PBS Pro™ 5.1

Administrator Guide

PBS Pro

Release 5.1

Administrator Guide

Portable Batch System Administrator Guide

PBS-3BA01, Release: PBS Pro^{TM} 5.1, Updated: August 21, 2001

Edited by: James Patton Jones

Contributing authors include: Albeaus Bayucan, Robert L. Henderson, James Patton Jones, Casimir Lesiak, Bhroam Mann, Bill Nitzberg, Tom Proett, Judith Utley.

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For more information, redistribution, licensing, or additional copies of this publication, contact:

Veridian Systems
PBS Products Dept.
2672 Bayshore Parkway, Suite 810
Mountain View, CA 94043

Phone: +1 (650) 967-4675
FAX: +1 (650) 967-3080
URL: www.pbspro.com
Email: sales@pbspro.com

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Acknowledgements

PBS Pro is an enhanced commercial version of the PBS software originally developed for NASA. The NASA version had a number of corporate and individual contributors over the years, for which the PBS developers and PBS community are most grateful. Below we provide formal legal acknowledgements to corporate and government entities, then special thanks to individuals.

The NASA version of PBS contained software developed by NASA Ames Research Center, Lawrence Livermore National Laboratory, and MRJ Technology Solutions. In addition, it included software developed by the NetBSD Foundation, Inc., and its contributors, as well as software developed by the University of California, Berkeley and its contributors.

Other contributors to the NASA version of PBS include Bruce Kelly and Clark Streeter of NERSC; Kent Crispin and Terry Heidelberg of LLNL; John Kochmar and Rob Pennington of *Pittsburgh Supercomputing Center*; and Dirk Grunwald of *University of Colorado, Boulder*. The ports of PBS to the Cray T3e and the IBM SP SMP were funded by *DoD USAERDC*, Major Shared Research Center; the port of PBS to the Cray SV1 was funded by DoD MSIC.

No list of acknowledgements for PBS would possibly be complete without special recognition of the first two beta test sites. Thomas Milliman of the *Space Sciences Center* of the *University of New Hampshire* was the first beta tester. Wendy Lin of *Purdue University* was the second beta tester and holds the honor of submitting more problem reports than anyone else outside of NASA.

Preface

Intended Audience

This document provides the system administrator with the information required to install, configure, and manage the Portable Batch System (PBS). PBS is a workload management system from Veridian that provides a unified batch queuing and job management interface to a set of computing resources.

Related Documents

The following publications contain information that may also be useful in the management and administration of PBS.

PBS-3BU01 **PBS Pro User Guide**: Provides an overview of PBS Pro and serves as an introduction to the software, explaining how to use both user commands and graphical user interface to submit, monitor, track, delete, and manipulate jobs.

PBS-3BE01 **PBS External Reference Specification**: Discusses in detail the PBS application programming interface (API), security within PBS, and intra-daemon communication.

Ordering Software and Publications

To order additional copies of this manual and other PBS publications, or to purchase additional software licenses, contact the PBS Products Department of Veridian. Full contact information is included on the copyright page of this document.

Document Conventions

PBS documentation uses the following typographic conventions.

abbreviation — If a PBS command can be abbreviated (such as subcommands to qmgr) the shortest acceptable abbreviation is underlined.

`command` — This fixed width font is used to denote literal commands, filenames, error messages, and program output.

input — Literal user input is shown in this bold, fixed-width font.

`manpage`(x) — Following UNIX tradition, manual page references include the corresponding section number in parentheses appended to the man page name.

terms — Words or terms being defined, as well as variable names, are in italics.

Chapter 1
Introduction

This book, the **Administrator Guide** to the Portable Batch System, Professional Edition (PBS Pro) is intended as your knowledgeable companion to the PBS Pro software. The information herein pertains to PBS in general, with specific information for PBS Pro 5.1. It covers both the binary distribution of PBS Pro, as well as the source code distribution.

1.1 Book Organization

This book is organized into 14 chapters, plus an appendix. Depending on your intended use of PBS, some chapters will be critical to you, and others can be safely skipped.

Chapter 1 **Introduction**: Gives an overview of this book, PBS, and the PBS Products Department of Veridian.

Chapter 2 **Concepts and Terms**: Discusses the components of PBS and how they interact, followed by definitions of terms used in PBS.

Chapter 3 **Pre-Installation Planning**: Helps the reader plan for a new installation of PBS.

Chapter 4 **Installation**: Covers the installation of the binary distribution of PBS and software licenses.

Chapter 5 **Installation from Source**: Covers the installation of PBS from source code. This chapter can be skipped if you are installing the binary distribution.

Chapter 6 **Upgrading PBS**: Provides important information for sites that are upgrading from a previous version of PBS.

Chapter 7 **Configuring the Server**: Describes how to configure the PBS Server daemon.

Chapter 8 **Configuring MOM**: Describes how to configure the PBS MOM daemons.

Chapter 9 **Configuring the Scheduler**: Describes how to configure the PBS Scheduler daemon.

Chapter 10 **Example PBS Configurations**: Provides examples and sample configurations.

Chapter 11 **Administration**: Discusses PBS management and administration.

Chapter 12 **Problem Solving**: Discusses how to trouble-shoot PBS problems, and describes the tools provided by PBS to assist with problem solving.

Chapter 13 **Alternate Schedulers**: Provides information on customizing PBS. This chapter can be skipped by most sites.

Chapter 14 **Alternate Schedulers**: Discusses how to create and/or use alternate schedulers with PBS. This chapter can be skipped by most sites.

Appendix A **Error Codes**: Provides a listing and description of the PBS error codes.

1.2 What is PBS Pro?

PBS Pro is the professional version of the Portable Batch System (PBS), a flexible resource and workload management system, originally developed to manage aerospace computing resources at NASA. PBS has since become the leader in supercomputer workload management and the *de facto* standard on Linux clusters.

Today, growing enterprises often support hundreds of users running thousands of jobs across different types of machines in different geographical locations. In this distributed heterogeneous environment, it can be extremely difficult for administrators to collect detailed, accurate usage data or to set system-wide resource priorities. As a result, many computing resource are left under-utilized, while others are over-utilized. At the same time, users are confronted with an ever expanding array of operating systems and platforms. Each year, scientists, engineers, designers, and analysts must waste countless hours learning the nuances of different computing environments, rather than being able to focus on their core priorities. PBS Pro addresses these problems for computing-intensive enterprises such as science, engineering, finance, and entertainment.

Now you can use the power of PBS Pro to take better control of your computing resources. This product enables you to unlock the potential in the valuable assets you already have. By reducing dependency on system administrators and operators, you will free them to focus on other actives. PBS Pro can also help you to effectively manage growth by tracking real usage levels across your systems and by enhancing effective utilization of future purchases.

1.2.1 History of PBS

In the past, UNIX systems were used in a completely interactive manner. Background jobs were just processes with their input disconnected from the terminal. However, as UNIX moved onto larger and larger processors, the need to be able to schedule tasks based on available resources increased in importance. The advent of networked compute servers, smaller general systems, and workstations led to the requirement of a networked batch scheduling capability. The first such UNIX-based system was the Network Queueing System (NQS) from NASA Ames Research Center in 1986. NQS quickly became the *de facto* standard for batch queueing.

Over time, distributed parallel systems began to emerge, and NQS was inadequate to handle the complex scheduling requirements presented by such systems. In addition, computer system managers wanted greater control over their compute resources, and users wanted a single interface to the systems. In the early 1990's NASA needed a solution to this problem, but found nothing on the market that adequately addressed their needs. So NASA lead an international effort to gather requirements for a next-generation resource management system. The requirements and functional specification were later adopted as an IEEE POSIX standard (1003.2d). Next, NASA funded the development of a new resource management system compliant with the standard. Thus the Portable Batch System (PBS) was born.

PBS was quickly adopted on distributed parallel systems and replaced NQS on traditional supercomputers and server systems. Eventually the entire industry evolved toward distributed parallel systems, taking the form of both special purpose and commodity clusters. Managers of such systems found that the capabilities of PBS mapped well onto cluster systems.

The latest chapter in the PBS story began when Veridian (the R&D contractor that developed PBS for NASA) released the Portable Batch System Professional Edition (PBS Pro), a complete workload management solution.

1.3 About Veridian

The PBS Pro product is brought to you by the same team that originally developed PBS for NASA over six years ago. In addition to the core engineering team, the Veridian PBS Products department includes individuals who have supported PBS on computers all around the world, including the largest supercomputers in existence. The staff includes internationally-recognized experts in resource- and job-scheduling, supercomputer optimization, message-passing programming, parallel computation, and distributed high-performance computing.

In addition, the PBS team includes co-architects of the NASA Metacenter (the first full-production geographically distributed meta-computing environment), co-architects of the Department of Defense MetaQueueing Project, co-architects of the NASA Information Power Grid, and co-chair of the Grid Forum’s Scheduling Group. Veridian staff are routinely invited as speakers on a variety of information technology topics.

Veridian is an advanced information technology company delivering trusted solutions in the areas of national defense, critical infrastructure, and essential business systems. A private company with annual revenues of $650 million, Veridian operates at more than 50 locations in the US and overseas, and employs nearly 5,000 computer scientists and software development engineers, systems analysts, information security and forensics specialists, and other information technology professionals. The company is known for building strong, long-term relationships with a highly sophisticated customer base.

Chapter 2
Concepts and Terms

PBS is a distributed workload management system. As such, PBS handles the management and monitoring of the computational workload on a set of one or more computers. Modern workload/resource management solutions like PBS include the features of traditional batch queueing but offer greater flexibility and control than first generation batch systems (such as the original batch system NQS).

Workload management systems have three primary roles:

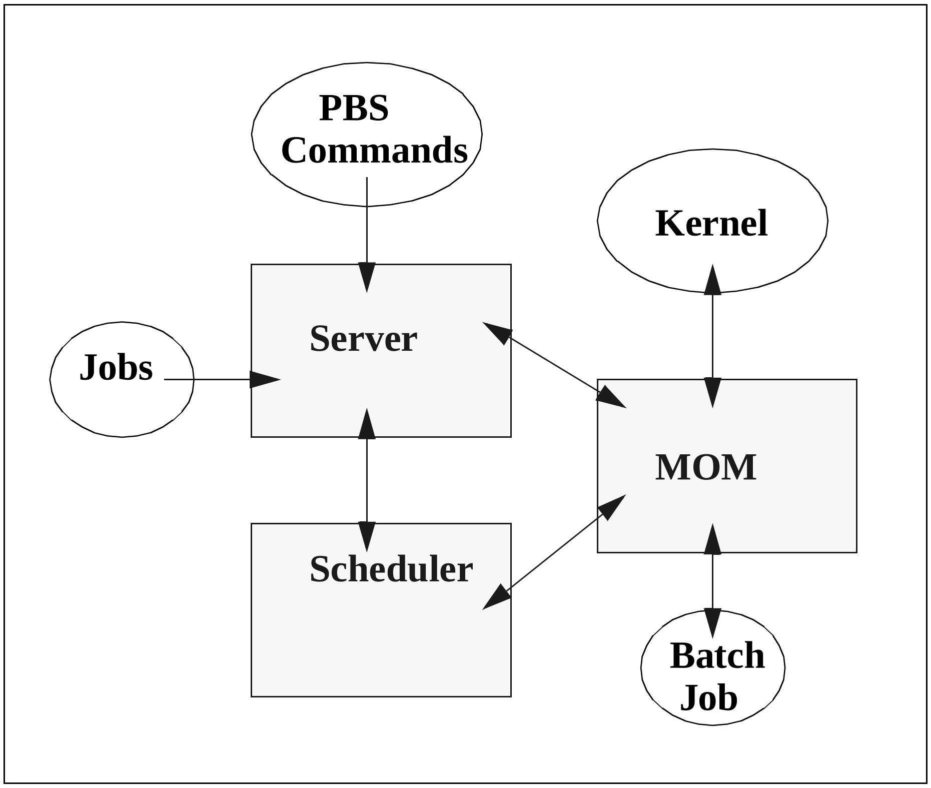
Queuing The collecting together of work or tasks to be run on a computer. Users submit tasks or "jobs" to the resource management system where they are queued up until the system is ready to run them.

Scheduling The process of selecting which jobs to run when and where, according to a predetermined policy. Sites balance competing needs and goals on the system(s) to maximize efficient use of resources (both computer time and people time).

Monitoring The act of tracking and reserving system resources and enforcing usage policy. This covers both user-level and system-level monitoring as well as monitoring of the scheduling algorithms to see how well they are meeting the stated goals

2.1 PBS Components

PBS consist of two major component types: user-level commands and system daemons. A brief description of each is given here to help you make decisions during the installation process.



Commands PBS supplies both command line programs that are POSIX 1003.2d conforming and a graphical interface. These are used to submit, monitor, modify, and delete jobs. These *client commands* can be installed on any system type supported by PBS and do not require the local presence of any of the other components of PBS.

There are three classifications of commands: user commands which any authorized user can use, operator commands, and Manager (or administrator) commands. Operator and Manager commands require specific access privileges, as discussed in section 11.5 “Security” on page 123.

Job Server

The *Job Server* daemon is the central focus for PBS. Within this document, it is generally referred to as *the Server* or by the execution name *pbs_server.* All commands and daemons communicate with the Server via an *Internet Protocol* (IP) network. The Server's main function is to provide the basic batch services such as receiving/creating a batch job, modifying the job, protecting the job against system crashes, and running the job. Typically there is one Server managing a given set of resources.

Job Executor (MOM)

The *Job Executor* is the daemon which actually places the job into execution. This daemon, *pbs_mom*, is informally called *MOM* as it is the mother of all executing jobs. (MOM is a reverse-engineered acronym that stands for Machine Oriented Miniserver.) MOM places a job into execution when it receives a copy of the job from a Server. MOM creates a new session that is as identical to a user login session as is possible. For example, if the user's login shell is csh, then MOM creates a session in which `.login` is run as well as `.cshrc`. MOM also has the responsibility for returning the job's output to the user when directed to do so by the Server. One MOM daemon runs on each computer which will execute PBS jobs.

A special version of MOM, called the *Globus MOM*, is available if it is enabled during the installation of PBS. It handles submission of jobs to the Globus environment. Globus is a software infrastructure that integrates geographically distributed computational and information resources. Globus is discussed in more detail in the "Globus Support" section of the **PBS User Guide**.

Job Scheduler

The *Job Scheduler* daemon, *pbs_sched*, implements the site's policy controlling when each job is run and on which resources. The Scheduler communicates with the various MOMs to query the state of system resources and with the Server to learn about the availability of jobs to execute. The interface to the Server is through the same API as used by the client commands. Note that the Scheduler interfaces with the Server with the same privilege as the PBS Manager.

2.2 Defining PBS Terms

The following section defines important terms and concepts of PBS. The reader should review these definitions before beginning the planning process prior to installation of PBS. The terms are defined in an order that best allows the definitions to build on previous terms.

Node A *node* to PBS is a computer system with a single *operating system* (OS) image, a unified virtual memory space, one or more CPUs and one or more IP addresses. Frequently, the term *execution host* is used for node. A computer such as the SGI Origin 3000, which contains multiple processing units running under a single OS, is one node. Systems like the IBM SP and Linux clusters, which contain many computational units each with their own OS, are collections of many nodes. Nodes can be defined as either *cluster nodes* or *timeshared nodes*, as discussed below.

Nodes & Virtual Processors A node may be declared to consist of one or more *virtual processors (VPs).* The term virtual is used because the number of VPs declared does not have to equal the number of real processors on the physical node. The default number of virtual processors on a node is the number of currently functioning physical processors; the PBS Manager can change the number of VPs as required by local policy.

Cluster Node A node whose purpose is geared toward running parallel jobs is called a *cluster node*. If a cluster node has more than one virtual processor, the VPs may be assigned to different jobs (*job-shared*) or used to satisfy the requirements of a single job (*exclusive*). This ability to temporally allocate the entire node to the exclusive use of a single job is important for some multi-node parallel applications. Note that PBS enforces a one-to-one allocation scheme of cluster node VPs ensuring that the VPs are not over-allocated or over-subscribed between multiple jobs.

Timeshared Node In contrast to cluster nodes are hosts that **always** service multiple jobs simultaneously, called *timeshared nodes*. Often the term *host* rather than node is used in conjunction with timeshared, as in *timeshared host.* A timeshared node will never be allocated exclusively or temporarily-shared. However, unlike cluster nodes, a timeshared node **can** be over-committed if the local policy specifies to do so.

Cluster This is any collection of nodes controlled by a single instance of PBS (i.e., by one PBS Server).

Exclusive VP An exclusive VP is one that is used by one and only one job at a time. A set of VPs is assigned exclusively to a job for the duration of that job. This is typically done to improve the performance of message-passing programs.

Temporarily-shared VP A *temporarily-shared node* is one where one or more of its VPs are temporarily shared by jobs. If several jobs request multiple temporarily-shared nodes, some VPs may be allocated commonly to both jobs and some may be unique to one of the jobs. When a VP is allocated on a temporarily-shared basis, it remains so until all jobs using it are terminated. Then the VP may be re-allocated, either again for temporarily-shared use or for exclusive use.

