



Application and System Memory Use, Configuration, and Problems on Bassi

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NERSC User Services

ScicomP 13

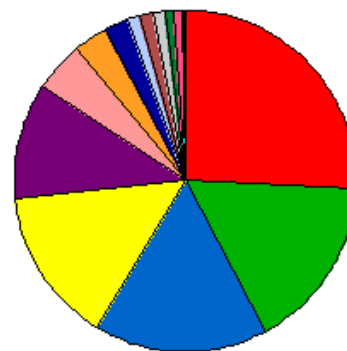
Garching bei München, Germany, July 17, 2007

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- **About Bassi**
- **Memory on Bassi**
- **Large Page Memory (It's Great!) **
- **System Configuration**
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- **Workload Characterization**

- **NERSC IBM POWER 5 p575: Bassi**
 - 111 (114) node single-core 1.9 GHz P5
 - 8-way SMP
 - 32 GB physical memory per node
 - **Very diverse workload**
 - ~400 active users
 - ~400 jobs per day
 - 28% node-hrs >32 nodes
 - 44% node-hrs < 8 nodes
 - 12% node-hrs = 1 node
 - Fortran, C, C++, mixed-mode
 - MPI, OpenMP, pThreads
 - shmget()
 - MPMD, SPMD, emb. parallel

Raw Hours By Science Field





Memory on Bassi

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Bassi Memory Overview

- **Each node has 32 GB of memory**
- **Memory is partitioned into two types**
 - Large Page pool
 - Small Page pool
- **Large pages are required for HPS**
- **AIX uses small pages only**
- **Applications can use either**
 - Small pages only
 - Large and small pages



Large Page Memory

It's Great!

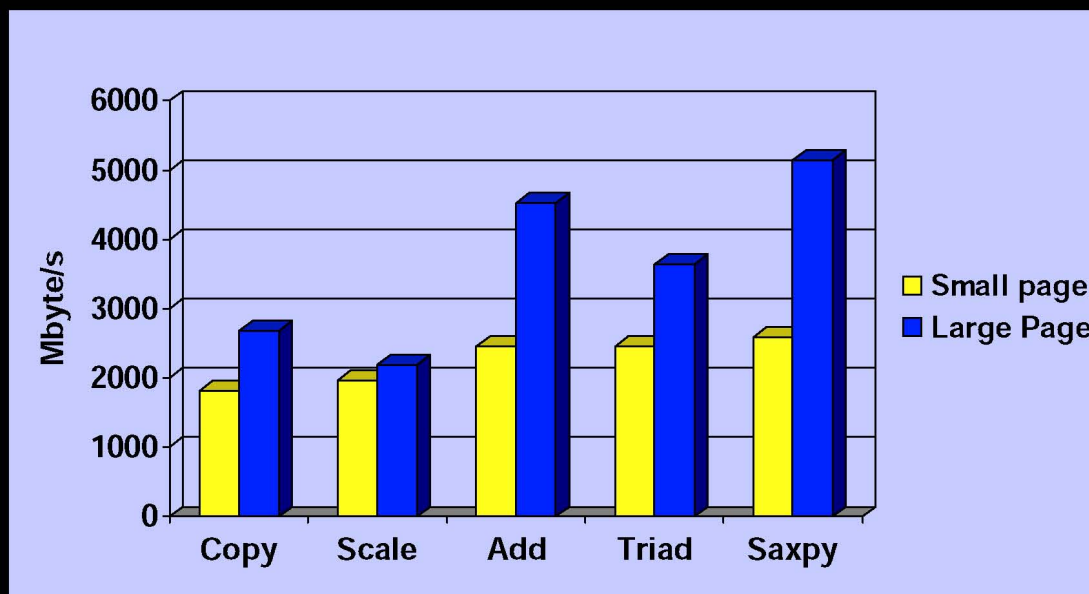


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Large Page Memory

- **Large memory pages are 16 MB**
 - Can not be swapped to disk
 - Number of large pages per node is set at boot
 - Large Page memory is backed by Small Pages
- **Small memory pages are 4 KB**
 - Can be swapped to disk
- **Large Page memory is good for most scientific applications**
 - Enhanced memory bandwidth
 - 16 GB TLB coverage (vs. 4 MB for small)
 - 131072 cache lines (vs. 32 for small)

