14.232.612) 99.173 ms 72.14.205 ms 3 72.14.232.612 (72.14.232.612) 99.173 ms 72.14.205 ms 4 72.14.232.62 (72.14.232.612) 99.174 ms 72.14.205 ms 4 72.14.232.612 (72.14.232.612) 99.174 ms 4 72.14.232.62 (72.14.232.613) 100.908 ms 4 72.14.232.612 (72.14.232.66 (72.14.232.66) 100.434 ms 4 72.14.232.62 (72.14.232.66) 99.173 ms 4 72.14.232.612 (72.14.232.66) 99.174 ms 4 72.14.232.612 (72.</pre>	rw-rr- 1 ucsd_plush slices 32923 May 8 22:46 logfile-planetlab1-15415-1178664362.txt	
<pre>rwxrwxrwx 1 ucsd_plush slices 41 May 8 22:47 client.txt -&gt;./logfile=planetlab1=15415=1178664430.txt rww-rr 1 ucsd_plush slices 168123 May 8 22:48 logfile=planetlab1=15415=1178664430.txt ucsd_plush@planetlab1 ~]\$ traceroute www.google.com raceroute: Warning: www.google.com (72.14.205.99), 30 hops max, 38 byte packets 1 152.3.138.61 (152.3.138.61) 0.330 ms 0.275 ms 0.229 ms 2 152.3.219.69 (152.3.219.69) (152.3.219.69) 0.353 ms 0.300 ms 0.230 ms 3 tellsp-roti.netcom.duke.edu (152.3.219.54) 0.281 ms 0.333 ms 0.245 ms 4 te2-1581.tr01-asbnva01.transitrail.net (137.164.131.173) 7.633 ms 7.663 ms 8.402 ms 5 te1=2.tr01-st1wa01.transitrail.net (137.164.129.34) 93.630 ms 93.511 ms 93.597 ms 7 calren-trcust.plalca01.transitrail.net (137.164.131.254) 99.644 ms 97.167 ms 93.723 ms 8 * * 9 209.85.130.4 (209.85.130.4) 95.293 ms 97.987 ms 94.702 ms 0 64.233.174.81 (64.233.174.81) 86.525 ms 86.340 ms 86.495 ms MPLS Label=684000 Co5=0 TTL=1 5=1 1 72.14.236.20 (72.14.236.20) 93.077 ms 110.785 ms 93.037 ms 2 72.14.232.113 (72.14.232.113) 100.908 ms 96.452 ms 98.807 ms 3 72.14.232.62 (72.14.232.62) 99.173 ms 72.14.236.142 (95.319 ms 72.14.232.66 (72.14.232.66) 100.434 ms</pre>	rwxrwxrwx 1 ucsd_plush slices 35 May 8 22:47 plush-logfile.txt -> ./plush-logfile15415-1178664430.txt	
<pre>rvm-rr 1 ucsd_plush slices 313 May 8 22:47 plush-logfile1545-1178664430.txt rvm-rr 1 ucsd_plush slices 168123 May 8 22:48 logfile-planetlab1-15415-1178664430.txt ucsd_plush&amp;planetlab1 ~]\$ traceroute www.google.com rraceroute: Warning: www.google.com has multiple addresses; using 72.14.205.99 rraceroute to www.l.google.com (72.14.205.99), 30 hops max, 38 byte packets 1 152.3.138.61 (152.3.138.61) 0.330 ms 0.275 ms 0.229 ms 2 152.3.219.69 (152.3.219.69) 0.353 ms 0.300 ms 0.230 ms 3 tellsp-roti.netcom.duke.edu (152.3.219.54) 0.281 ms 0.333 ms 0.245 ms 4 te21581.tr01-ashrva01.transitrail.net (137.164.131.173) 7.633 ms 7.663 ms 8.402 ms 5 tel-2.tr01-sttlwa01.transitrail.net (137.164.129.37) 76.141 ms 84.463 ms 76.121 ms 6 te4-1160.tr01-plalca01.transitrail.net (137.164.129.34) 93.630 ms 93.511 ms 93.597 ms 7 calren-trcust.plalca01.transitrail.net (137.164.131.254) 99.644 ms 97.167 ms 93.723 ms 8 * * 9 209.85.130.4 (209.85.130.4) 95.293 ms 97.987 ms 94.702 ms 0 64.233.174.81 (64.233.174.81) 86.525 ms 86.340 ms 86.495 ms MPLS Label=684000 Co5=0 TTL=1 S=1 1 72.14.236.20 (72.14.236.20) 93.077 ms 110.785 ms 93.037 ms 3 72.14.232.113 (72.14.232.113) 100.908 ms 96.452 ms 98.807 ms 3 72.14.232.62 (72.14.232.62) 99.173 ms 72.14.236.142 (72.14.236.142) 95.319 ms 72.14.232.66 (72.14.232.66) 100.434 ms</pre>	rwxrwxrwx 1 ucsd_plush slices 41 May 8 22:47 client.txt -> ./logfile-planetlab1-15415-1178664430.txt	
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<pre>raceroute to www.l.google.com (/2.14.205.99), 30 hops max, 38 byte packets 1 f52.3.138.61 (152.3.138.61) 0.330 ms 0.275 ms 0.229 ms 2 f52.3.219.69 (152.3.219.69) 0.353 ms 0.300 ms 0.230 ms 3 tellsp-roti.netcom.duke.edu (152.3.219.54) 0.281 ms 0.333 ms 0.245 ms 4 te2-1581.tr01-asbnva01.transitrail.net (137.164.131.173) 7.633 ms 7.663 ms 8.402 ms 5 te1-2.tr01-sttlwa01.transitrail.net (137.164.129.37) 76.141 ms 84.463 ms 76.121 ms 6 te4-1160.tr01-plalca01.transitrail.net (137.164.129.34) 93.630 ms 93.511 ms 93.597 ms 7 calren-trcust.plalca01.transitrail.net (137.164.131.254) 99.644 ms 97.167 ms 93.723 ms 8 * * 9 209.85.130.4 (209.85.130.4) 95.293 ms 97.987 ms 94.702 ms 0 644.233.174.81 (64.233.174.81) 86.525 ms 86.340 ms 86.495 ms MPLS Label=684000 Co5=0 TTL=1 S=1 1 72.14.236.20 (72.14.236.20) 93.077 ms 110.785 ms 93.037 ms 2 72.14.232.113 (72.14.232.113) 100.908 ms 96.452 ms 98.807 ms 3 72.14.232.62 (72.14.232.62) 99.173 ms 72.14.236.142 (72.14.236.142) 95.319 ms 72.14.232.66 (72.14.232.66) 100.434 ms </pre>	raceroute: Warning: www.google.com has multiple addresses; using 72.14.205.99	
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<pre>2 15:3:219:09 (15:3:219:09) (0:53 ms 0:000 ms 0:330 ms 3 tellsp-roti.netcom.duke.edu (152.3:219:54) 0:281 ms 0.333 ms 0.245 ms 4 te2-1581.tr01-asbnva01.transitrail.net (137.164.131.173) 7.633 ms 7.663 ms 8.402 ms 5 te1-2.tr01-sttlwa01.transitrail.net (137.164.129.34) 93.630 ms 93.511 ms 93.597 ms 7 calren-trcust.plalca01.transitrail.net (137.164.131.254) 99.644 ms 97.167 ms 93.723 ms 8 ** 9 209.85.130.4 (209.85.130.4) 95.293 ms 97.987 ms 94.702 ms 0 64.233.174.81 (64.233.174.81) 86.525 ms 86.340 ms 86.495 ms MPLS Label=684000 CoS=0 TTL=1 S=1 1 72.14.236.20 (72.14.236.60) 93.077 ms 110.785 ms 93.037 ms 3 72.14.232.113 (72.14.232.113) 100.908 ms 96.452 ms 98.807 ms 3 72.14.232.113 (72.14.232.113) 100.908 ms 96.245 ms 98.807 ms 3 72.14.232.162 (72.14.232.66) 99.173 ms 72.14.236.142 (95.319 ms 72.14.232.66) 100.434 ms </pre>	1 152.3.138.61 (152.3.138.61) 0.330 ms 0.2/5 ms 0.229 ms	
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<pre>4 te2=1301.tV1-as01wa01.transitral1.net (137.164.139.17/3) 7.053 ms 7.050 ms 6.702 ms 5 te1-2.tr01-st1wa01.transitral1.net (137.164.129.37) 76.141 ms 84.463 ms 76.121 ms 6 te4-1160.tr01-plalca01.transitral1.net (137.164.131.254) 99.630 ms 93.511 ms 93.597 ms 7 calren-trcust.plalca01.transitral1.net (137.164.131.254) 99.644 ms 97.167 ms 93.723 ms 8 ** * 9 209.85.130.4 (209.85.130.4) 95.293 ms 97.987 ms 94.702 ms 0 64.233.174.81 (64.233.174.81) 86.525 ms 86.340 ms 86.495 ms MPLS Label=684000 Co50= OTTL=1 5=1 1 72.14.236.20 (72.14.236.20) 93.077 ms 110.785 ms 93.037 ms 2 72.14.232.113 (72.14.232.113) 100.908 ms 96.452 ms 98.807 ms 3 72.14.232.62 (72.14.232.62) 99.173 ms 72.14.236.142 (72.14.236.142) 95.319 ms 72.14.232.66 (72.14.232.66) 100.434 ms </pre>	5 LETISP-FOLL.NELLUM.duke.edu (132.5.219.34) 0.201 MB 0.355 MB 0.245 MB	
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#### **Project Difficulty (S08)**