If a host is defined as timeshared, it will never be allocated exclusively or temporarily-shared.

Load Balance A policy wherein jobs are distributed across multiple timeshared hosts to even out the workload on each host. Being a policy, the distribution of jobs across execution hosts is solely a function of the Job Scheduler.

Queue A *queue* is a named container for jobs within a Server. There are two types of queues defined by PBS, *routing* and *execution*. A *routing queue* is a queue used to move jobs to other queues including those that exist on different PBS Servers. Routing queues are similar to the old NQS pipe queues. A job must reside in an *execution queue* to be eligible to run and remains in an execution queue during the time it is running. In spite of the name, jobs in a queue need not be processed in queue order (first-come first-served or *FIFO*).

Node Attribute Nodes have attributes associated with them that provide control information. The attributes defined for nodes are: state, type (ntype), the list of jobs to which the node is allocated, properties, max_running, max_user_run, max_group_run, and both assigned and available resources (“resources_assigned” and “resources_available”).

Node Property A set of zero or more *properties* may be given to each node in order to have a means of grouping nodes for allocation. The property is nothing more than a string of alphanumeric characters (first character must be alphabetic) without meaning to PBS. The PBS administrator may assign to nodes whatever property names desired. Your choices for property names should be relayed to the users.

Portable Batch System PBS consists of one Job Server (pbs_server), one or more Job Scheduler (pbs_sched), and one or more execution servers (pbs_mom). The PBS System can be set up to distribute the workload to one large timeshared system, multiple time shared systems, a cluster of nodes to be used exclusively or temporarily-shared, or any combination of these.

The remainder of this chapter provides additional terms, listed in alphabetical order.

Account An *account* is arbitrary character string, which may have meaning to one or more hosts in the batch system. Frequently, account is used as a grouping for charging for the use of resources.

Administrator See Manager.

API PBS provides an *Application Programming Interface (API)* which is used by the commands to communicate with the Server. This API is described in the **PBS External Reference Specification**. A site may make use of the API to implement new commands if so desired.

Attribute An *attribute* is an inherent characteristic of a parent object (Server, queue, job, or node). Typically, this is a data item whose value affects the operation or behavior of the object and can be set by the owner of the object. For example, the user can supply values for attributes of a job.

Batch or Batch Processing This refers to the capability of running jobs outside of the interactive login environment.

Complex A *complex* is a collection of hosts managed by one batch system. It may be made up of nodes that are allocated to only one job at a time or of nodes that have many jobs executing at once on each node or a combination of these two scenarios.

Destination This is the location within PBS where a job is sent for processing. A destination may uniquely define a single queue at a single Server or it may map into many locations.

Destination Identifier This is a string that names the destination. It is composed two parts and has the format queue@server where server is the name of a PBS Server and queue is the string identifying a queue on that Server.

File Staging *File staging* is the movement of files between a specified location and the execution host. See “Stage In” and “Stage Out” below.

Group ID (GID) This numeric identifier is uniquely assigned to each group (see Group).

Group *Group* refers to collection of system users (see Users). A user must be a member of a group and may be a member of more than one. Within UNIX and POSIX systems, membership in a group establishes one level of privilege. Group membership is also often used to control or limit access to system resources.

Hold An artificial restriction which prevents a job from being selected for processing. There are three types of holds. One is applied by the job owner, another is applied by the operator or administrator, and a third applied by the system itself or the PBS administrator.

Job or Batch Job The basic execution object managed by the batch subsystem. A job is a collection of related processes which is managed as a whole. A job can often be thought of as a shell script running in a POSIX session. (A session is a process group the member processes cannot leave.) A non-singleton job consists of multiple tasks of which each is a POSIX session. One *task* will run the job shell script.

Manager The *manager* is the person authorized to use all restricted capabilities of PBS. The Manager may act upon the Server, queues, or jobs. The Manager is also called the administrator.

Operator A person authorized to use some but not all of the restricted capabilities of PBS is an *operator*.

Owner The owner is the user who submitted the job to PBS.

POSIX This acronym refers to the various standards developed by the “Technical Committee on Operating Systems and Application Environments of the IEEE Computer Society” under standard P1003.

Rerunable If a PBS job can be terminated and its execution restarted from the beginning without harmful side effects, the job is rerunable.

Stage In This process refers to moving a file or files to the execution host prior to the PBS job beginning execution.

Stage Out This process refers to moving a file or files off of the execution host after the PBS job completes execution.

User Each system *user* is identified by a unique character string (the user name) and by a unique number (the user id).

Task *Task* is a POSIX session started by MOM on behalf of a job.

User ID (UID) Privilege to access system resources and services is typically established by the *user id*, which is a numeric identifier uniquely assigned to each user (see User).

Virtual Processor (VP) See Cluster Node.

Chapter 3
Pre-Installation Planning

This chapter presents two sets of information needed prior to installing PBS. First, a summary of new features in this release of PBS Pro, version 5.1, is provided. Next is the information necessary to make certain planning decisions.

3.1 New Features in PBS Pro 5.1

The following is a list of major new features in release 5.1 of PBS Pro. Full descriptions are given in the referenced sections of the PBS Pro documentation:

Admin Simplification of distinction between cluster and timeshared nodes. (See “Changes to Time-shared and Cluster Nodes” on page 14.)

Admin Placement of PBS related files is now specified in the `/etc/pbs.conf` file. (See “/etc/pbs.conf” on page 119.)

Admin Simplified authentication in sites with common user namespace. (See “User Authorization” on page 125.)

Admin Ability to shutdown all of PBS with a single command. (See “Stopping PBS” on page 122.)

Admin Ability to requeue or abort a job running on a failed node. (See “Handling Jobs on Failed Nodes” on page 132.)

Admin Enhancements to pbsnodes command. (See “pbsnodes Command Changes” on page 140.)

Scheduler New Scheduler support for SMP clusters. (See “SMP Cluster Support” on page 99.)

Scheduler Improved Scheduler load balancing. (See “Enhanced Load Balancing” on page 100.)

Scheduler New preemptive scheduling feature. (See “Preemptive Scheduling” on page 101.)

Scheduler Ability to schedule dynamic consumable resources. (See “Dynamic Consumable Resources” on page 102.)

Scheduler Scheduling of new node attributes. (See “New Node Attributes” on page 103.)

User Changes to node and resource specification syntax. (See “New Node Specification Syntax” in the **PBS User Guide**.)

User Support for OpenMP jobs. (See “OpenMP Jobs with PBS” in the **PBS User Guide**.)

User Enhancements to Advance Reservation feature. (See “Advance Reservation of Resources” in the **PBS User Guide**.)

3.2 Changes to Time-shared and Cluster Nodes

For planning purposed, note that the differences between time-shared and cluster nodes in PBS Pro 5.1 have been reduced to:

1. Time-shared nodes are first choice for jobs that do not have a node specification.
2. Time-shared nodes may not be requested exclusively with the `#excl` suffix.
3. More processes than CPUs can be run on time-shared nodes but

not on cluster nodes.

4. If load balancing by "load average" is activated in the Job Scheduler, it applies only to time-shared nodes.

Allocation of cluster nodes remains based on the number of (virtual) processors.

3.3 Planning

PBS is able to support a wide range of configurations. It may be installed and used to control jobs on a single system or to load balance jobs on a number of systems. It may be used to allocate nodes of a cluster or parallel system to both parallel and serial jobs. It can also deal with a mix of these situations.

3.3.1 Single Timesharing System

If PBS is to be installed on one time-sharing system, all three daemons may reside on that system; or you may place the Server (pbs_server) and/or the Scheduler (pbs_sched) on a “front end” system. MOM (pbs_mom) must run on the system where jobs are to be executed.

3.3.2 Timesharing Cluster

If PBS is to be installed on a collection of time-sharing systems, a MOM must be on each execution host and the Server and Scheduler may be installed on one of the systems or on a front end system.

3.3.3 Large SMP systems

For large SMP systems (e.g. SGI Origin or Cray vector systems) it is best to plan to create these as “time-shared” systems rather than “cluster nodes”, in order to maximize the scheduling efficiency on these systems. In fact, to use the “cpuset” feature of an SGI Origin 2000/3000 system, you must declare the node as “time-shared”.

3.3.4 Interfacing with Globus

If Globus support is enabled, then a separate pbs_mom_globus must be run on the same host where the pbs_server is running. An entry must be made in the node file with `:gl` appended to the name. This is the only case in which two nodes may be defined with the same node name. One may be a Globus node (MOM), and the other a non-Globus node.

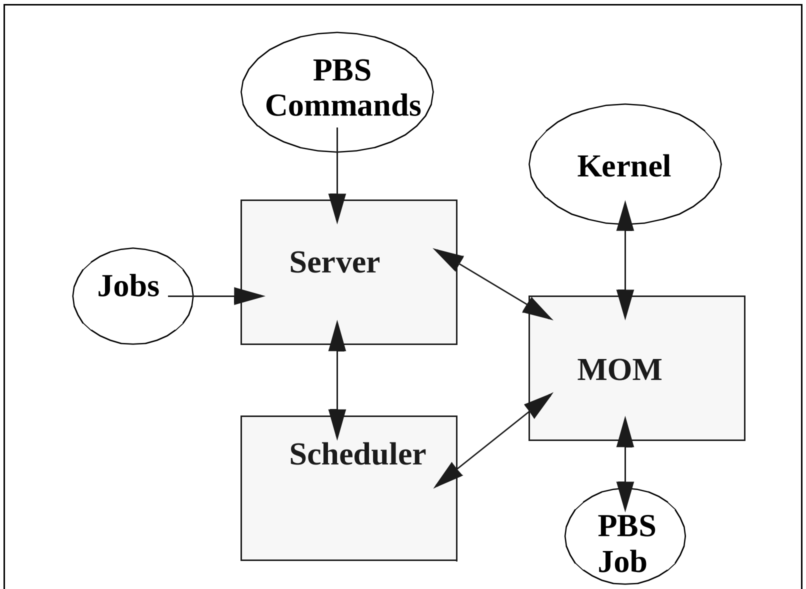
(Globus is discussed in more detail in the “Globus Support” section of the **PBS User Guide**.)

3.3.5 Running on Scyld Beowulf Clusters

If installing on a Scyld Beowulf cluster note that the cluster is controlled by a central "master node". This machine will run a single MOM. There is no need to have PBS installed on any of the Scyld Beowulf compute nodes.

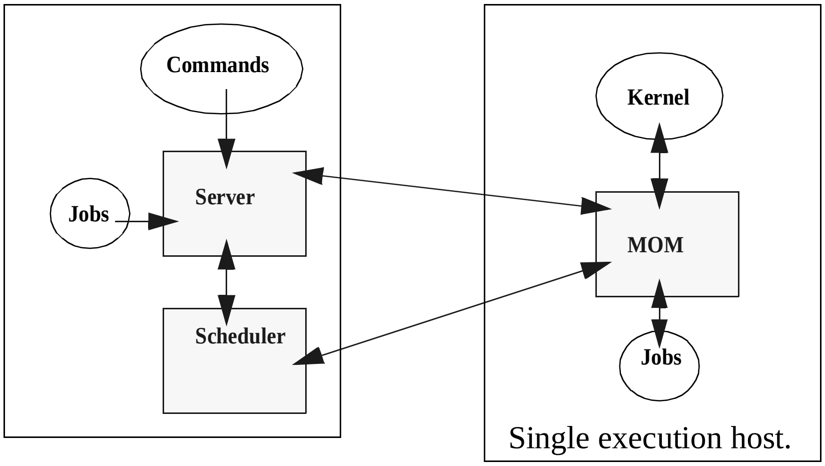
3.4 Single Execution System

If you are installing PBS on a single system, you are ready to install, configure the daemons, and select your scheduling policy.



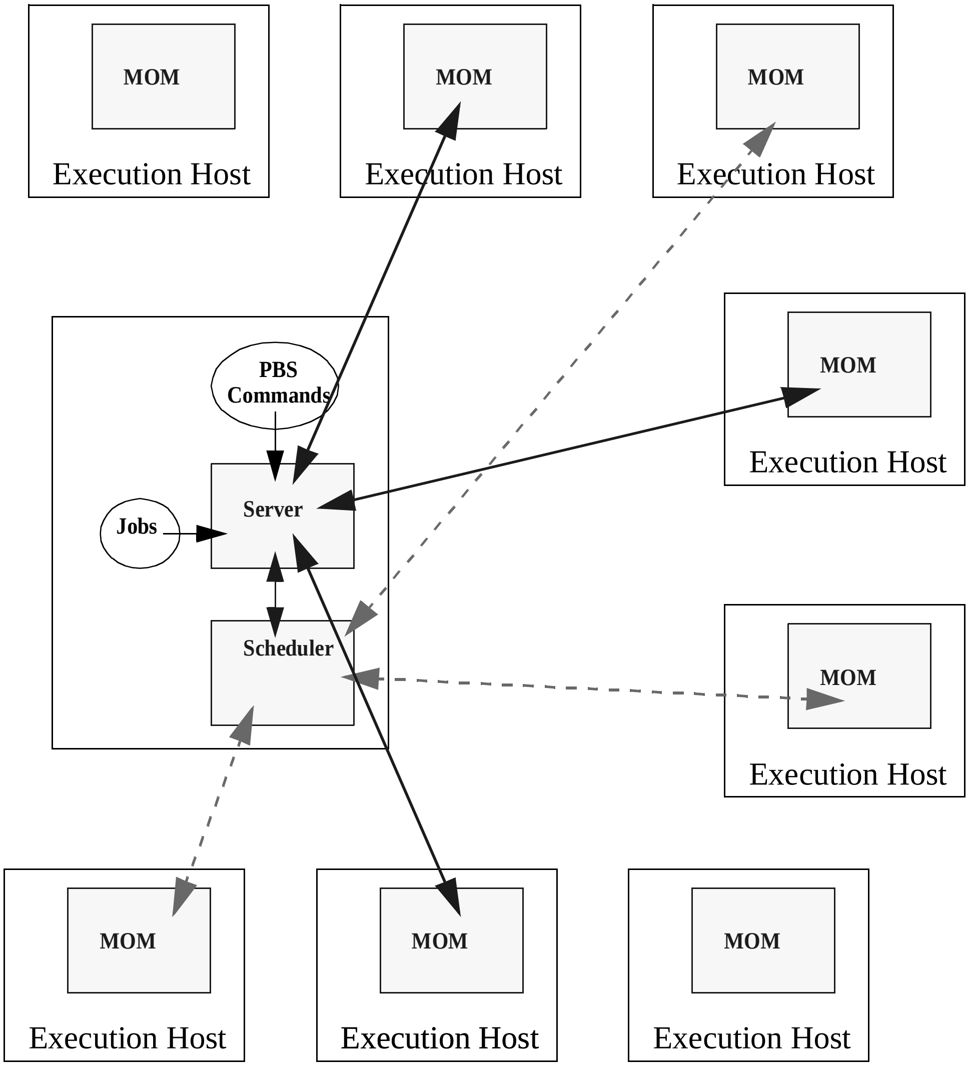
All daemons on a single host.

If you wish, the PBS Server and Scheduler, `pbs_server` and `pbs_sched`, can run on one system and jobs can execute on another. This is a trivial case of multiple execution systems discussed in the next section.



3.5 Multiple Execution Systems

If you are planning to run PBS on more than one computer, you will need to install the execution daemon (`pbs_mom`) on each system where jobs are expected to execute. The following diagram illustrates this for an eight node cluster.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Chapter 4
Installation

This chapter discusses the installation procedures for the PBS binary distribution package. This is the normal installation method for most sites. However, if you intend to install from the source code package, you should skip this chapter and read Chapter 5 “Installation from Source” on page 27.

4.1 Overview

The PBS software can be installed from the PBS CD-ROM or downloaded from the PBS website. The installation procedure is slightly different depending on the distribution source. However, the basic steps of PBS installation are:

Step 1	Prepare distribution media
Step 2	Extract and install the software
Step 3	Acquire a PBS license
Step 4	Install the license

4.2 Media Setup

If installing from the PBS CD-ROM, follow these instructions, with superuser privilege to set up the media for installation:

Step 1 Insert the PBS CD into the system CD-ROM drive
Step 2 Mount the CD-ROM onto the system
Step 3 Change directory to the mount point

```
# mount /cdrom
# cd /cdrom
```

Step 4 Continue with installation as described in the next section.

If not installing from CD-ROM, follow these instructions:

Step 1 Download the distribution file from the PBS website
Step 2 Move distribution file to `/tmp` on the system from which you intend to install PBS,

then, as superuser:

Step 3 Create a temporary location under `/tmp` from which to install the distribution
Step 4 Change directory to the temporary installation directory
Step 5 Uncompress the distribution file
Step 6 Extract the distribution file

```
# mkdir /tmp/pbs_tmp
# cd /tmp/pbs_tmp
# gunzip /tmp/pbspro_5_1.tgz
# tar -xvf /tmp/pbspro_5_1.tar
# cd PBSPro_5_1_1
```

Step 7 Continue with installation as described in the next section.