Large Pages: Bandwidth Enhancement



POWER5 1.45 GHz



LP Memory & NERSC Benchmarks

- **Large page memory improves performance on NERSC “Bassi” benchmarks**
 - **NPB MG 2.4 Class C: 38%**
 - **NPB SP 2.4 Class C: 16%**
 - **NPB FT 2.4 Class C: 13%**
 - **GTC (PIC Fusion): 7%**
 - **PARATEC (Materials): 8%**
 - **CAM 3.0 (Climate Atms): 1%**



System Configuration

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System Configuration

- **It appears that Large Pages are good for HPC applications**
- **Why not configure system for as many large pages as possible, leaving adequate small pages for AIX?**
- **After consultation with IBM, NERSC chose to allocate 24 GB to the large page pool**



System and Application Memory

- **On an idle compute node**
 - **AIX uses about 4 GB of small page memory; ~4 GB free**
 - **HPS reserves 69 large pages, or 1.078 GB; 22.922 GB free**
- **Applications can access the remaining memory**
 - **4 GB + 23 GB \cong 27 GB**



Large Page “Gotchas”



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Large Page “Gotchas”

- **Users must enable codes to run in Large Pages; it is not the default**
- **The application stack must reside in small page memory**
- **FORTRAN 90 “regular” arrays are allocated on the stack by default; programmer must change to using allocated arrays**
- **Shared memory segments are allocated in small page memory by default**
- **OpenMP PRIVATE data is allocated on the stack**
- **Large Page memory allocation is slow (scripts and serial commands should use small pages)**



Bad Things Happen When Small Page Memory is Exhausted

- **Small Page memory must swap to disk when exhausted**
- **When jobs exhaust small-page memory**
 - Slows, hangs, or kills the application
 - Makes the node unresponsive
 - GPFS dies
 - Causes other havoc
- **Why?**
 - Theory: AIX memory manager can't deal with 8 tasks concurrently trying to allocate/access large chunk of memory that is not physically present and must be paged to disk



NERSC Mitigation Efforts

- **Set the mp* compilers to enable large pages by default**
 - “Serial” compiled codes use small pages
- **Set runtime environment variables to force batch jobs into large pages**
- **Identify shmget() programmers and tell them to set SHM_LGPAGE and SHM_PIN flags**
- **Tell FORTRAN 90 users to use allocatable arrays**
- **Compile with -qlargepage to put XLF runtime temporary arrays into large pages**
- **WLM ConsumableMemory settings and low paging space kills**



The Plague



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- **NERSC has been plagued by users exhausting small page memory and effectively disabling nodes**
 - Node becomes unresponsive; services die
 - Users' jobs die
 - Node may or may not recover by itself
 - System admins get paged
 - Consultants have to contact users to try to get more information
 - Users get disabled so they won't kill the nodes again



System Monitoring

- **We starting monitoring the memory usage on all compute nodes**
 - **Used LoadLeveler “llstatus -l” utility**
 - **Free small page memory**
 - **Free large page memory**
 - **Sampled every 15 mins since mid April 2007**
 - **Recorded user and StepID running on each node**

- **In about 70 days we found**
 - Large pages exhausted 3.3% of the time
 - Small pages exhausted 0.87% (1/115) of the time
 - Node paging to disk 0.29% (1/345) of the time
 - Paging with LP use, but free LPs 0.24% (1/417) of the time
- **We identified three common node failure modes**
 - Just using too much memory (>27 GB)
 - Running without enabling large page use
 - Using some large pages, but nonetheless exhausting small page memory
- **We contacted users to get more information about their codes and job scripts**