### Recommend Again? (S08)



### Student Feedback

- "I loved the papers! This was the first class that required critical responses to papers like that and I was surprised by how much I enjoyed it."
- "Evaluating the papers, while kind of a pain sometimes, was actually quite valuable in retrospect; I learned a lot about distributed systems that way, and I'm glad we did them."
- "[The P2P project] was one of the hardest and most rewarding projects I've done at Williams."
- "I really felt like this was one of the most real-life applicable CSCI courses I took at Williams."

#### Instructor Feedback

- Students loved Projects I and 4 (one student turned Project 4 into a senior thesis)
  - Projects 2 and 3 were too easy initially; better now
  - Some students loved open-endedness of Project 4; some struggled with it (default project helps)
  - Need about 4 weeks for final project
- I spent 4-5 hours per week in lab helping students
  - Students worked an avg of 10 hours per week
- Good writers != good technical writers
  - Students need practice writing technical/scientific papers!
- Students enjoy reading research papers
  - ...when they understand the content

### Conclusions

- We should teach undergraduates how to design and implement Distributed Systems!
- Shared computing platforms provide students with the opportunity to gain hands-on experience with large-scale, wide-area distributed computing
  - Use shared platforms as learning laboratories
  - Bring tech-richness of big universities to small colleges
- Frameworks like Hadoop, Plush/Gush lower entry barrier for distributed systems innovation
  - Undergrads are capable of doing great work!

### Thanks!

- More info:
  - http://www.cs.williams.edu/~jeannie/cs339
  - jeannie@cs.williams.edu
- PlanetLab / GENI
  - http://www.planet-lab.org
  - http://www.geni.net
- Plush and Gush
  - http://plush.cs.williams.edu
  - http://gush.cs.williams.edu