4.3 Default Install Options

The installation program of PBS installs the various PBS components into specific locations on the system. The installation program, however, allows you to override these default locations if you wish. The locations are written to the `/etc/pbs.conf` file created by the installation process. For details see the description of “/etc/pbs.conf” on page 119.

4.4 Installation

For a given system, the PBS install script uses the native package installer provided with that system. This means that the PBS package should install into what is considered the “normal” location for third-party software.

The following example shows a typical installation under Sun Solaris. The process is very similar for other operating systems, but may vary depending on the native package installer on each system.

```
# ./INSTALL
Installation of PBS

The following directory will be the root of the
installation. Several subdirectories will be created
if they don't already exist: bin, sbin, lib, man and
include.
Execution directory? [/usr/pbs]

PBS needs to have a private directory (referred to as
"PBS_HOME" in the documentation) where it can permanently
store information.
Home directory? [/usr/spool/PBS]

/usr/spool/PBS does not exist, I'll make it.
done

[ Description of the different configuration options ]

PBS Installation:
        1. Server, execution and commands
        2. Execution only
        3. Commands only
(1|2|3)?
```

You need to decide what kind of PBS installation you want for each machine. There are three possibilities: a Server node, an execution node, or a client host. If you are going to run PBS on a single timesharing host, install the Server package. If you are going to have a cluster of machines, you need to pick one to be the front end and install the Server package there. Then, install the execution package on all the other nodes in the cluster. The client package is for a host which will not be used for execution but still has access to PBS. It contains the commands, the GUI and man pages. This gives the ability to submit jobs and check status.

For the following examples, we will assume that you are installing PBS on a single large Server/execution host, on which all the daemons will run, and from which users will submit jobs. Given this, we select option **1** to the question shown in the example above, followed by “all” when asked which packages to add, as shown:

```
(1|2|3)? 1

Installing PBS for a Server Host.
The following packages are available:
  1  pbs64     pbs64    (sparc) 5.0

Select package(s) you wish to process (or 'all' to process
all packages). (default: all) [?,??,q]: all

Veridian Systems PBS department
## Processing package information.
## Processing system information.
## Verifying disk space requirements.
## Checking for conflicts with packages already installed.
## Checking for setuid/setgid programs.
```

Next the installation program will ask you to confirm that it is acceptable to install setuid/setgid programs as well as to run installation sub-programs as root. You should answer yes (or “**y**”) to both of these questions, as shown below.

```
## Checking for setuid/setgid programs.

The following files are being installed with setuid and/or
setgid permissions:
  /opt/pbs/sbin/pbs_iff <setuid root>
  /opt/pbs/sbin/pbs_rcp <setuid root>

Do you want to install these as setuid/setgid files
[y,n,?,q] y

This package contains scripts which will be executed with
super-user permission during the process of installing
this package.

Do you want to continue with the installation of <pbs64>
[y,n,?] y
```

Next, the installation program will proceed to extract and install the PBS package(s) that you selected above. The process should look similar to the example below.

```
Installing pbs64 as <pbs64>

## Installing part 1 of 1.
/etc/init.d/pbs
[ listing of files not shown for brevity ]

## Executing postinstall script.
*** PBS Installation Summary
***
*** The PBS Server has been installed in /opt/pbs/sbin.
***
*** The PBS commands have been installed in /opt/pbs/bin.
***
*** This host has the PBS Server installed, so
*** the PBS commands will use the local server.
*** The PBS command server host is mars
***
*** PBS Mom has been installed in /opt/pbs/sbin.
***
*** The PBS Scheduler has been installed in /opt/pbs/sbin.
***
Installation of <pbs64> was successful.
```

4.4.1 Installing MOM with SGI “cpuset” Support

PBS Pro for SGI IRIX systems provides optional (site-selectable) support for IRIX “cpusets”. A cpuset is a named region of the SGI system which contains a specific set of CPUs and associated memory. PBS has the ability to use the cpuset feature to “fence” PBS jobs into their own cpuset. This helps to prevent different jobs from interfering with each other. To enable use of this feature, a different PBS MOM binary needs to be installed, as follows:

```
# /etc/init.d/pbs stop
# cd /usr/pbs/sbin
# rm pbs_mom
# ln -s pbs_mom.cpuset pbs_mom
```

Additional information on configuring and using IRIX cpusets is discussed later in this manual. For scheduler configuration details, see section 9.3.1 “Scheduler Support for SGI IRIX cpusets” on page 109.

4.5 Installing the PBS License

The PBS license manager can handle multiple license keys in the PBS license file. This is useful when you expand your PBS configuration, you can simply add the additional licenses. This section describes adding a single license (such as following an initial installation of PBS Pro). The next section discusses adding multiple licenses.

Note that when requesting or generating your license key(s), the number of CPUs field should correspond with the total number of actual CPUs on which you wish to run PBS jobs.

When the installation of PBS is complete, you will need to install your PBS license key. If you already have your PBS license key, type it in when prompted by the license installation program, as shown below.

.

```
PBS license installation

Using /usr/spool/PBS as PBS_HOME
To get a license, please visit
        www.pbspro.com/license.html
 or call PBSpro toll free at 877-905-4PBS
 and have the following information handy:

***     host name:      mars.pbspro.com
***     host id:        12927f28
***     site id from the PBSPro package
***     number of cpus you purchased

Please enter the license string(s) (^d to end).
? 5-00020-99999-0044-PfV/fjuivg-5Jz

Installing: 5-00020-99999-0044-PfV/fjuivg-5Jz

Please enter the next license string(s) (^d to end).
?
Would you like to start PBS now (y|[n])? n
To start PBS, type '/etc/init.d/pbs start'
#
```

At this point, you can probably safely skip forward to Chapter 7 “Configuring the Server” on page 57.

However, if you have not yet received your PBS license key, follow the instructions printed by the installation program (see example above) to receive your key. Then rerun the PBS license key installation program as root:

```
# /usr/pbs/etc/pbs_setlicense
```

4.6 Installing Multiple PBS Licenses

As mentioned earlier, it is possible to add multiple licenses to the PBS License file. This can be done during installation of PBS Pro, or at some future time. If the installation program detects that you already have a PBS license file, it will prompt you as to what you want done: keep the file, replace the file, or append to it. Specify the option that corresponds to the action you wish to take.

Then, if you have multiple license keys, simply type them in when prompted by the license installation program, as shown in the example on the next page.

Note that you can invoke the license key installation program directly (as may be needed following an increase in the size of the system or cluster managed by PBS), using the “-a” (append) option:

```
# /usr/pbs/etc/pbs_setlicense -a
```

```
PBS license installation

Using /usr/spool/PBS as PBS_HOME
A license already exists in
 /usr/spool/server_priv/license_file.

Would you like to (k)eep it, (r)replace it, (a)ppend to
it, or (q)uit
([k]|a|q)? a

To get a license, please visit
     www.pbspro.com/UserArea/license_list.php
 or call PBSpro toll free at 877-905-4PBS
 and have the following information handy:

***     host name:      mars.pbspro.com
***     host id:        12927f28
***     site id from the PBSPro package
***     number of cpus you purchased

Please enter the license string(s) (^d to end).
? 5-00020-99999-0044-PfV/fjuivg-5Jz

Installing: 5-00020-99999-0044-PfV/fjuivg-5Jz

Please enter the next license string(s) (^d to end).
? 5-00020-99999-0010-XdsXdfssf-5Xj

Installing: 5-00020-99999-0010-XdsXdfssf-5Xj

Please enter the next license string(s) (^d to end).
?

Would you like to start PBS now (y|[n])? n
To start PBS, type '/etc/init.d/pbs start'
#
```

Chapter 5

Installation from Source

This chapter explains how to build and install PBS from the source code distribution. If you are installing from the binary distribution package, you should skip this chapter, and continue with Chapter 7 “Configuring the Server” on page 57.

5.1 Tar File

The PBS source distribution is provided as a single tar file. The tar file contains:

1. This document in both postscript and PDF form.
2. A “configure” script, and all source code, header files, and make files required to build and install PBS.
3. A full set of manual page sources. These are troff input files.

When the PBS tar file is extracted, a subtree of directories is created in which all the above mentioned files are created. The name of the top level directory of this subtree will reflect the release version and patch level of the version of PBS being installed. For example, the directory for PBS Pro 5.1 will be named pbspro_5_1_0.

5.2 Optional Components

To build PBS from source and to include support for optional features, several third party applications are required. This section describes these additional requirements.

5.2.1 POSIX make

PBS uses a `configure` script, generated by GNU's `autoconf` facility, to produce makefiles. If you have a POSIX-compliant `make` program then the makefiles generated by `configure` will try to take advantage of POSIX `make` features. If the `make` program that exists on your system is unable to process the makefiles, try using GNU's `make` program.

5.2.2 tcl/tk

If the Tcl/tk based GUI (`xpbs` and `xpbsmon`) or the Tcl based Scheduler is used, the Tcl header files and libraries are required. Versions of Tcl prior to 8.0 cannot be used with PBS. The official site for Tcl is:

```
http://www.scriptics.com/
ftp://ftp.scriptics.com/pub/tcl/tcl8_0
```

5.2.3 Globus Toolkit

If the Globus feature is enabled, ensure that Globus clients and libraries are installed. PBS currently works with the version 1.1.3 release of Globus. Check the following site for obtaining the Globus source code:

```
http://www.globus.org/
```

5.3 Build Steps

To generate a usable PBS installation, the following steps are required. Each step is explained in detail in the subsequent sections of this book.

Step 1 Read this guide and plan a general configuration of hosts and PBS.

Step 2 Decide where the PBS source and objects are to go. See also section 3.3 “Planning” on page 15.

Step 3 Unzip and untar the distribution file into the source tree. See section 5.5 “Overview” on page 30.

Step 4 Change the current working directory to that directory which is to be the top of the object tree. See section 5.5 “Overview” on page 30.

Step 5 Select “configure” options and run `configure` from the top of the object tree. See section 5.6 “Build Details” on page 33.

Step 6 Compile the PBS modules by typing `make` at the top of the object tree. See section 5.7 “Make File Targets” on page 41.

Step 7 As superuser, change directory to the top of the object tree, and install the PBS modules by typing `make install`.

Step 8 As superuser, complete the installation of PBS and set up license key file by typing `make postinstall`.

Step 9 Choose and follow a method for installing MOM. See section 5.9 “Install Options” on page 48.

Details of building PBS are given below. After installation, you can continue with Chapter 7 “Configuring the Server” on page 57 of this manual. If, however, you are planning to use an alternate scheduler you may wish to read Chapter 14 “Alternate Schedulers” on page 157 before continuing with the configuration of PBS.

5.4 Building PBS

This section explains in detail the steps to build and install PBS. In the following descriptions, the *source tree* is the subtree that gets created when the PBS tarfile is extracted. The *target tree* is the subtree of parallel directories in which the object modules are actually compiled. This tree may (and generally should) be separate from the source tree. So it is recommended that you create a separate directory to be the top of the target tree. The target tree is fleshed out with subdirectories and makefiles when `configure` is run.

The PBS build and installation process is accomplished using the make file and subdirectories that got created by running `configure`, a script created for PBS using GNU’s autoconf facility. You should change directory to the top level of the PBS target tree when doing the build and subsequent installation of PBS. This installation procedure requires more manual configuration than is “typical” for many packages. There are a number of options which involve site policy and therefore cannot be determined automagically.

5.5 Overview

As indicated above, the normal PBS build procedure is to separate the source tree from the target tree. This allows the placement of a single copy of the source on a shared file system from which multiple different target systems can be built. Also, the source can be protected from accidental destruction or modification by making the source read-only. However, if you choose, objects may be made within the source tree.

An overview of the “configure”, compile, installation and PBS configuration steps is listed here. Detailed explanation of symbols will follow. It is recommended that you read completely through these instructions before beginning the installation. To install PBS:

Step 1 Place the tar file on the system where you would like to maintain the source.

Step 2 Untar the tar file. For example:

```
# cd /usr/local/src
# tar xpf /CDROM/PBSPro_5.1.tar
#
```

It will untar in the current directory producing a single directory named for the current release and patch number. Under that directory will be several files and subdirectories. This directory and the subdirectories make up the *source tree*. You may write-protect the source tree at this point should you so choose.

In the top directory are two files, named `Release_Notes` and `INSTALL`. The `Release_Notes` file contains information about the release contents, changes since the last release and a reference to this guide for installation instructions. The `INSTALL` file consists of standard notes about the use of GNU’s configure.

Step 3 If you choose (as recommended) to have separate target and source trees, then create the top level directory of what will become the *target tree* at this time. The target tree must reside on a file system mounted on the same architecture as the target system for which you are generating the PBS binaries. This may be the same system that holds the source or it may not. Change directory to the top of the target tree. For example,

```
cd /usr/local/pbs/obj
```

Step 4 Make a job Scheduler choice. A unique feature of PBS is its external Scheduler module. This allows a site to implement any policy of its choice. To provide even more freedom in implementing policy, PBS provides two Scheduler frameworks. Schedulers may be developed in the C language, or the Tcl scripting language.

As distributed, `configure` will default to a C language based Scheduler known as *Standard*. This Scheduler can be configured to several common scheduling policies. When this Scheduler is installed, certain configuration files are installed in `/usr/spool/PBS/sched_priv/`. You will need to modify these files for your site. These files are discussed in Chapter 9 “Configuring the Scheduler” on page 97.

To change the selected Scheduler, see the two `configure` options `--set-sched` and `--set-sched-code` in the Features and Package Options section of this chapter. Additional information on the use and configuration of other Schedulers can be found in Chapter 14 “Alternate Schedulers” on page 157.

Step 5 Read section 5.6 “Build Details” on page 33 then, from within the top of the target tree created in step 3, type the following command

```
# /usr/local/src/pbspro_51/configure [options]
#
```

If you are building at the top of the source tree, type

```
./configure [options]
```

This will generate the complete target tree (starting with the current working directory), a set of header files, and all the make files needed to build PBS. Re-running the `configure` script will only need to be done if you choose to change options specified on the configure command line. See section 5.6 “Build Details” on page 33 for information on the configure options, or type

```
./configure --help
```

No options are absolutely required. Note that while GNU’s C compiler (gcc) will work with PBS, the vendor supplied C compiler is usually preferable. If you wish to build the GUI to PBS, and the Tcl libraries are not in the normal place (`/usr/local/lib`) then you will need to specify `--with-tcl=directory` giving the path to the Tcl libraries. If you want to enable Globus support within PBS, then you will need to specify the definitions for *SSL_DIR* and *LDAP_DIR* directories using `--with-globus=DIR`.

Running `configure` without any (other) options will prepare the build process to produce a working PBS system with the following defaults (which can be overridden as described below):

A. User commands are installed in `/usr/local/bin`.
B. Daemons and administrative commands are installed in /usr/local/sbin
C. Working directory for the daemons is `/usr/spool/PBS`
D. C-based Standard Scheduler will be selected

Because the number of options you select may be large and because each option is rather wordy you may wish to create a shell script consisting of the configure command and the selected options.

Step 6 After running the `configure` script, the next step is to compile PBS by typing

```
make
```

from the top of the target tree.

Step 7 To install PBS you must be running with root privileges. As root, type

```
make install
```

from the top of the target tree. This generates the working directory structures required for running PBS and installs the programs in the proper executable directories.

When the working directories are made, they are also checked to see that they have been setup with the correct ownership and permissions. This is performed to ensure that files are not tampered with and the security of PBS and your system are not compromised.

Running `make install` will create the `/etc/pbs.conf` file, or if it already exists then `/etc/pbs.conf.new` containing the locations for the executables and PBS_HOME set to what was specified on the configure options. (For details, see “/etc/pbs.conf” on page 119.)

Step 8 Complete the installation of PBS and set up the license key file by typing, as root:

```
make postinstall
```

First the `postinstall` program will create the PBS Server database (if it doesn’t already exist). When complete, it will contain the default queue and Server configuration described throughout this manual.

Next, `postinstall` will run `pbs_setlicense` which will prompt you for your PBS license key(s). For a full description of the license key installation process, with examples, see “Installing the PBS License” on page 24.

5.6 Build Details

While the overview gives sufficient information to build a basic PBS system, there are lots of options available to allow you to custom tailor PBS to suite your specific environment. The following tables list detailed information on the options to the `configure` script. This information is broken into three separate tables: generic `configure` options, directory and file options, and feature-specific options.

The table below lists the generic configure options available. These alter the behavior of `configure` itself, and therefore do not affect the functionality of PBS.

Generic Configure Options	Description and Defaults
`--cache-file=`*`FILE`*	Cache the system configuration test results in file *FILE* Default: `config.cache`
`--help`	Prints out information on the available options.
`--no-create`	Do not create output files.
`--quiet,--silent`	Do not print “checking” messages.
`--version`	Print the version of autoconf that created configure.
`--enable-depend-cache`	Turn on configure’s ability to cache *makedepend* information across runs of configure. This can be bad if the user makes certain configuration changes and reruns configure, but it can save time in the hands of experienced developers. Default: disabled

This second table lists configure options which allow you to specify the directories in which the PBS objects will be placed, as well as the location of specific files.