- **Users override default programming environment**
 - Executables are not large-page enabled
 - Batch environmental variable not set (LDR_CNTRL)
 - ‘bash’ configuration file issues
- **Using large automatic arrays, OpenMP PRIVATE data, runtime temporary arrays**
- **Making shared memory calls without LP flags**
- **Programming errors**
- **Users don't really understand their code's memory requirements**
- **Third-party libraries**
- **Unknown issues**

- **Work one-on-one with users to resolve known issues**
- **Work with third-party developers to incorporate P5-friendly code**
 - Global Arrays, NWChem, MOLPRO, GAMESS
- **NERSC reduced Large Page pool to 20 GB on 7/11/2007 to accommodate codes that need a larger stack**
- **Possibly set `-qlargepage` and `-qsmallstack` as default for f90 compilers?**
- **New system configuration setting promised by IBM to monitor and kill jobs based on small page memory use**



Workload Characterization

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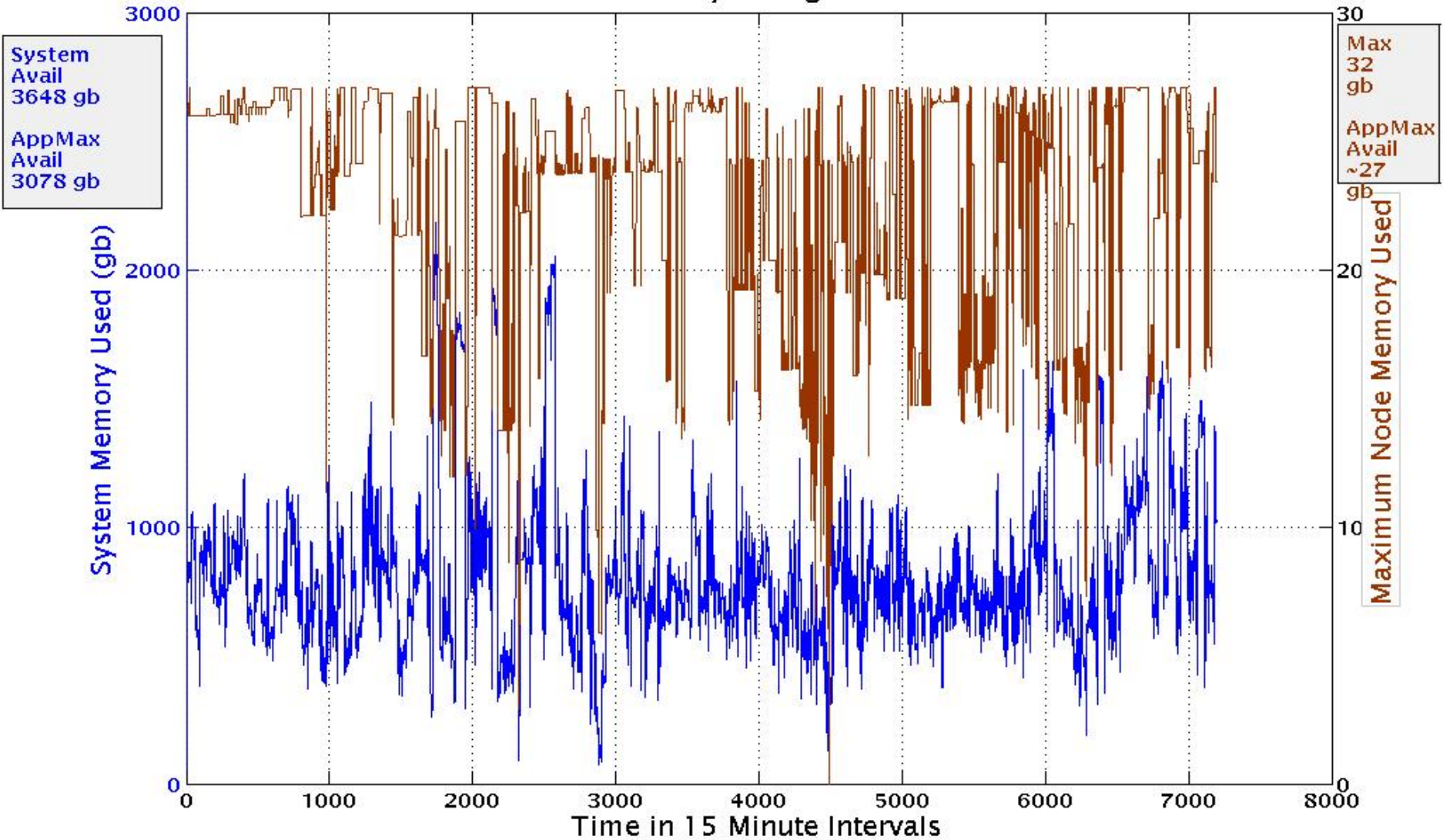
Workload Characterization