Directory and File Options	Description and Defaults
`--prefix=`*`PREFIX`*	Install files in subdirectories of directory *PREFIX* Default: **/usr/local**
`--exec-prefix=`*`EPREFIX`*	Install architecture dependent files in subdirectories of *EPREFIX*. The value specified will be written to the `/etc/pbs.conf` file. Default: *PREFIX (***/usr/local***)*
`--bindir=`*`DIR`*	Install user executables (commands) in subdirectory *DIR*. Default: *EPREFIX*/bin (**/usr/local/bin**)
`--sbindir=`*`DIR`*	Install System Administrator executables in subdirectory *DIR*. This includes certain administrative commands and the daemons. Default: *EPREFIX*/sbin (**/usr/local/sbin**)

Directory and File Options	Description and Defaults
--libdir=*DIR*	Object code libraries are placed in *DIR*. This includes the PBS API library, libpbs.a. Default: *PREFIX*/lib (**/usr/local/lib**
--includedir=*DIR*	C language header files are installed in *DIR*. Default: *PREFIX*/include (**/usr/local/include**)
--mandir=*DIR*	Install man pages in *DIR*. Default: *PREFIX*/man (**/usr/local/man**)
--srcdir=*TREE*	PBS sources can be found in directory *TREE*. Default: location of the `configure` script.
--x-includes=*DIR*	X11 header files are in directory *DIR*. Default: attempts to autolocate the header files
--x-libraries=*DIR*	X11 libraries are in directory DIR. Default: attempts to autolocate the libraries
--with-globus=*DIR*	Adding this option will enable Globus support within PBS. This will search *DIR* for the Globus header files, libraries, and `etc/makefile_header`. This option will cause a separate pbs_mom_globus daemon to be compiled and directories created.
--with-ssl=SSL*DIR*	Searches *SSLDIR* for the SSL include files and libraries. Use this option only if `--with-globus` could not expand *SSL_DIR*.
--with-ldap=*DIR*	Searches *DIR* for the OpenLDAP include files and libraries. Use this option only if `--with-globus` could not expand *LDAP_DIR*.

This third table lists the feature-specific options to configure. In general, these options take the following forms:

--disable-*FEATURE*	Do not compile for *FEATURE*, same as --enable-*FEATURE*=no
--enable-*FEATURE*	Compile for *FEATURE*
--with-*PACKAGE*	Compile to include *PACKAGE*
--without-PACKAGE	*Do not compile to include PACKAGE, same as --with-PACKAGE=no*
--set-*OPTION*	Set the value of *OPTION*

The recognized feature/package specific options of PBS are:

Feature Option	Description and Default
`--enable-server`	Build (or not build) the PBS Job Server, pbs_server. Normally all components (Commands, Server, MOM, and Scheduler) are built. Default: enabled
`--enable-mom`	Build (or not build) the PBS job execution daemon, pbs_mom. Default: enabled
`--enable-clients`	Build (or not build) the PBS commands. Default: enabled
`--with-tcl=`*`TDIR`*	Use this option if you wish Tcl based PBS features compiled and the Tcl libraries are not in `/usr/local/lib`. These Tcl based features include the GUI interface, `xpbs` and `xpbsmon`. If the following option, `--with-tclx`, is set, use this option only if the Tcl libraries are not co-located with the Tclx libraries. When set, *TDIR* must specify the absolute path of the directory containing the Tcl Libraries. Default: if `--enable-gui` is enabled, Tcl utilities are built; otherwise they are not built.
`--with-tclx=`*`TDIR`*	Use this option if you wish the Tcl based PBS features to be based on Tclx. This option implies `--with-tcl`. Default: Tclx is not used.
`--enable-gui`	Build the `xpbs` and `xpbsmon` GUI. Only valid if `--with-tcl` is set. Default: enabled
`--set-cc=`*`cprog`*	Specify which C compiler should be used. This will override the *CC* environment setting. If only `--set-cc` is specified, then *CC* will be set to `cc` Default: `gcc` (after all, configure is from GNU also)

Feature Option	Description and Default
`--set-cflags=`*`FLAGS`*	Set the compiler flags. This is used to set the *CFLAGS* variable. If only `--set-cflags` is specified, then *CFLAGS* is set to `“”`. Default: *CFLAGS* is set to a best guess for the system type.
`--enable-debug`	Builds PBS with debug features enabled. This causes the daemons to remain attached to standard output and produce vast quantities of messages. Default: disabled
`--set-tmpdir=`*`DIR`*	Set the temporary directory in which `pbs_mom` will create temporary scratch directories for jobs. Used on Cray systems only. Default: **`/tmp`**
`--set-server-home=`*`DIR`*	Sets the top level directory name for the PBS working directories, *PBS_HOME*. This directory **MUST reside on a file system which is local to the host** on which any of the daemons are running. That means you must have a local file system on any system where a pbs_mom is running as well as where pbs_server and/or pbs_sched is running. PBS uses synchronous writes to files to maintain state. We recommend that the file system has the same mount point and path on each host, that enables you to copy daemons from one system to another rather than having to build on each system. The value specified will be written to `/etc/pbs.conf`. Default: **/usr/spool/PBS**
`--set-server-name-file=`*`FILE`*	Set the file name which will contain the name of the default Server. This file is used by the commands to determine which Server to contact. If *FILE* is not an absolute path, it will be evaluated relative to the value of `--set-server-home`, *PBS_HOME*. The value specified will be written to the `/etc/pbs.conf` file. Default: `server_name`

Feature Option	Description and Default
`--set-default-server=HOST`	Set the name of the host that clients will contact when not otherwise specified in the command invocation. It must be the primary network name of the host. The value specified will be written to `/etc/pbs.conf`. Default: the name of the host on which PBS is being compiled.
`--set-environ=`*`PATH`*	Set the path name of the file containing the environment variables used by the daemons and placed in the environment of the jobs. For AIX based systems, we suggest setting this option to `/etc/environment`. Relative path names are interpreted relative to the value of `--set-server-home`, *PBS_HOME*. The value specified will be written to `/etc/pbs.conf`. Default: the file `pbs_environment` in the directory *PBS_HOME*.
`--enable-plock-daemons=`*`WHICH`*	Enable daemons to lock themselves into memory to improve performance. The argument *WHICH* is the bitwise-or of 1 for pbs_server, 2 for pbs_sched, and 4 for pbs_mom (7 is all three daemons). This option is recommended for Unicos systems. It must **not** be used for AIX systems. Note, this feature uses the plock() system call which is not available on Linux and bsd derived systems. Before using this feature, check that plock(3) is available on the system. Default: disabled.
`--enable-syslog`	Enable the use of syslog for error reporting. This is in addition to the normal PBS logs. Default: disabled
`--set-sched=`*`TYPE`*	Set the Scheduler (language) type. If set to `cc` a C based Scheduler will be compiled. If set to `tcl`, a Tcl based Scheduler will be used. If set to `no`, no Scheduler will be compiled. Default: cc

Feature Option	Description and Default
`--set-sched-code=`*`PATH`*	Sets the name of the file or directory containing the source for the Scheduler. This is only used for C Schedulers, where `--set-sched` is set to `cc`. For C Schedulers, this should be a directory name. If the path is not absolute, it will be interpreted relative to *`SOURCE_TREE`*`/src/scheduler.`*`SCHED_TYPE`*`/samples`. Default: `standard` (C based Scheduler)
`--enable-tcl-qstat`	Builds qstat with the Tcl interpreter extensions. This allows site and user customizations. Only valid if `--with-tcl` is already present. Default: disabled
`--set-tclatrsep=`*`CHAR`*	Set the character to be used as the separator character between attribute and resource names in Tcl/Tclx scripts. Default: `“.”`
`--set-mansuffix=`*`CHAR`*	Set the character to be used as the man page section suffix letter. For example, the qsub man page is installed as `man1/qsub.1B`. To install without a suffix, `--set-mansuffix=””`. Default: `“B”`
`--set-qstatrc-file=`*`FILE`*	Set the name of the file that qstat will use if there is no .qstatrc file in the user’s home directory. This option is only valid when `--enable-tcl-qstat` is set. If *FILE* is a relative path, it will be evaluated relative to the PBS Home directory, see `--set-server-home`. Default: *`PBS_HOME`*`/qstatrc`
`--with-scp`	Directs PBS to attempt to use the *Secure Copy Program* `scp` when copying files to or from a remote host. This option cause `PBS_SCP` to be set in `/etc/pbs.conf` with the indicated path. Default: `sbindir/pbs_rcp`

Feature Option	Description and Default
`--enable-shell-pipe`	When enabled, pbs_mom passes the name of the job script to the top level shell via a pipe. If disabled, the script file is the shell's standard input file. Default: enabled
`--enable-rpp`	Use the Reliable Packet Protocol, RPP, over UDP for resource queries to MOM by the Scheduler. If disabled, TCP is used instead. Default: enabled
`--enable-sp2`	Turn on special features for the IBM SP. This option is only valid when the PBS machine type is aix4. The PBS machine type is automatically determined by the configure script. With PSSP software before release 3.1, access to two IBM supplied libraries, libjm_client.a and libSDR.a, are required. These libraries are installed when the ssp.clients fileset in installed, and PBS will expect to find them in the normal places for libraries. With PSSP 3.1 and later, libjm_client.a and libSDR.a are not required, instead libswitchtbl.a is used to load and unload the switch. See the discussion under the sub-section **IBM SP** in section 5.8 “Machine Dependent Build Instructions” on page 41. Default: disabled
`--enable-nodemask`	Build PBS with support for SGI Origin2000 nodemask. Requires Irix 6.x. Default: disabled
`--enable-pemask`	Build PBS on Cray T3e with support for Scheduler controlled pe-specific job placement. Requires Unicos/MK2. Default: disabled
`--enable-srfs`	This option enables support for Session Reservable File Systems. It is only valid on Cray systems with the NASA modifications to support SRFS. Default: disabled

Feature Option	Description and Default
`--enable-cpuset`	Setting this under Irix 6.x forces the use of cpusets. Cpuset is a named set of CPUs where member processes are to be run. Enabling this feature does not use Array Session tracking; instead, jobs are tracked by session ids. Default: disabled
`--enable-uselog`	Setting this option will send `pbs_rcp` file transfer statistics to the system's log file. `pbs_rcp` is the default file transfer utility used by PBS to deliver user's input/output/error files. In order for this option to work, ensure that **LOG_INFO**, **LOG_DELAY**, or **LOG_LOCAL4** messages are enabled for your syslog. Default: disabled

5.7 Make File Targets

The following target names are applicable for make:

all The default target, it compiles everything.
build Same as all.
depend Builds the header file dependency rules.
install Installs everything.
clean Removes all object and executable files in the current subtree.
distclean Leaves the object tree very clean. It will remove all files that were created during a build.
postinstall Runs the script that installs the PBS license key(s).

5.8 Machine Dependent Build Instructions

There are a number of possible variables that are only used for a particular type of machine. If you are not building for one of the following types, you may ignore this section.

5.8.1 Linux

Redhat Linux version 4.x-7.x are supported with no special `configure` options required.

5.8.2 Sun Solaris Systems

On Solaris systems, if the system has more than 2GB of physical memory, PBS must be built with `--set-cflags="-g -xarch=v9"`, in order to correctly calculate memory amounts.

5.8.3 Digital UNIX

The following is the recommended value for CFLAGS when compiling PBS under Tru64 4.0D: `--set-cflags="-std1",` that is s-t-d-one.

5.8.4 HP-UX

The following is the recommended value for CFLAGS when compiling PBS under HP-UX 10.x:

```
--set-cflags="-Ae"
```

Under HP-UX 11.x, Tcl and Tk are not located in the directory expected by PBS's configure script. You will need to make a common directory for Tcl and Tk and point to it by setting

`--with-tcl=`*`new_directory`*.

Also, before compiling PBS under HP-UX 11.x, you need to define the environment variable: `AR=ar`

If building for a V2500 or N4000 system with PA8500 processors, also set the following variable for performance reasons:

```
CCOPTS=+DA2.0 ; export CCOPTS
```

If building for a PA2 system on which you may run 64 bit programs, you must build PBS with the following option added to *CFLAGS* so that PBS can correctly monitor memory use of 64 bit programs:

```
--set-cflags="-D_PSTAT64 -Ae"
```

5.8.5 IBM Workstations

PBS supports IBM workstations running AIX 4.x, however the AIX `man`(1) command has difficulty with the PBS man pages. When man pages are installed in *mandir* the default man page file name suffix, “B”, must be removed. This can be accomplished with the configure option `--set-mansuffix=””`. Also, do not use the configure option:

```
--enable-plock
```

on AIX workstations as it will crash the system by reserving all system memory.

5.8.6 IBM SP

Everything under the discussion about IBM Workstations also applies to the IBM SP series. Be sure to read the section 3.5 “Multiple Execution Systems” on page 17 before configuring the Server.

Set the special SP option, `--enable-sp2` to compile special code to deal with the SP high speed switch.

If the library *`libswitchtbl.a`* is not detected, it is assumed that you are running with PSSP software prior to 3.1. In this case, the IBM `poe` command sets up the high speed switch directly and PBS interfaces with the IBM Resource (Job) Manager to track which nodes jobs are using. PBS requires two libraries, `libjm_client.a` and `libSDR.a`, installed with the ssp.clients fileset.

If the library `libswitchtbl.a` is detected, it is assumed you are running with PSSP 3.1 or later software. In this case, PBS takes on the responsibility of loading the high speed switch tables to provide node connectivity.

Important: The PBS_HOME directory, see `--set-server-home`, used by the `pbs_mom` located on each node, **must** be on local storage and must have an identical path on each node. If the directory is setup in a different path, then MOM will not be able to initialize the SP switch correctly.

The node names provided to the Server **must** match the node names shown by the st_status command. This should be the “reliable” node name.

Important: Regardless of the number of real processors per node, the number of virtual processors that may be declared to the Server is limited to the number of Switch windows supported by the PSSP software. At the present time, this is eight (8). Therefore only eight virtual processors may be declared per node.

With PSSP 3.1, two additional items of information must be passed to the job: the switch window id (via a file whose name is passed), and a *job key* which authorizes a process to use the switch. As `poe` does not pass this information to the processes it creates, an underhanded method had to be created to present them to the job. Two new programs are compiled and installed into the *bindir* directory, `pbspoe` and `pbspd`.

`pbspoe` is a wrapper around the real `poe` command. pbspoe must be used by the user in place of the real `poe`. `pbspoe` modifies the command arguments and invokes the real `poe`, which is assumed to be in `/usr/lpp/ppe.poe/bin`. If a user specifies:

```
pbspoe a.out args
```

that command is converted to the effective command:

```
/usr/lpp/ppe.poe/bin/poe pbspd job_key \
winid_file a.out args -hfile $PBS_NODEFILE
```

PBS_NODEFILE of course contains the nodes allocated by pbs. The `pbs_mom` on those nodes have loaded the switch table with the user's uid, the job key, and a window id of zero. `pbspd` places the job key into the environment as *MP_PARTITION* and the window id as *MP_MPI_NETWORK* `pbspd` then exec's a.out with the remaining arguments.

If the user specified a command file to `pbspoe` with `-cmdfile` *`file`* then `pbspoe` prefixes each line of the command file with `pbspd job_key` and copies it into a temporary file. The temporary file is passed to `poe` instead of the user's file.

`pbspoe` also works with `/usr/lpp/ppe.poe/bin/pdbx` and `/usr/lpp/ppe.poe/bin/xpdbx`. This substitution is done to make the changes as transparent to the user as possible.

Important: Not all `poe` arguments or capabilities are supported. For example, `poe` job steps are not supported.

For transparent usage, it is **necessary** that after PBS is installed that you perform these additional steps:

Step 1 Remove IBM's `poe`, `pdbx`, and `xpdbx` from `/usr/bin` or any directory in the user's normal path. Be sure to leave the commands in /usr/lpp/ppe.poe/bin which should not be in the user's path, or if in the user's path must be after /usr/bin.

Step 2 Create a link named /usr/bin/poe pointing to*{bindir}*/pbspoe. Also make links for /usr/bin/pdbx and /usr/bin/xpdbx which point to *{bindir}*/pbspoe.

Step 3 Be sure that pbspd is installed in a directory in the user's normal path on each and every node.

5.8.7 SGI Systems Running IRIX 6

If built for Irix 6.x, pbs_mom will track which processes are part of a PBS job using POSIX session numbers. The PBS machine type (PBS_MACH) is set to irix6.

PBS can be built with cpuset support by setting --enable-cpuset. A cpuset names a set of CPUs for a job. Processes spawned for a job will be restricted to this set (both cpu-wise and memory-wise).