- **We have these memory snapshots, so we can ask questions about the NERSC workload**
 - **How much memory is used on average?**
 - **What is the maximum memory usage?**
 - **How many Large Pages should we allocate?**
 - **Can we help users understand their codes' memory use patterns (e.g. find memory leaks)**
 - **Can we identify classes of jobs based on memory use patterns?**

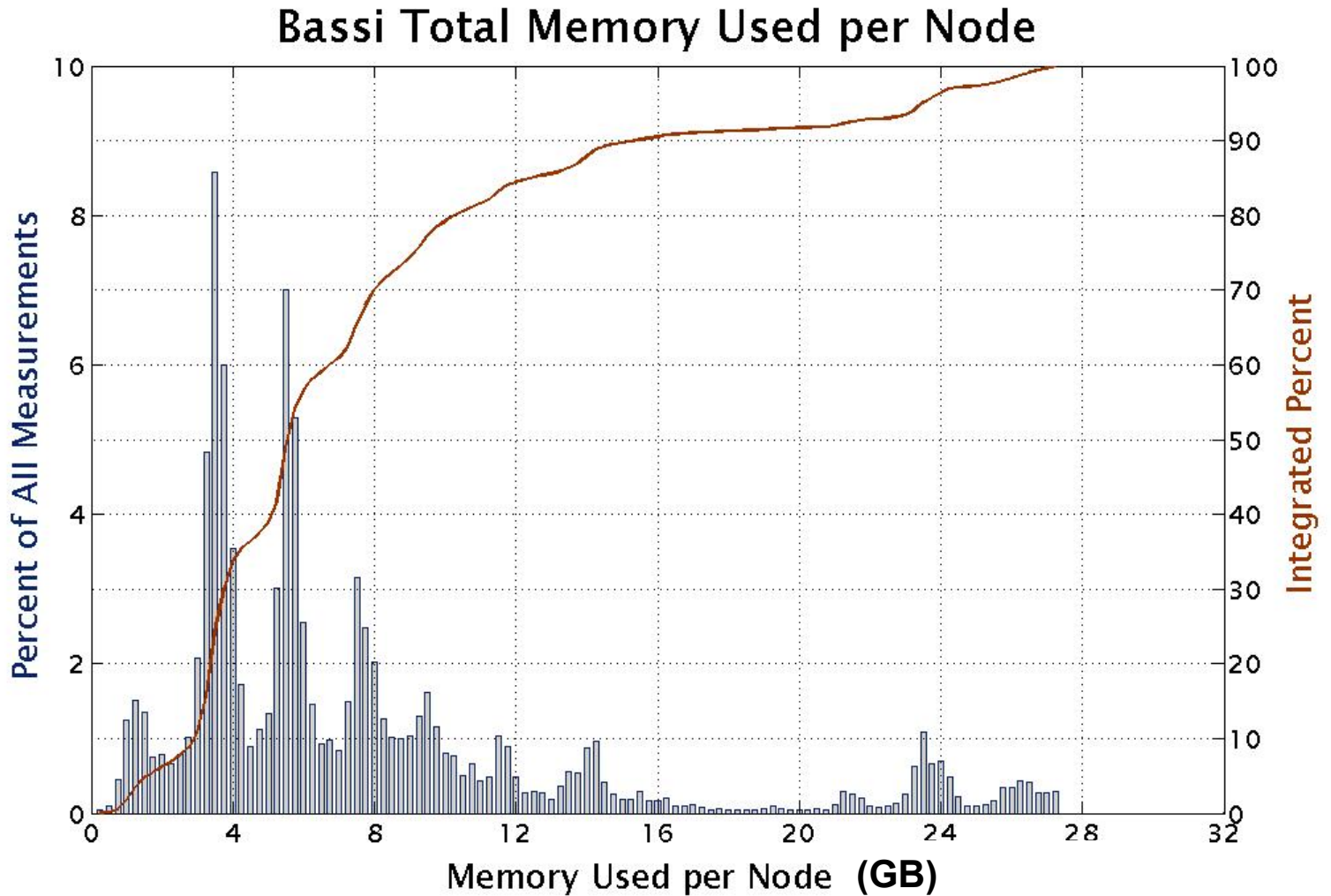