Specifically, PBS sets the following flags during cpuset creation:

```
CPUSET_CPU_EXCLUSIVE,
CPUSET_MEMORY_LOCAL
CPUSET_MEMORY_EXCLUSIVE
CPUSET_MEMORY_KERNEL_AVOID
CPUSET_MEMORY_MANDATORY
CPUSET_POLICY_KILL
CPUSET_EVENT_NOTIFY
```

See cpusetCreate(3) for more details.

The PBS machine type (PBS_MACH) is set to irix6cpuset. Note, if a Globus MOM (pbs_mom_globus) is being built, it will always have PBS_MACH set to "irix6".

A special job attribute *ssinodes* is expected to be set by the Scheduler, in order for pbs_mom to determine the list of CPUs to assign. *ssinodes* refers the number of single-system-image nodes to be assigned to a job. Another attribute, *nodemask* is set by pbs_mom to a hexadecimal string showing the nodes/CPUs assigned to a job-- 1 bit represents 1 node.

Finally, a special job attribute *hpm* can be used in a scheduler to take into account SGI's Hardware Performance Monitor (HPM). This is an attribute that allows users to take advantage of such software as `perfex`. SGI Origin2000's only allow one global counter at a time, so when the system is using it, users are unable to do so and vice versa. Specifying "`hpm`" in the job submission, specifies if it is to use the HPM counters.

The Standard Scheduler supports cpusets, as does one of the alternate schedulers: `sgi_origin_cpuset`. If you wish to use this alternate scheduler, review the configuration information in the documentation for this scheduler in the following directory of the source tree: `src/scheduler.cc/samples/sgi_origin_cpus`et. To enable this scheduler, be sure to specify these configure options:

```
--set-sched=cc
--set-sched-code=sgi_origin_cpuset
```

Important: IRIX 6 supports both 32 and 64 bit objects. In prior versions, PBS was typically built as a 32 bit object. Because of changes in structure sizes, PBS will not be able to recover any Server, queue, or job information recorded by a PBS Server built with 32 bit objects, or vice versa. Please read Chapter 6 "Upgrading PBS" on page 51 for instructions on dealing with this incompatibility.

5.8.8 Cray C90, J90, and T90 Systems

On the traditional Cray systems such as the C90, PBS supports Unicos versions 8, 9 and 10. Because of the fairly standard usage of the symbol ***TARGET*** within the PBS makefiles, when building under Unicos you cannot have the environment variable *TARGET* defined. Otherwise, it is changed by Unicos's make to match the makefile value, which confuses the compiler. If set, type `unsetenv TARGET` before making PBS.

If your system supports the Session Reservable File System (SRFS) enhancement by NASA, run configure with the `--enable-srfs` option. If enabled, the Server and MOM will be compiled to have the resource names *srfs_tmp, srfs_big, srfs_fast,* and *srfs_wrk.* These may be used from `qsub` to request SRFS allocations.

The file `/etc/tmpdir.conf` is the configuration file for this. An example file is:

```
# Shell environ var Filesystem
TMPDIR
BIGDIR /big/pbs
FASTDIR /fast/pbs
WRKDIR /big/pbs
```

The directory for *TMPDIR* will default to that defined by *JTMPDIR* in Unicos's `/usr/include/tmpdir.h`.

Without the SRFS mods, MOM under Unicos will create a temporary job scratch directory. By default, this is placed in `/tmp`. The location can be changed via `--set-tmpdir=`*`DIR`*

5.8.9 Unicos 10 with MLS

If you are running Unicos MLS, required in Unicos 10.0 and later, the following action is required after the system is built and installed. MOM updates **ue_batchhost** and **ue_batchtime** in the UDB for the user. In an MLS system, MOM must have the security capability to write the protected UDB. To grant this capability, change directory to wherever `pbs_mom` has been installed and type:

```
spset -i 16 -j daemon -k exec pbs_mom
```

You, the administrator, must have capabilities **secadm** and **class 16** to issue this command. You use the `setucat` and `setucls` commands to get to these levels if you are authorized to do so. The UDB **reclsfy** permission bit gives a user the proper authorization to use the `spset` command.

5.8.10 Cray T3E

On the Cray T3E MPP systems, PBS supports the microkernal-based Unicos/MK version 2. On this system PBS "cooperates" with the T3E Global Resource Manager (GRM) in order to run jobs on the system. This is needed primarily since jobs on the T3E must be run on physically contiguous processing elements (PEs).

Previous discussions regarding the environment variable *TARGET,* support for Session Reservable File System, and the changing of *TMPDIR* are also applicable to the Cray T3E.

5.9 Install Options

There are four ways in which a MOM may be installed on each of the various execution hosts.

Step 1 The first method is to do a full install of PBS on each host. While this works, it is a bit wasteful.

Step 2 The second way is to rerun configure with the following options:
`--disable-server --set-sched=no`

You may also choose `--disable-clients` but users often use the PBS commands within a job script so you will likely want to build the commands. You will then need to recompile and then do an install on each execution host.

Step 3 The third way is to install just MOM (and maybe the commands) on each system. If the system will run the same binaries as where PBS was compiled, then as root:

```
      # cd src/resmom
      # make install
      # cd ../cmds
      # make install.
      #
```

If the system requires recompiling, do so at the top level to recompile the libraries and then proceed as above.

Step 4 The fourth requires that the system be able to execute the existing binaries and that the directories *`sbindir`* and *`bindir`* in which the PBS daemons and commands were installed during the initial full build be available on each host. These directories, unlike the *PBS_HOME* directory can reside on a network file system.

If the target tree is accessible on the host, as root execute the following commands on each execution host:

```
sh {target_tree}/buildutils/pbs_mkdirs [-d new_dir] mom
sh {target_tree}/buildutils/pbs_mkdirs [-d new_dir] aux
sh {target_tree}/buildutils/pbs_mkdirs [-d new_dir] default
```

This will build the required portion of *PBS_HOME* on each host. Use the `-d` option if you wish to place *PBS_HOME* in a different place on the node. This directory must be on local storage on the node, not on a shared file system. If you use a different path for *PBS_HOME* than was specified when configure was run, you must also start pbs_mom with the corresponding `-d` option so she knows where *PBS_HOME* is located.

If the target tree is not accessible, copy the `pbs_mkdirs` shell script to each execution host and, again as root, execute it with the above operands.

Note that the initial run of the Server or any first time run after recreating the home directory must be with the `-t create` option. This option directs the Server to create a new Server database. This is best done by hand.

If a database is already present, it is discarded after receiving a positive validation response. At this point it is necessary to configure the Server. See Chapter 7 “Configuring the Server” on page 57 for details. The create option leaves the Server in a “idle” state. In this state the Server will not contact the Scheduler and jobs are not run, except manually via the `qrun`(1B) command.

Once the Server is up and configured, it can be placed in the “active” state by setting the Server attribute `scheduling` to a value of `true`:

```
# qmgr -c “set server scheduling=true”
```

The value of `scheduling` is retained across Server terminations/starts. After the Server is configured it may be placed into service.

You will now need to configure the PBS daemons as discussed in Chapter 7, Chapter 8, and Chapter 9.

Chapter 6
Upgrading PBS

This chapter provides important information on upgrading from a previous version of PBS. If you are not currently running PBS, you can safely skip this chapter at this time. Be sure to refer to it before preforming a future upgrade of PBS.

6.1 Running Multiple PBS Versions

Once you have a running PBS configuration, there will come a time when you will want to update or install a new version. It is assumed that you will want to test the new version, possibly while leaving your existing configuration in place and running. PBS allows you to do this by specifying alternative daemon directories and port numbers.

When the new version is ready to be placed into service, you will wish to move jobs from the old system to the new. The following procedure is suggested. All Servers must be run by root. The `qmgr` and `qmove` commands should be run by a PBS administrator (likely, root is good).

Step 1 With the old PBS daemons running, disable the queues by setting each queue’s “enabled” attribute to false, and stop any further scheduling by setting the Server’s “scheduling” attribute to false.

```
# qmgr
Qmgr: set queue workq enabled = false
Qmgr: set server scheduling = false
Qmgr: quit
```

Step 2 Backup this Server’s jobs directory, `/usr/spool/PBS/server_priv/jobs` -- tar may used for this.

```
# cd /usr/spool/PBS/server_priv
# tar -cf /tmp/pbs_jobs_save jobs
```

Assuming the change is a minor update (change in third digit of the release version number) or a local change where the job structure did not change from the old version to the new, it is likely that you could start the new system in the old directory and all jobs would be recovered. However, if the job structure has changed (i.e. when upgrading to PBS Pro 5.1) you will need to *move* the jobs from the old system to the new. The release notes will contain a warning if the job structure has changed or the move is required for other reasons.

To move the jobs, continue with the following steps:

Step 3 Start the new PBS Server in its new *PBS_HOME* (e.g. `/usr/local/PBS`) directory. If the new *PBS_HOME* is different from the directory when it was compiled, use the -d option to specify the new location. Use the -t option if the Server has not been configured for the new directory. Also start with an alternative port using the -p option. Turn off attempts to schedule with the -a option:

```
# pbs_server -t create -d new_home \
  -p 13001 -a false
```

Remember, you will need to use the `:port` syntax when commanding the new Server.

Step 4 Duplicate on the new Server the current queues and Server attributes (assuming you wish to do so). Enable each queue which will receive jobs at the new Server.

```
# qmgr -c “print server" > /tmp/q_config
# qmgr host:13001  < /tmp/q_config
# qenable workq@host:13001
# qenable someq@host:13001
 ...
```

Step 5 Now list the jobs at the original Server and move a few jobs one at a time from the old to the new Server:

```
# qstat
# qmove workq@host:13001 job_id
# qstat @host:13001
```

If all is going well, move the remaining jobs a queue at a time:

```
# qmove workq@host:13001 ‘qselect -q workq‘
# qstat workq@host:13001
# qmove someq@host:13001 ‘qselect -q someq‘
# qstat someq@host:13001
...
```

Step 6 At this point, all of the jobs should be under control of the new Server and located in the new Server’s home. If the new Server’s home is a temporary directory, shut down the new Server with `qterm` and move everything to the real home as follows:

```
# cp -R new_home real_home
```

or, if the real (new) home is already set up, do the following to copy just the jobs from the jobs subdirectory:

```
# cd new_home/server_priv/jobs
# cp * real_home/server_priv/jobs
```

Now you are ready to start and enable the new batch system.

You should be aware of one quirk when using `qmove`. If you wish to move a job from a Server running on a test port to the Server running on the normal port (15001), you may attempt, *unsuccessfully* to use the following command:

```
# qmove workq@host 123.job.host:13001
```

However, doing so will only serve to move the job to the end of the queue it is already in. The Server receiving the move request (e.g. the Server running on port 13001), will compare the destination Server name, host, with its own name only, not including the port. Hence it will match and it will not send the job where you intended. To get the job to move to the Server running on the normal port you have to specify that port in the destination:

```
# qmove workq@host:15001 123.job.host:13001
```

6.2 Alternate Test Systems

Running an alternate or test version of PBS requires a couple extra steps. In particular, the alternate version will need a separate PBS directory structure to run from, which must be created before attempting to start the alternate version.

If building PBS from source code, the easiest manner to create the alternate directory structure is to rerun the `configure` command with the --set-server-home option set the desired value for the alternate *PBS_HOME***.** Next, rebuild and install PBS. (See Chapter 5 for additional information on building from source.)

If not building from source code, you can copy your existing PBS directory tree to the new location. (`Tar` may be used for this.) However you will want to ensure that you delete any job data that might have been copied to the alternate location.

```
# cd existing_PBS_HOME
# tar -cvf /tmp/pbs_tree.tar .
# mkdir /path/to/alternate_PBS_HOME
# cd /path/to/alternate_PBS_HOME
# tar -xvf /tmp/pbs_tree.tar
# /bin/rm server_priv/jobs/*  mom_priv/jobs/*
#
```

Alternate or test copies of the various daemons may be run through the use of the command line options which set their home directory and service port. For example, the following commands would start the three daemons with a home directory of `/tmp/altpbs` and four ports around 13001, the Server on 13001, MOM on 13002 and 13003, optional MOM Globus on 13004, 13005, and the Scheduler on 13004.

```
# pbs_server -t create -d /tmp/altpbs -p 13001 -M 13002 \
   -R 13003 -S 13004 -g 13005 -G 13006
# pbs_mom -d /tmp/altpbs -M 13002 -R 13003
# pbs_sched -d /tmp/altpbs -S 13004 -r script_file
# pbs_mom_globus -d /tmp/altpbs -M 13005 -R 13006
```

Note that when the Server is started with a non-standard port number (i.e. with the `-p` option as shown above) the Server “name” becomes *host_name.domain:port* where port is the numeric port number being used.

Jobs may now be directed to the test system by using the `-q` option to qsub with the `server:port` syntax. Status is also obtained using the `:port` syntax. For example, to submit a job to the default queue on the above test Server, request the status of the test Server, and request the status of jobs at the test Server:

```
# qsub  -q @host:13001 jobscript
# qstat -Bf host:13001
# qstat @host:13001
#
```

Important: If using job dependencies on or between test systems, there are minor problems of which you (and the users) need to be aware. The syntax of both the dependency string and the job `host:port` syntax use colons in an indistinguishable manner. The way to work around this is covered in “Dependent Jobs and Test Systems” on page 146 of this manual.

Chapter 7

Configuring the Server

Now that PBS has been installed, the Server and MOMs must be configured and the scheduling policy selected. The next three chapters will walk you through this process.

If you installed PBS from the binary distribution, then further configuration may not be required as the default configuration may completely meet your needs. However, you are advised to read this chapter to determine if the default configuration is indeed complete for you, or if any of the optional setting may apply.

7.1 Network Addresses and Ports

PBS makes use of fully qualified host names for identifying the jobs and their location. A PBS installation is known by the host name on which the Server is running. The name used by the daemons, or used to authenticate messages is the canonical host name. This name is taken from the primary name field, `h_name`, in the structure returned by the library call `gethostbyaddr()`. According to the IETF RFCs, this name must be fully qualified and consistent for any IP address assigned to that host.

The daemons and the commands will attempt to use `/etc/services` to identify the standard port numbers to use for communication. The port numbers need not be below the magic 1024 number. The service names that should be added to `/etc/services` are:

```
pbs                15001/tcp # PBS Server (pbs_server)
pbs_mom            15002/tcp # MOM to/from Server
pbs_resmon         15003/tcp # MOM RM requests
pbs_resmon         15003/udp # MOM RM requests
pbs_sched          15004/tcp # PBS Scheduler
pbs_mom_globus     15005/tcp # MOM Globus
pbs_resmon_globus  15006/tcp # MOM Globus RM requests
pbs_resmon_globus  15006/udp # MOM Globus RM requests
```

The port numbers listed are the default numbers used by this version of PBS. If you change them, be careful to use the same numbers on all systems. Note, the name *pbs_resmon* is a carry-over from early versions of PBS when there existed separate daemons for job execution (pbs_mom) and resource monitoring (pbs_resmon). The two functions were combined into pbs_mom though the term "resmom" might be found referring to the combined functions. If the services cannot be found in /etc/services, the PBS components will default to the above listed numbers.

7.2 qmgr

The PBS manager command, qmgr, provides a command-line administrator interface to the PBS Server. There are several command line options to qmgr.

Option	Action
-a	Abort qmgr on any syntax errors or any requests rejected by a Server.
-c command	Execute a single command and exit qmgr. The command must be enclosed in quote marks, e.g. qmgr -c "print server"
-e	Echo all commands to standard output.
-n	No commands are executed, syntax checking only is performed.
-z	No errors are written to standard error.

If qmgr is invoked without the -c option and standard output is connected to a terminal, qmgr will write a prompt to standard output and read a directive from standard input.

A command is terminated by a new line character or a semicolon (";”) character. Multiple commands may be entered on a single line. A command may extend across lines by escaping the new line character with a back-slash (“\”). Comments begin with the “#” character and continue to end of the line. Comments and blank lines are ignored by `qmgr`. The syntax of each directive is checked and the appropriate request is sent to the Server(s). A `qmgr` directive takes one of the following forms:

```
command server [names] [attr OP value[,...]]
command queue  [names] [attr OP value[,...]]
command node   [names] [attr OP value[,...]]
```

Where command is the command to perform on a object. Commands are:

Command	Explanation
active	Sets the active objects. If the active objects are specified, and the name is not given in a `qmgr` command the active object names will be used.
create	Create a new object, applies to queues and nodes.
delete	Destroy an existing object, applies to queues and nodes.
set	Define or alter attribute values of the object.
unset	Clear the value of the attributes of the object. Note, this form does no accept an OP and value, only the attribute name.
list	List the current attributes and associated values of the object.
print	Print all the queue and Server attributes in a format that will be usable as input to the `qmgr` command.

Other qmgr syntax definitions follow:

Variable	qmgr Variable/Syntax Description
names	The list of one or more names of specific objects. The name list is in the form: `[name][@server][,name[@server]...]` with no intervening white space. The name of an object is declared when the object is first created. If the name is @server, then all the object of specified type at the Server will be effected.
attr	Specifies the name of an attribute of the object which is to be set or modified. The attributes of objects are described in section 2 of the **PBS ERS**. If the attribute is one which consists of a set of resources, then the attribute is specified in the form: attribute_name.resource_name
OP	An operation to be performed with the attribute and its value:
=	Set the value of the attribute. If the attribute has an existing value, the current value is replaced with the new value.
+=	Increase the current value of the attribute by the amount in the new value.
-=	Decrease the current value of the attribute by the amount in the new value.
value	The value to assign to an attribute. If value includes white space, commas, or other special characters, such as "#", the value string must be inclosed in quote marks (" ").

The list or print subcommands of qmgr can be executed by the general user. Creating or deleting a queue requires PBS Manager privilege. Setting or unsetting Server or queue attributes requires PBS Operator or Manager privilege.

Here are several examples that illustrate using the qmgr command. Full explanation of these and other qmgr commands are given below in explanation of the specific tasks they accomplish.

```
% qmgr
Qmgr: create node mars ntype=cluster
Qmgr: set node mars resources_available.ncpus=2
Qmgr: create node venus properties=”inner,moonless”
Qmgr: set node mars properties = inner
Qmgr: set node mars properties += haslife
Qmgr: delete node mars
Qmgr: d n venus
```

Important: Commands can be abbreviated to their minimum unambiguous form (as shown in the last line in the example above).

7.3 Default Configuration

Server management consists of configuring the Server attributes, defining nodes, and establishing queues and their attributes. The default configuration from the binary installation sets the minimum Server settings, and some recommended settings for a typical PBS cluster. (The default Server configuration is shown below.) The subsequent sections in this chapter list, explain, and provide the default settings for all the Server’s attributes for the default binary installation.

```
% qmgr
Qmgr: print server
# Create queues and set their attributes.
#
# Create and define queue workq
#
create queue workq
set queue workq queue_type = Execution
set queue workq enabled = True
set queue workq started = True
#
# Set server attributes.
#
set server scheduling = True
set server default_queue = workq
set server log_events = 511
set server mail_from = adm
set server query_other_jobs = True
set server scheduler_iteration = 600
```

7.4 Server Attributes

This section explains all the available Server attributes and gives the default values for each. Note that the possible values for the “boolean” format are any of: “TRUE”, “True”, “true”, “Y”, “y”, “1”; “FALSE”, “False”, “false”, “N”, “n”, “0”.

The privilege required to set or change some Server attributes has changed since the previous release. Specifically, `mail_from`, `resources_cost`, and `system_cost` now require Manager privilege. `comment` requires at least operator privilege.

acl_host_enable

Attribute which when `true` directs the Server to use the `acl_hosts` access control lists. Requires full Manager privilege to set or alter. Format: boolean
Default value: false = disabled
`Qmgr:` **`set server acl_hosts_enable=true`**

acl_hosts

List of hosts which may request services from this Server. This list contains the fully qualified network name of the hosts. Local requests, i.e. from the Server’s host itself, are always accepted even if the host is not included in the list. Wildcards (“*”) may be used in conjunction with host names and host.subdomain names.
Format: “[+|-]hostname.domain[,...]”.
Default value: all hosts
`Qmgr:` **`set server acl_hosts=*.pbspro.com`**

acl_user_enable

Attribute which when true directs the Server to use the Server level `acl_users` access list. Requires full Manager privilege to set or alter.
Format: boolean (see acl_group_enable).
Default value: disabled
`Qmgr:` **`set server acl_user_enable=true`**

acl_users

List of users allowed or denied the ability to make any requests of this Server. Requires full Manager privilege to set or alter.
Format: “[+|-]user[@host][,...]”.
Default value: all users allowed
`Qmgr:` **`set server acl_users=bob,tom@sol,sue@sol`**

acl_roots

List of superusers who may submit to and execute jobs at this Server. If the job execution id would be zero (0), then the job owner, root@host, must be listed in this access control list or the job is rejected.
Format: “[+|-]user[@host][,...]”.
Default value: no root jobs allowed
`Qmgr:` **`set server acl_roots=host`**

comment

A text string which may be set by the scheduler or other privileged client to provide information to PBS users. Format: any string.
Default value: none

```
Qmgr: set server comment=”Planets Cluster”
```

default_node

A node specification to use if there is no other supplied specification. The default value allows jobs to share a single node.
Format: a node specification string.
Default value: 1#shared

```
Qmgr: set server default_node=”1#shared”
```

default_queue

The queue which is the target queue when a request does not specify a queue name.
Format: a queue name.
Default value: none, must be set to an existing queue

```
Qmgr: set server default_queue=workq
```

flatuid

Attribute which directs the Server to automatically grant authorization for a job to be run under the user name of the user who submitted the job even if the job was submitted from a different host. If not set `true`, then the Server will check the authorization of the job owner to run under that name if not submitted from the Server's host. See section 11.6.4 “User Authorization” on page 125.
Format: boolean
Default value: False

```
Qmgr: set server flatuid=True
```

log_events

A bit string which specifies the type of events which are logged, (see also section 11.10 “Use and Maintenance of Logs” on page 130).
Format: integer.
Default value: 511, all events

```
Qmgr: set server log_events=255
```

mail_from

The uid from which Server generated mail is sent to users.
Format: integer uid
Default value: 0 for root

```
Qmgr: set server mail_uid=1264
```

managers

List of users granted PBS Manager privileges.
Format: “user@host.sub.domain[,user@host.sub.domain...]” .
The host, sub-domain, or domain name may be wild carded by the use of an * character. Requires Manager privilege to set or alter.
Default value: root on the local host

```
Qmgr: set server managers+=boss@sol.pbspro.com
```

max_running

The maximum number of jobs allowed to be selected for execution at any given time. Advisory to the Scheduler, not enforced by the Server. Format: integer.
Default value: none

```
Qmgr: set server max_running=24
```

max_user_run

The maximum number of jobs owned by a single user that are allowed to be running from this queue at one time. This attribute is advisory to the Scheduler, it is not enforced by the Server.
Format: integer
Default value: none

```
Qmgr: set server max_user_run=6
```

max_group_run

The maximum number of jobs owned by any users in a single group that are allowed to be running from this queue at one time. This attribute is advisory to the Scheduler, it is not enforced by the Server.
Format: integer
Default value: none

```
Qmgr: set server max_group_run=16
```

node_pack

Controls how multiple processor nodes are allocated to jobs. If this attribute is set to true, jobs will be assigned to the multiple processor nodes with the fewest free processors. This packs jobs into the fewest possible nodes leaving multiple processor nodes free for jobs which need many processors on a node. If set to `false`, jobs will be scattered across nodes reducing conflicts over memory between jobs. If unset, the jobs are packed on nodes in the order that the nodes are declared to the Server (in the nodes file).
Format: boolean
Default value: unset (assigns nodes in order declared)

```
Qmgr: set server node_pack=true
```

operators

List of users granted batch operator privileges.
Format of the list is identical with `managers` above. Requires full Manager privilege to set or alter.
Default value: root on the local host.

```
Qmgr: set server operators=sue,bob,joe,tom
```

query_other_jobs

The setting of this attribute controls whether or not general users, other than the job owner, are allowed to query the status of or select the job. Requires Manager privilege to set or alter (see `acl_host_enable`).
Format: boolean
Default value: false (users may not query or select jobs owned by other users.)

```
Qmgr: set server query_other_jobs=true
```

resources_available

The list of resources and amounts available to jobs run by this Server. The sum of the resources of each type used by all jobs running by this Server cannot exceed the total amount listed here. Advisory to the Scheduler, not enforced by the Server.
Format: “resources_available.resource_name=value[,...]”.

```
Qmgr: set server resources_available.ncpus=16
Qmgr: set server resources_available.mem=400mb
```

resources_cost

The cost factors of various types of resources. These values are used in determining the order of releasing members of synchronous job sets. For the most part, these values are purely arbitrary and have meaning only in the relative values between systems. The cost of the resources requested by a job is the sum of the products of the various `resources_cost` values and the amount of each resource requested by the job. It is not necessary to assign a cost for each possible resource, only those which the site wishes to be considered in synchronous job scheduling.
Format: “resources_cost.resource_name=value[,...]”
Default value: none (cost of resource is not computed)

```
Qmgr: set server resources_cost.mem=100
```

resources_default

The list of default resource values that are set as limits for a job executing on this Server when the job does not specify a limit, and there is no queue default.
Format: “resources_default.resource_name=value[,...]
Default value: no limit

```
Qmgr: set server resources_default.mem=8mb
Qmgr: set server resources_default.ncpus=1
```

resources_max

The maximum amount of each resource which can be requested by a single job executing on this Server if there is not a `resources_max` valued defined for the queue in which the job resides.
Format: “resources_max.resource_name=value[,...]
Default value: infinite usage

```
Qmgr: set server resources_max.mem=1gb
Qmgr: set server resources_max.ncpus=32
```

scheduler_iteration

The time, in seconds, between iterations of attempts by the Server to schedule jobs. On each iteration, the scheduler examines the available resources and runnable jobs to see if a job can be initiated. This examination also occurs whenever a running job terminates or a new job is placed in the queued state in an execution queue.
Format: integer seconds
Default value: 10 minutes

```
Qmgr: set server scheduler_iteration=300
```

scheduling Controls if the Server will request job scheduling by the PBS Scheduler. If true, the scheduler will be called as required; if false, the Scheduler will not be called and no job will be placed into execution unless the Server is directed to do so by a PBS operator or Manager. Setting or resetting this attribute to `true` results in an immediate call to the Scheduler.
Format: boolean (see `acl_host_enable`)
Default value: value of `-a` option when Server is invoked, if `-a` is not specified, the value is recovered from the prior Server run. If it has never been set, the value is “false”.

```
Qmgr: set server scheduling=true
```

system_cost An arbitrary value factored into the resource cost of any job managed by this Server for the purpose of selecting which member of a synchronous set is released first.
Default value: none, cost of resource is not computed

```
Qmgr: set server system_cost=7
```

The following attributes are read-only: they are maintained by the Server and cannot be changed by a client.

resources_assigned
The total amount of certain resources allocated to running jobs.

server_name The name of the Server, which is the same as the host name. If the Server is listening to a non-standard port, the port number is appended, with a colon, to the host name. For example: `host.domain:9999`

server_state The current state of the Server. Possible values are:

State	Meaning
Active	The Server is running and will invoke the Scheduler as required to schedule jobs for execution.
Idle	The Server is running but will not invoke the Scheduler
Scheduling	The Server is running and there is an outstanding request to the job scheduler
Terminating	The Server is terminating. No additional jobs will be scheduled
Terminating, Delayed	The Server is terminating in delayed mode. The Server will not run any new jobs and will shutdown when the last currently running job completes.

state_count The total number of jobs managed by the Server currently in each state

total_jobs The total number of jobs currently managed by the Server.

PBS_version The release version number of the Server.

7.5 Queue Attributes

Once you have the Server attributes set the way you want them, you will next want to review the queue attributes. The default (binary) installation creates one queue with the required attributes, as shown in the example below.

You may wish to change these settings or add other attributes or add additional queues. The following discussion will be useful in modifying the PBS queue configuration to best meet your specific needs.

```
% qmgr
Qmgr: print queue work
#
# Create and define queue workq
#
create queue workq
set queue workq queue_type = Execution
set queue workq enabled = True
set queue workq started = True
#
Qmgr:
```

There are two types of queues defined by PBS: routing and execution. A routing queue is a queue used to move jobs to other queues including those which exist on different PBS Servers. Routing queues are similar to the old NQS pipe queues. A job must reside in an execution queue to be eligible to run. The job remains in the execution queue during the time it is running. In spite of the name, jobs in a queue need not be processed in queue-order (first-come first-served or *FIFO*). A Server may have multiple queues of either or both types, but there must be at least one queue defined. Typically it will be an execution queue; jobs cannot be executed while residing in a routing queue.

Queue attributes fall into three groups: those which are applicable to both types of queues, those applicable only to execution queues, and those applicable only to routing queues. If an “execution queue only” attribute is set for a routing queue, or vice versa, it is simply ignored by the system. However, as this situation might indicate the administrator made a mistake, the Server will issue a warning message about the conflict. The same message will be issued if the queue type is changed and there are attributes that do not apply to the new type.

Queue public attributes are alterable on request by a client. The client must be acting for a user with Manager or Operator privilege. Certain attributes require the user to have full administrator privilege before they can be modified. The following attributes apply to both queue types:

acl_group_enable

Attribute which when true directs the Server to use the queue’s group access control list `acl_groups`.
Default value: false = disabled
`Qmgr: set queue QNAME acl_group_enable=true`

acl_groups

List which allows or denies enqueuing of jobs owned by members of the listed groups. The groups in the list are groups on the Server host, not submitting host.
Format: “[+|-]group_name[,...]”
Default value: all groups allowed
`Qmgr: set queue QNAME acl_groups=math,physics`

acl_host_enable

Attribute which when true directs the Server to use the `acl_hosts` access list.
Format: boolean
Default value: disabled
`Qmgr: set queue QNAME acl_host_enable=true`

acl_hosts

List of hosts which may enqueue jobs in the queue.
Format: “[+|-]hostname[...]”
Default value: all hosts allowed
`Qmgr: set queue QNAME acl_hosts=sol,star`

acl_user_enable

Attribute which when true directs the Server to use the `acl_users` access list for this queue.
Format: boolean (see acl_group_enable);
Default value: disabled
`Qmgr: set queue QNAME acl_user_enable=true`

acl_users

List of users allowed or denied the ability to enqueue jobs in this queue.

Format: “[+|-]user[@host][,...]”
Default value: all users allowed

```
Qmgr: set queue QNAME acl_users=sue,bob@star
```

enabled

Queue will or will not accept new jobs. When false the queue is *disabled* and will not accept jobs.
Format: boolean
Default value: disabled

```
Qmgr: set queue QNAME enabled=true
```

from_route_only

When true, this queue will accept jobs only when being routed by the Server from a local routing queue. This is used to force user to submit jobs into a routing queue used to distribute jobs to other queues based on job resource limits.
Default value: disabled

```
Qmgr: set queue QNAME from_route_only=true
```

max_queuable

The maximum number of jobs allowed to reside in the queue at any given time.
Default value: infinite

```
Qmgr: set queue QNAME max_queuable=200
```

max_running

The maximum number of jobs allowed to be selected from this queue for routing or execution at any given time. For a routing queue, this is enforced by the Server, if set.

```
Qmgr: set queue QNAME max_running=16
```

priority

The priority of this queue against other queues of the same type on this Server. May affect job selection for execution/routing.

```
Qmgr: set queue QNAME priority=123
```

queue_type

The type of the queue: execution or route. This attribute must be explicitly set.
Format: “execution”, “e”, “route”, “r”.

```
Qmgr: set queue QNAME queue_type=route
Qmgr: set queue QNAME queue_type=execution
```

resources_max

The maximum amount of each resource which can be requested by a single job in this queue. The queue value supersedes any Server wide maximum limit.

```
Qmgr: set queue QNAME resources_max.mem=2gb
Qmgr: set queue QNAME resources_max.ncpus=32
```

resources_min

The minimum amount of each resource which can be requested by a single job in this queue.

```
Qmgr: set queue QNAME resources_min.mem=1b
Qmgr: set queue QNAME resources_min.ncpus=1
```

resources_default

The list of default resource values which are set as limits for a job residing in this queue and for which the job did not specify a limit. If not set, the default limit for a job is determined by the first of the following attributes which is set: Server's `resources_default`, queue's `resources_max`, Server's `resources_max`. An unset resource is viewed as unlimited.
Format: "resources_default.*resource_name*=*value*"
Default value: none

```
Qmgr: set queue QNAME resources_default.mem=1b
Qmgr: set queue QNAME resources_default.ncpus=1
```

started

Jobs may be scheduled for execution from this queue. When false, the queue is considered *stopped.*

```
Qmgr: set queue QNAME started=true
```

The following attributes apply only to execution queues:

checkpoint_min

Specifies the minimum interval of cpu time, in minutes, which is allowed between checkpoints of a job. If a user specifies a time less than this value, this value is used instead.

```
Qmgr: set queue QNAME checkpoint_min=5
```

kill_delay

The amount of the time delay between the sending of SIGTERM and SIGKILL when a `qdel` command is issued against a running job. Format: integer seconds
Default value: 2 seconds

```
Qmgr: set queue QNAME kill_delay=5
```

hasnodes

If true, indicates that the queue has nodes associated with it.
Format: boolean

max_user_run

The maximum number of jobs owned by a single user that are allowed to be running from this queue at one time.

```
Qmgr: set queue QNAME max_user_run=5
```

max_group_run

The maximum number of jobs owned by any users in a single group that are allowed to be running from this queue at one time.

```
Qmgr: set queue QNAME max_group_run=20
```

resources_available

The list of resource and amounts available to jobs running in this queue. The sum of the resource of each type used by all jobs running from this queue cannot exceed the total amount listed here.

```
Qmgr: set queue QNAME resources_available.mem=1gb
```

The following attributes apply only to route queues:

alt_router

If true, a site-supplied alternative job router function is used to determine the destination for routing jobs from this queue. Otherwise, the default, round-robin router is used.

```
Qmgr: set queue QNAME alt_router=true
```

route_destinations

The list of destinations to which jobs may be routed.
Default value: none, should be set to at least one destination.

```
Qmgr: set queue QNAME route_destinations=QueueTwo
```

route_held_jobs

If true, jobs with a hold type set may be routed from this queue. If false, held jobs are not to be routed.

```
Qmgr: set queue QNAME route_held_jobs=true
```

route_lifetime

The maximum time a job is allowed to exist in a routing queue. If the job cannot be routed in this amount of time, the job is aborted. If unset or set to a value of zero (0), the lifetime is infinite.
Format: integer seconds
Default infinite

```
Qmgr: set queue QNAME route_lifetime=600
```

route_retry_time

Time delay between route retries. Typically used when the network between servers is down.
Format: integer seconds
Default value: PBS_NET_RETRY_TIME (30 seconds)

```
Qmgr: set queue QNAME route_retry_time=120
```

route_waiting_jobs

If true, jobs with a future `execution_time` attribute may be routed from this queue. If false, they are not to be routed.

```
Qmgr: set queue QNAME route_waiting_jobs=true
```

The following data items are read-only attributes of the queue. They are visible to client commands, but can-not be changed by them.

total_jobs The number of jobs currently residing in the queue.

state_count The total number of jobs currently residing in the queue in each state.

resources_assigned

The total amount of certain types of resources allocated to jobs running from this queue.