Total and Max Memory Used

Bassi Memory Usage over Time



Total Memory Used

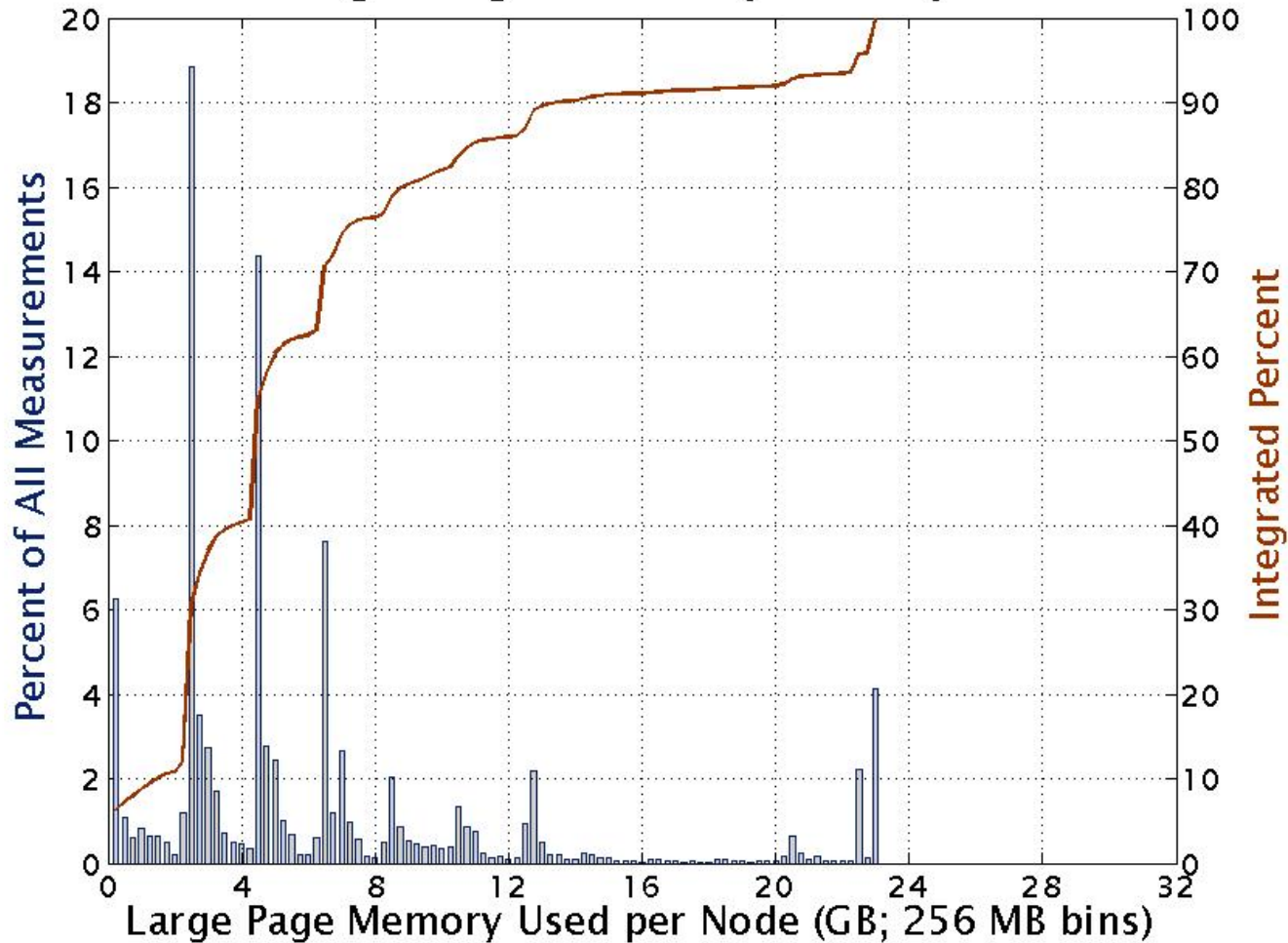


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Large Page Memory Used