Important: Note, an *unset* resource limit for a job is treated as an infinite limit.

Important: The privilege required to set or change some queue attributes has changed since the previous release. Specifically, `from_route_only`, `route_destinations`, and `alt_router` now require Manager privilege.

7.6 Nodes

Where jobs will be run is determined by an interaction between the Scheduler and the Server. This interaction is affected by the contents of the PBS `nodes` file, and the system configuration onto which you are deploying PBS. Without this list of nodes, the Server will not establish a communication stream with the MOM(s) and MOM will be unable to report information about running jobs or notify the Server when jobs complete.

If the PBS configuration consists of a single timeshared host on which the Server and MOM are running, all the jobs will run there. The Scheduler only needs to specify which job it wants run.

If you are running a timeshared complex with *one* or more execution hosts, where MOM is on a different host than the Server, then distributing jobs across the various hosts is a matter of the Scheduler determining on which host to place a selected job.

If your cluster is made up of cluster nodes and you are running distributed (multi-node) jobs, as well as serial jobs, the Scheduler typically uses the *Query Resource* or *Avail* request to the Server for each queued job under consideration. The Scheduler then selects one of the jobs that the Server replied could run, and directs that the job should be run. The

Server will then allocate one or more virtual processors on one or more nodes as required to the job.

By setting the Server's `default_node` specification to one temporarily-shared node (e.g. `1#shared`) jobs which do not request nodes will be placed together on a few `temporarily-shared` nodes.

If your system contains both cluster nodes and one timeshared node, the situation is like the above, except you may wish to change the value of `default_node` to be that of the timeshared host. Jobs that do not ask for nodes will end up running on the timeshared host.

If you have a configuration supporting both cluster nodes and multiple time shared hosts, you have a complex system. The Scheduler must recognize which jobs request nodes and use the *Avail* request to the Server. It must also recognize which jobs are to be balanced among the timeshared hosts, and provide the host name to the Server when directing that the job be run. The Standard scheduler does this.

Important: Regardless of node type, each node must be defined in the Server's nodes file, `/usr/spool/PBS/server_priv/nodes`. Time-shared nodes have `:ts` appended to their node name. Cluster nodes have no name suffix.

In PBS, allocation of cluster nodes (actually the allocation of virtual processors, VPs, of the nodes) to a job is handled by the Server. Each node must have its own copy of MOM running on it. If only timeshared hosts are to be served by the PBS batch system, the Job Scheduler must direct where the job should be run. If unspecified, the Server will execute the job on the host where it is running.

7.6.1 PBS Nodes File

A basic nodes file is created for you by the install procedure. This file contains only the name of the host from which the install was run and set as a time-shared host. If you have more than one host in your PBS cluster or you are not planning on running jobs on the Server's host, you need to edit the list of nodes to reflect your site.

You may edit the nodes list in one of two ways. If the Server is not running, you may directly edit the `nodes` file with a text editor. If the Server is running, you should use `qmgr` to edit the list of nodes.

The *node list* is defined to the Server in the file `/usr/spool/PBS/server_priv/nodes`. This is a simple text file with the specification of a single node per line in the file.

The format of each line in the file is:

```
node_name[:ts] [attributes]
```

The *node name* is the network name of the node (host name), it does not have to be fully qualified (in fact it is best if it is as short as possible). The optional `:ts` appended to the name indicates that the node is a timeshared node.

Nodes can have attributes associated with them. Attributes come in three types: properties, name=value pairs, and name.resource=value pairs.

Zero or more properties may be specified. The *property* is nothing more than a string of alphanumeric characters (first character must be alphabetic) without meaning to PBS. Properties are used to group classes of nodes for allocation to a series of jobs.

Any legal node name=value pair may be specified in the node file in the same format as on a `qsub` directive: `attribute.resource=value`. For example:

```
NodeA resource_available.ncpus=3 max_running=1
```

The expression `np=`*`NUMBER`* may be used as shorthand for `resources_available.ncpus=NUMBER`, which can be added to declare the number of virtual processors (VPs) on the node. *NUMBER* is a numeric string, for example `np=4`. This expression will allow the node to be allocated up to *NUMBER* times to one job or more than one job. If `np=`*`NUMBER`* is not specified for a cluster node, it is assumed to have one VP.

Important: Note that some attribute values are obtained from MOM, if not specified in the nodes file.

These include:

```
resources_available.ncpus
resources_available.arch
resources_available.mem
```

Each item on the line must be separated by white space. The items may be listed in any order, except that the host name must always be first. Comment lines may be included if the first non-white space character is the pound sign ’#’.

The following is an example of a possible nodes file for a cluster called “planets”:

```
# The first set of nodes are cluster nodes.
# Note that the properties are provided to
# logically group certain nodes together.
# The last node is a timeshared node.
#
mercury    inner moonless
venus      inner moonless np=1
earth      inner np=1
mars       inner np=2
jupiter    outer np=18
saturn     outer np=16
uranus     outer np=14
neptune    outer np=12
pluto:ts
```

7.6.2 Creating or Adding nodes:

After `pbs_server` is started, the node list may be entered or altered via the `qmgr` command:

```
create node node_name [attribute=value]
```

where the attributes and their associated possible values are shown in the table below.

The `busy` state is set by the execution daemon, `pbs_mom`, when a load-average threshold is reached on the node. See *max_load* in MOM’s config file (“Static Resources” on page 93). `The job-exclusive` and `job-sharing` states are set when jobs are running on the node.

Important: Please note, all comma separated strings must be enclosed in quotes.

Below are several examples of setting node attributes via `qmgr`.

```
% qmgr
Qmgr: create node mars np=2,ntype=cluster
Qmgr: create node venus properties=”inner,moonless”
```

Modify nodes: Once a node has been created, its attributes and/or properties can be modified using the following `qmgr` syntax:

`set node` *`node_name`* `[attribute[+|-]=value]`

where attributes are the same as for `create`. For example:

```
% qmgr
Qmgr: set node mars properties=inner
Qmgr: set node mars properties+=haslife
```

Delete nodes: Nodes can be deleted via `qmgr` as well, using the `delete node` syntax, as the following example shows:

```
% qmgr
Qmgr: delete node mars
Qmgr: delete node pluto
```

7.7 Node Attributes

A node has the following public attributes:

state — The state of the node, one of: `free, down, offline`
Format: string
`Qmgr: `**`set node`** ***`MyNode`*** **`state=offline`**

properties — Any alphanumeric string or comma separated set of strings, starting with an alphabetic character.
Format: string
`Qmgr: `**`set node`** ***`MyNode`*** **`properties=”red,blue”`**

ntype — The type of the node, one of : `cluster, time-shared`
Format: string
`Qmgr: `**`set node`** ***`MyNode`*** **`ntype=cluster`**

resources_available

List of resources available on node.
Format: resource list

np

Abbreviation for `resources_available.ncpus`. A number of virtual processors greater than zero.
Format: integer > 0

```
Qmgr: set node MyNode np=12
```

resources_assigned

List of resources in use on node.
Format: resource list

max_running

Maximum number of running jobs; advisory to scheduler.
Format: integer

```
Qmgr: set node MyNode max_running=22
```

max_user_run

Maximum number of running jobs per user; advisory.
Format: integer

```
Qmgr: set node MyNode max_user_run=4
```

max_group_run

Maximum number of running jobs per group; advisory.
Format: integer

```
Qmgr: set node MyNode max_group_run=8
```

queue

Name of an execution queue (if any) associated with the node. Only jobs from the named queue will be run on associated node.
Format: queue specification

```
Qmgr: set node MyNode queue=MyQueue
```

reservations

List of reservations pending on the node; read-only.
Format: reservation specification

comment

General comment, e.g. the reason the node is marked down or offline; can be set by Manager or Operator.
Format: string

```
Qmgr: set node MyNode comment=”Down until 5pm”
```

7.7.1 Setting Node Limits

It is possible to set limits on queues (and the Server) as to how many nodes a job can request. The `nodes` resource itself is a text string and difficult to limit. However, two additional Read-Only resources exist for jobs. They are `nodect` and `neednodes`. `Nodect` (node count) is set by the Server to the integer number of nodes desired by the user as declared in the "`nodes`" resource specification. That declaration is parsed and the resulting total number of nodes is set in `nodect`. This is useful when an administrator wishes to place an integer limit, `resources_min` or `resources_max` on the number of nodes used by a job entering a queue.

Based on the earlier example of declaring nodes, if a user requested a nodes specification of: `3:inner+2:outer`, then `nodect` would get set to 5 (i.e. 3+2). `Neednodes` is initially set by the Server to the same value as `nodes`. `Neednodes` may be modified by the job Scheduler for special policies. The contents of `neednodes` determines which nodes are actually assigned to the job. `Neednodes` is visible to the Manager but not to an unprivileged user.

If you wish to set up a queue default value for "`nodes`" (a value to which the resource is set if the user does not supply one), corresponding default values must be set for "`nodect`" and "`neednodes`". For example:

```
% qmgr
Qmgr: set queue small resources_default.nodes=1:inner
Qmgr: set queue small resources_default.nodect=1
Qmgr: set queue small resources_default.neednodes=1:inner
```

Minimum and maximum limits are set for "`nodect`" only. For example:

```
% qmgr
Qmgr: set queue small resources_min.nodect=1
Qmgr: set queue small resources_max.nodect=15
Qmgr:
```

Important: Minimum and maximum values must **not** be set for either `nodes` or `neednodes` as their value are strings.

7.7.2 Nodes Specification Information

This section provides additional information about working with the PBS nodes file and nodes specification.

Step 1 If a single specific host is named in the Run Job request and the host is specified in the nodes file as a *timeshared* host, the Server will attempt to run the job on that host.

Step 2 If either:

(a) a specific host is named in the Run Job and the named node does not appear in the Server's `nodes` file as a timeshared host;

or

(b) a "+" separated list of hosts [or node properties] is specified in the Run Job request;

then, the Server attempts to allocate one (or more as requested) virtual processor on the named *cluster* node(s)named in the job. All of the named nodes have to appear in the Server's `nodes` file. If the allocation succeeds, the job [shell script] is run on the first of the nodes allocated.

Step 3 If no location was specified on the Run Job request, but the job requests nodes, then the required number of virtual processors on cluster nodes which match the request are allocated if possible. If the allocation succeeds, the job is run on the node allocated to match the first specification in the node request. Note, the Scheduler may modify the job's original node request, see the job attribute `neednodes`

For SMP nodes, where multiple virtual processors have been declared, the order of allocation of processors is controlled by the setting of the Server attribute `node_pack`

If set true, VPs will first be taken from nodes with the fewest free VPs. This *packs* jobs into the fewest possible nodes, leaving nodes available with many VPs for those jobs that need many VPs on a node.

If `node_pack` is set false, VPs are allocated from nodes with the most free VPs. This scatters jobs across the nodes to minimize conflict between jobs.

If `node_pack` is not set to either true or false, i.e. *unset* then the VPs are allocated in the order that the nodes are declared in the

Server's nodes file.

Important: Be aware, that if `node_pack` is set, the internal order of nodes is changed. If `node_pack` is later unset, the order will no longer be changed, but it will not be in the order originally established in the `nodes` file.

Step 4 If the Server attribute `default_node` is set, its value is used. If this matches the name of a time-shared node, the job is run on that node. If the value of `default_node` can be mapped to a set of one or more free cluster nodes, they are allocated to the job.

Step 5 If `default_node` is not set, and at least one time-shared node is defined, that node is used. If more than one is defined, the first is selected for the job.

Step 6 The last choice is to act as if the job has requested `1#shared`. The job will have allocated to it an existing job-shared VP, or if none exists, then a free VP is allocated as job-shared.

The `exec_host` string and the `runjob` destination string is now of the form:

```
nodename/P[*C][+nodename/P[*C]...]
```

where **`P`** is the number of processes (tasks) to run on that node and **`C`** is the number of CPUs per process.

7.7.3 Node Comments

Nodes have a "comment" attribute which can be used to display information about that node. If the comment attribute has not be explicitly set by the PBS Manager and the node is down, it will be used by the PBS Server to display the reason the node was marked down. If the Manager has explicitly set the attribute, the Server will not overwrite the comment.

The comment attribute may be set via the `qmgr` command:

```
% qmgr
Qmgr: set node alpha comment=”node will be up at 5pm”
```

7.8 Job Attributes

Tabular listing of attributes of a PBS job are given in the **PBS User Guide** under the heading “Job Attributes”.

7.9 PBS Resources

PBS has a standard set of "resources" which may be specified as a job requirement. Common examples of the predefined standard resources are:

cput	amount of CPU time
mem	amount of real memory
ncpus	number of CPUs
nodes	number and type of execution nodes
walltime	amount of real clock time

Depending on site policy, the required resources may be considered against the availability of the resources to determine ordering of jobs for execution and placement of jobs on an execution host.

7.9.1 Defining New Resources

It is possible for the PBS Manager to define new resources within PBS. Once created, jobs may request these new resources and the Scheduler can be directed to consider the new resources in the scheduling policy. (See section “Dynamic Consumable Resources” on page 102 for instructions on how to configure the Scheduler to use the new resources you create.) To define one or more new resources, the Administrator creates a file, `(PBS_HOME)/server_priv/resourcedef`. Each line in the file defines a resource. The format of each line is:

```
RESOURCE_NAME [type=RTYPE] [flag=FLAGS]
```

`RESOURCE_NAME` is any string made up of alphanumeric characters, starting with a alphabetic character. The underscore character, “_”, and the hyphen, “-”, are also allowed.

`RTYPE` is the type of the resource value, one of the following key words:

long	the value is a long integer

float the value is a floating point number

size the value is a integer number following by a suffix denoting magnitude k, m, g, t and b for bytes or w for words.

string a null terminated string

If not specified, the resource will default to type long.

FLAGS is a set of characters which indicate if the Server should accumulate the requested amounts of the resource in the attribute resources_assigned when the job is run. The value of flag is the concatenation of one or more of the following letters:

q the amount is tracked at the Queue and Server level

n the amount is tracked at the Node level, for all nodes assigned to the job

f the amount is tracked at the Node level for only the first node allocated to the job

If not specified, the resource will not be accumulated in resources_assigned. For example, if the Administrator created the following lines in /usr/spool/pbs/server_priv/resourcedef:

```
kolas   type=long       flag=q
pandas  type=size       flag=qn
kiwi    type=size       flag=f
wombat  type=string     flag=q
```

A user may specify any of these resources on job submission, as the following example shows:

```
% qsub -l kolas=4,pandas=10gb,wombat=brown \
  -l kiwi=3kb -lnodes=2  script
```

If the job resides in the execution queue "workq" and is executing on nodes NodeA and NodeB, then

queue "workq" would show:

```
resources_assigned.kolas=4
resources_assigned.pandas=10gb
```

```
     resources_assigned.wombat=brown
```

node NodeA, the first node allocated, would show:

```
     resources_assigned.kiwi=3gb
     resources_assigned.pandas=10gb
```

node NodeB would show:

```
     resources_assigned.pandas=10gb
```

7.9.2 Resource Min/Max Attributes

Minimum and maximum queue and Server limits work with numeric valued resources, including time and size values. Generally, they do not work with string valued resources because of character comparison order. However, setting the `min` and `max` to the same value to force an exact match will work even for string valued resources.

```
% qmgr
Qmgr: set queue big resources_max.arch=unicos8
Qmgr: set queue big resources_min.arch=unicos8
Qmgr:
```

The above example can be used to limit jobs entering queue `big` to those specifying `arch=unicos8`. Again, remember that if `arch` is not specified by the job, the tests pass automatically and the job will be accepted into the queue.