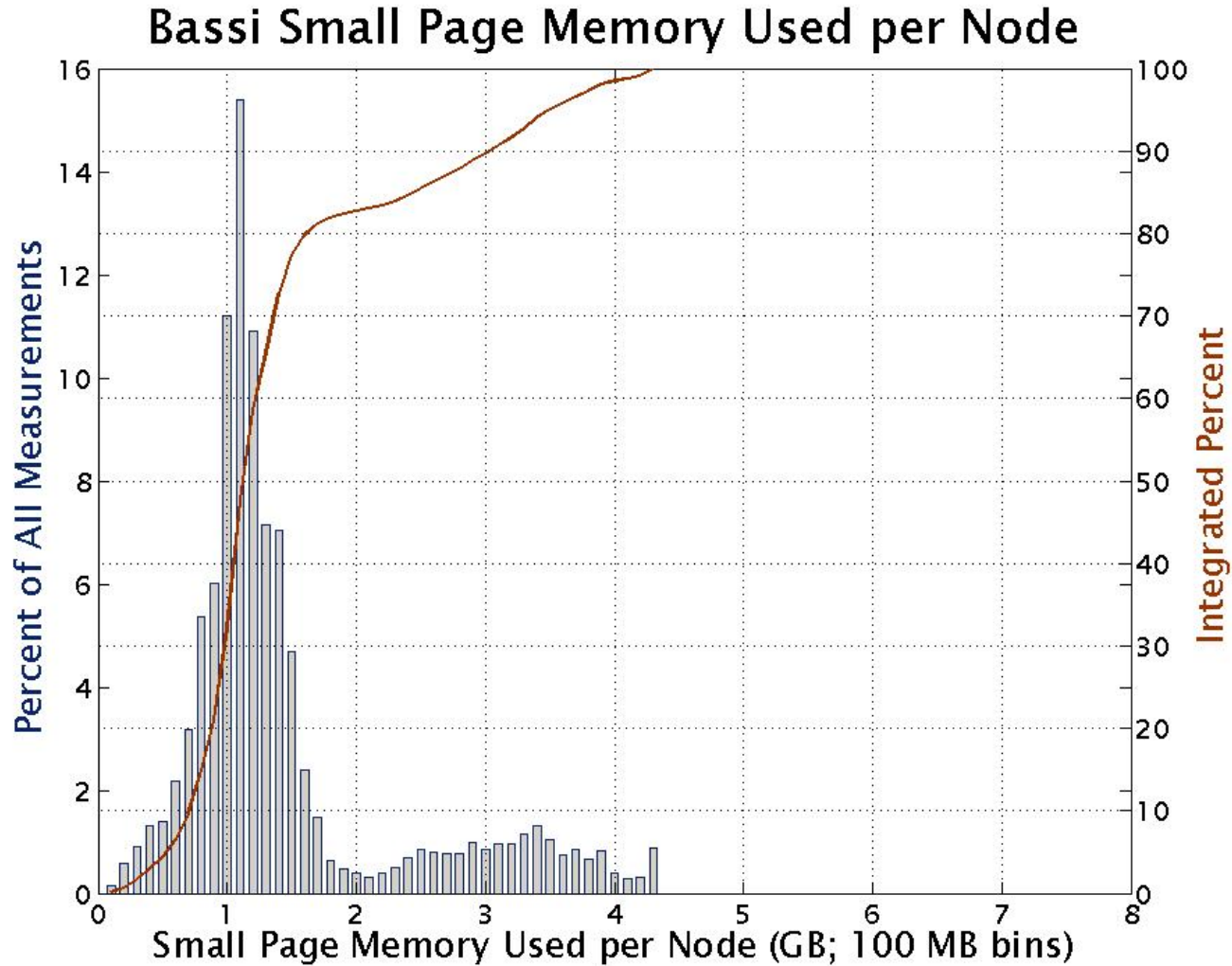
Bassi Large Page Memory Used per Node



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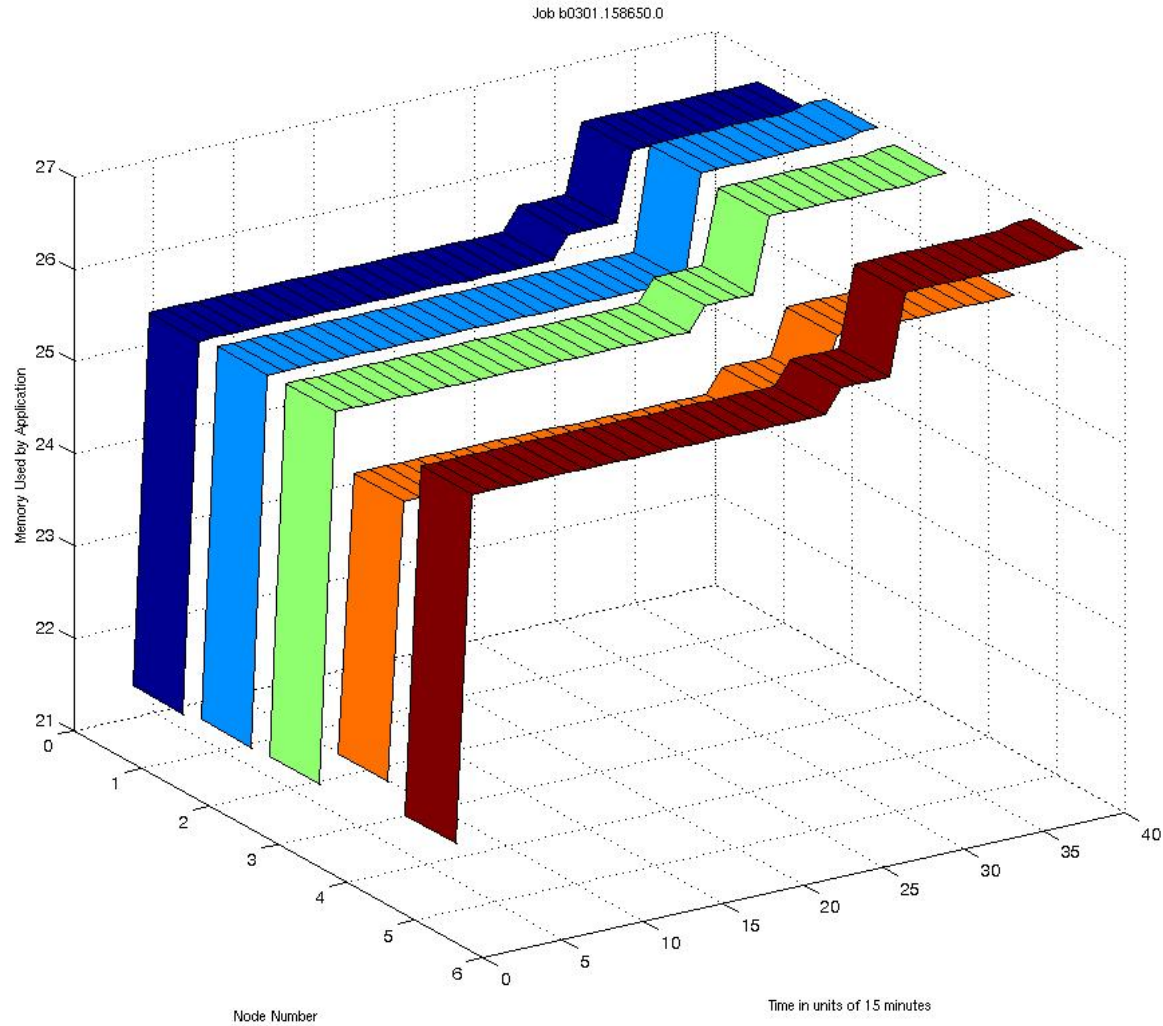
Small Page Memory Used

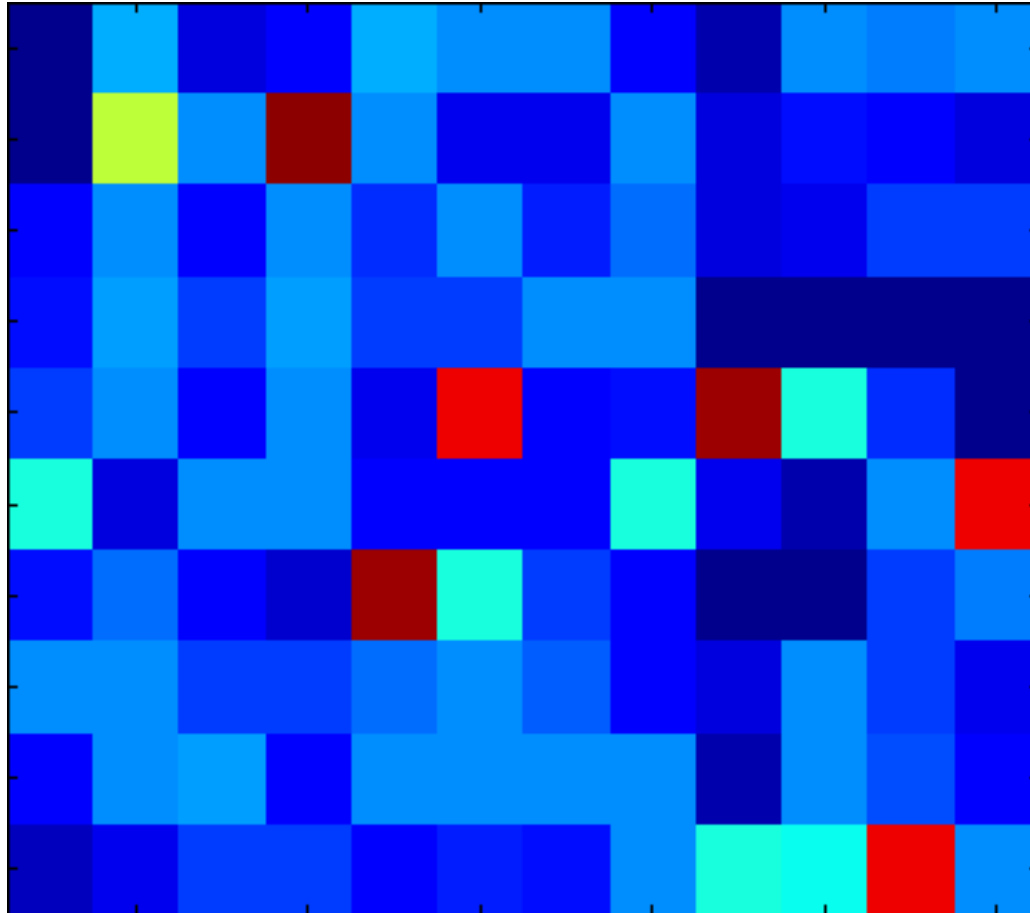


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Job Characterization





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