7.10 Advanced Configuration Options

This section discusses several advanced configuration options, and provides additional, supplemental information for configuration of the PBS Server.

7.10.1 Selective Routing of Jobs into Queues

Often it is desirable to route jobs to various queues on a Server, or even between Servers, based on the resource requirements of the jobs. The queue *resources_min* and *resources_max* attributes discussed above make this selective routing possible. As an example, let us assume you wish to establish two execution queues, one for short jobs of less than one minute cpu time, and the other for long running jobs of one minute or longer.

Call them `short` and `long`. Apply the `resources_min` and `resources_max` attribute as follows:

```
% qmgr
Qmgr: set queue short resources_max.cput=59
Qmgr: set queue long resources_min.cput=60
```

When a job is being enqueued, it’s requested resource list is tested against the queue limits: `resources_min` <= job_requirement <= `resources_max`. If the resource test fails, the job is not accepted into the queue. Hence, a job asking for 20 seconds of cpu time would be accepted into queue `short` but not into queue `long`.

Important: Note, if the `min` and `max` limits are equal, only that exact value will pass the test.

You may wish to set up a routing queue to direct jobs into the queues with resource limits.

For example:

```
% qmgr
Qmgr: create queue funnel queue_type=route
Qmgr: set queue funnel route_destinations =”short,long”
Qmgr: set server default_queue=funnel
```

A job will end up in either `short` or `long` depending on its cpu time request.

You should always list the destination queues in order of the most restrictive first as the first queue which meets the job’s requirements will be its destination (assuming that queue is enabled). Extending the above example to three queues:

```
% qmgr
Qmgr: set queue short resources_max.cput=59
Qmgr: set queue long resources_min.cput=1:00
Qmgr: set queue long resources_max.cput=1:00:00
Qmgr: create queue huge queue_type=execution
Qmgr: set queue funnel route_destinations=”short,long,huge”
Qmgr: set server default_queue=funnel
Qmgr:
```

A job asking for 20 minutes (20:00) of cpu time will be placed into queue `long`. A job asking for 1 hour and 10 minutes (1:10:00) will end up in queue `huge` by default.

Important: If a test is being made on a resource as shown with `cput` above, and a job does not specify that resource item (it does not appear in the `-l resource=`*`valuelist`* on the `qsub` command, the test will pass. In the above case, a job without a cpu time limit will be allowed into queue `short`. For this reason, together with the fact that an unset limit is considered to be an infinite limit, you may wish to add a default value to the queues or to the Server.

```
% qmgr
Qmgr: set queue short resources_default.cput=40
or
Qmgr: set server resources_default.cput=40
```

Either of these examples will ensure that a job without a cpu time specification is limited to 40 seconds. A `resources_default` attribute at a queue level only applies to jobs in that queue.

Important: Be aware of several important facts:

If a default value is assigned, it is done so after the tests against `min` and `max`. Default values assigned to a job from a queue `resources_default` are not carried with the job if the job moves to another queue. Those resource limits becomes unset as when the job was specified. If the new queue specifies default values, those values are assigned to the job while it is in the new queue. Server level default values are applied if there is no queue level default.

7.10.2 Recording Server Configuration

If you should you wish to record the configuration of a PBS Server for re-use later, you may use the `print` subcommand of `qmgr`(8B). For example,

```
% qmgr -c "print server" > /tmp/server.con
```

will record in the file `/tmp/server.con` the `qmgr` subcommands required to recreate the current configuration including the queues. The commands could be read back into qmgr via standard input:

```
% qmgr < /tmp/server.con
```

Node configuration information is not printed. To save the current node configuration information, make a copy of the server_priv/nodes file.

Chapter 8
Configuring MOM

The execution server daemons, MOMs, require much less configuration than does the Server. The installation process creates a basic MOM configuration file which contains the minimum entries necessary in order to run PBS jobs. This chapter describes the MOM configuration file, and explains all the options available to customize the PBS installation to your site.

8.1 MOM Config File

The behavior of MOM is controlled via a configuration file which is read upon daemon initialization (start-up) and upon re-initialization (when `pbs_mom` receives a SIGHUP signal).

If the `-c` option is not specified when MOM is started, she will open `/usr/spool/PBS/mom_priv/config` if it exists. If it does not, MOM will continue anyway. This file may be placed elsewhere or given a different name, in which case `pbs_mom` must be started with the `-c` option with the new file name and path specified.

The configuration file provides several types of run time information to MOM: access control, static resource names and values, external resources provided by a program to be run on request via a shell escape, and values to pass to internal functions at initialization (and re-initialization).

Each configuration entry is on a single line with the component parts separated by white space. If the line starts with a pound sign ("#"), the line is considered to be a comment and is ignored.

The installation process creates a MOM configuration file with the following entries, which are explained in detail in the subsequent sections of this chapter.

```
$logevent 0x1ff
$clienthost server-hostname
```

8.1.1 Access Control and Initialization Values

An initialization value directive has a name which starts with a dollar sign ("$") and must be known to MOM via an internal table. Currently the entries in this table are:

`$clienthost` Causes a host name to be added to the list of hosts which will be allowed to connect to MOM as long as it is using a privileged port. Two host names are always allowed to connect to MOM: "localhost" and the name returned by the system call gethostname(). These names need not be specified in the configuration file.

The Server's host must be either the same host as the MOM or be listed as a `clienthost` entry in each MOM's `config` file in order for MOM to receive this information from the Server.

The IP addresses of all the hosts (nodes) in the Server `nodes` file will be forwarded by the Server to the MOM on each host listed in the `nodes` file. These hosts need not be in the various MOM's configuration file as they will be added internally when the list is received from the Server.

The hosts which are provided by the Server to MOM comprise a *sisterhood* of hosts. Any one of the sisterhood will accept connections from a Scheduler [*Resource Monitor* (RM) requests] or Server [jobs to execute] from within the sisterhood. They will also accept *Internal MOM* (IM) messages from within the sisterhood. For a sisterhood to be able to communicate IM messages to each other, they must all share the same RM port.

For example, here are two lines for the configuration file which will allow the hosts "phobos" and "deimos" to connect to MOM:

```
$clienthost phobos
$clienthost deimos
```

`$restricted` Causes a host name to be added to the list of hosts which will be allowed to connect to MOM without needing to use a privileged port. The means for name specification allows for wildcard matching. Connections from the specified hosts are restricted in that only internal queries may be made. Only static resources from the config file will be reported and no control requests can be issued. This is to prevent any shell commands from being run by a non-root process.

This type of entry is typically used to specify hosts on which a monitoring tool, such as `xpbsmon`, can be run. `Xpbsmon` will query MOM for general resource information.

For example, here is a configuration file line which will allow queries from any host from the domain “pbspro.com”:

```
$restricted *.pbspro.com
```

`$logevent` Sets the mask that determines which event types are logged by pbs_mom. For example:

```
$logevent 0x1ff

$logevent 255
```

The first example would set the log event mask to 0x1ff (511) which enables logging of all events including debug events. The second example would set the mask to 0x0ff (255) which enables all events except debug events. The values of events are listed in section 11.10 “Use and Maintenance of Logs” on page 130.

`$ideal_load` Declares the low water mark for load on a node. It works in conjunction with a `$max_load` directive. When the load average on the node drops below the `ideal_load`, MOM on that node will inform the Server that the node is no longer busy. For example:

```
$ideal_load 2.0
$max_load 3.5
```

`$max_load` Declares the high water mark for load on a node. It is used in conjunction with a `$ideal_load` directive. When the load average exceeds the high water mark, MOM on that node will notify the Server that the node is busy. The state of the node will be shown as `busy`. A busy cluster node will not be allocated to jobs. This is useful in preventing allocation of jobs to nodes which are busy with interactive sessions.

A `busy` time-shared node may still run new jobs under the direction of the Scheduler. Both the `$ideal_load` and `$max_load` directives add a static resource, `ideal_load` and `max_load`, which may be queried by the Scheduler. These static resources are supported by the Standard scheduler when load-balancing jobs.

`$usecp` Directs MOM to use `/bin/cp` instead of `rcp` or `scp` for delivery of output files. If MOM is to move a file to a host other than her own, MOM normally uses a remote copy command (`scp` or `rcp`) to transfer the file. This applies to stage-in/out and delivery of the job's standard output/error. The destination is recorded as `hostx:/full/path/name`. So if `hostx` is not the same system on which MOM is running, she uses `scp` or `rcp`; if it is the same system, MOM uses `/bin/cp`.

However, if the destination file system is NFS mounted among all the systems in the PBS environment (cluster), `cp` may work better than `scp/rcp`. One or more `$usecp` directives in the config file can be used to inform MOM about those file systems where the `cp` command should be used instead of `scp/rcp`. The `$usecp` entry has the form:

`$usecp` *`hostspec`*`:`*`path_prefix new_prefix`*

The *`hostspec`* is either a fully qualified host–domain name or a wild-carded host–domain specification as used in the Server's host ACL attribute. The *`path_prefix`* is the leading (root) component of the fully qualified path for the NFS files as visible on the specified host. The *`new_prefix`* is the initial components of the path to the same files on MOM's host. If different mount points are used, the `path_prefix` and the `new_prefix` will be different. If the same mount points are used for the cross mounted file system, then the two prefixes will be the same.

When given a file destination, MOM will:

Step 1 Match the `hostspec` against her host name. If they match, MOM will use the `cp` command to move the file. If the `hostspec` is `"localhost"` then MOM will also use `cp`.

Step 2 If the match in step one fails, MOM will match the host portion of the destination against each `$usecp` `hostspec` in turn. If the host matches, MOM matches the `path_prefix` against the initial segment of the destination name. If this matches, MOM will discard the host name, replace the initial segment of the path that matched against `path_prefix` with the `new_prefix` and use `cp` with the resulting destination.

Step 3 If the host is neither the local host nor matches any of the `$usecp` directives, MOM will use the `scp` or `rcp` command to move the file.

For example, a user named Beth on host phobos.pbspro.com submits a job while her current working directory is:

```
/u/wk/beth/proj
```

The destination for her output would be given by PBS as:

`phobos.pbspro.com:/u/wk/beth/proj/123.OU`.

The job runs on node jupiter.pbspro.com which has the user's home file system cross mounted as `/r/home/beth`. Either of the following entries in the config file on node jupiter will result in a `cp` copy to `/r/home/beth/proj/123.OU` instead of an `rcp` copy to `phobos.pbspro.com:/u/wk/beth/proj/123.OU`

```
$usecp phobos.pbspro.com:/u/wk/ /r/home/

$usecp *.pbspro.com:/u/wk/ /r/home/
```

Note that the destination is matched against the `$usecp` entries in the order listed in the config file. The first match of host and file prefix determines the substitution. Therefore, if you have the same physical file system mounted as `/scratch` on node mars and as `/workspace` on every other host, then the entries in the config file on jupiter should be in the following order:

```
$usecp mars.pbspro.com:/scratch /workspace
$usecp *.pbspro.com:/workspace /workspace
```

`$cputmult` Sets a factor used to adjust cpu time used by a job. This is provided to allow adjustment of time charged and limits enforced where the job might run on systems with different cpu performance. If MOM's system is faster than the reference system, set `$cputmult` to a decimal value greater than 1.0. If MOM's system is slower, set `$cputmult` to a value between 1.0 and 0.0. The value is given by

value = speed_of_this_system / speed_of_reference_system

For example:

```
$cputmult 1.5
or
$cputmult 0.75
```

`$wallmult` Sets a factor used to adjust wall time usage by a job to a common reference system. The factor is used for walltime calculations and limits in the same way as `$cputmult` is used for cpu time.

`$prologalarm` Sets the time-out period in seconds for the prologue and epilogue scripts. (See discussion of the prologue and epilogue in section 11.9 "Job Prologue/Epilogue Scripts" on page 128.) An alarm is set to prevent the script from locking up the job if the script hangs or takes a very long time to execute. The default value is 30 seconds. An example:

```
$prologalarm 60
```

8.2 Static Resources

To identify static resource names and values, the MOM configuration file can contain a list of resource name/value pairs, one pair per line, separated by white space. These are most often used by the alternate schedulers, but are listed here for completeness. The names can be anything and are not restricted to actual hardware. For example the entry `“pongsoft 1”` could be used to indicate to the Scheduler that a certain piece of software (“pong”) is available on this system. Another example could be the number of tape drives of different types.

```
pongsoft 1
tapedat  1
tape8mm  1
```

8.3 Dynamic Resources

PBS provides the ability to extend the resource query capabilities of MOM by adding shell escapes to the MOM configuration file. While this feature is most often used by the alternate and site-customized schedulers, the functionality is described in full here. Another use is to add site-specific information to the PBS monitoring tool, `xpbsmon`.

If the first character of the value portion of a name/value pair is the exclamation mark (“!”), the entire rest of the line is saved to be executed through the services of the `system`(3) standard library routine. The first line of output from the shell command is returned as the response to the resource query.

The shell escape provides a means for the resource monitor to yield arbitrary information to the Scheduler and other client commands. Parameter substitution is done such that the value of any qualifier sent with the resource query, as explained below, replaces a token with a percent sign (%) followed by the name of the qualifier. For example, here is a configuration file line which gives a resource name of “echotest”:

```
echotest !echo %xxx %yyy
```

If a query for “`echotest`” is sent with no qualifiers, the command executed would be “`echo %xxx %yyy`”. If one qualifier is sent, “`echotest[xxx=hi]`”, the command executed would be “`echo  hi  %yyy`”. If two qualifiers are sent, “`echotest[xxx=hi]  [yyy=there]`”, the command executed would be “`echo  hi` `there`".

If a qualifier is sent with no matching token in the command line, “`echo-test[zzz=snafu]`”, an error is reported.

Another example would allow the Scheduler to have MOM query the existence of a file. The following entry would be placed in MOM’s config file:

```
file_test !if test -f %file; then echo yes; else echo no; fi
```

The query string

```
     file_test  [file=/tmp/lockout]
```

would return “`yes`” if the file exists and “`no`” if it did not.

Another possible use of the shell command configuration entry is to provide a means by which the use of floating software licenses may be tracked. If a program can be written to query the license server, the number of available licenses could be returned to tell the Scheduler if it is possible to run a job that needs a certain licensed package.

8.4 MOM Globus Configuration

For the optional Globus MOM, the same configuration mechanism applies as with the regular MOM except only three initiation value directives are applicable: `$clienthost`, `$restricted`, `$logevent`.

8.5 Example: Single Server

The following examples are for a site called “The WyeWidget Company” whose domain name is “wyewidget.com”. The following is an example of a config file for pbs_mom where the batch system is a single large multi-processor server. We want to log most records and specify that the system has one 8mm tape drive. In addition, the Scheduler runs on a front end machine named front.widget.com.

```
$logevent 0x0ff
$clienthost front.wyewidget.com
tape8mm 1
```

8.6 Example: Cluster

Now the WyeWidget Computer Center has expanded to two large systems. The new system has two tape drives and is 30% faster than the old system. The PBS Manager wishes to charge the users the same regardless of where their job runs. Basing the charges on the old system, she will need to multiple the time used on the new system by 1.3 to charge the same as on the old system. The config file for the “old” system stays the same. The config file for the “new” system is:

```
$logevent 0x0ff
$clienthost front.wyewidget.com
$cputmult 1.3
$wallmult 1.3
tape8mm 2
```

Now the WyeWidget Company has decided to assemble a cluster of PCs running Linux named “bevy”, as in a bevy of PCs. The Scheduler and Server are running on bevyboss.widget.com which also has the user’s home file systems mounted under `/u/home/`.

The nodes in the cluster are named bevy1.wyewidget.com, bevy2.wyewidget.com, etc. The user’s home file systems are NFS mounted as `/r/home/...` The administrator’s personal workstation, adm.wyewidget.com, is where she plans to run `xpbsmon` to do cluster monitoring. The config file for each MOM would look like:

```
$logevent 0x0ff
$clienthost bevyboss.wyewidget.com
$restricted adm.wyewidget.com
$usecp bevyboss.wyewidget.com:/u/home /r/home
```

Chapter 9
Configuring the Scheduler

Now that the Server and MOMs have been configured, we turn our attention to the Scheduler. As mentioned previously, the Scheduler is responsible for implementing the local site policy by which jobs are run, and on what resources. This chapter discusses the default configuration created in the installation process, and describes the full list of tunable parameters available for the PBS Standard Scheduler.

9.1 Default Configuration

This Standard Scheduler provides a wide range of scheduling policies. It provides the ability to sort the jobs in several different ways, in addition to FIFO order. It also has the ability to sort on user and group priority. As distributed, it is configured with the following options (which are described in detail below).

1. Two specific system resources are checked to make sure they are not exceeded: `mem` (memory requested) and `ncpus` (number of CPUs requested).

2. Queues are sorted by queue priority to determine the order in which they are to be considered.

3. All jobs in the current queue will be considered for execution before

considering any jobs from the next queue.

4. The jobs within each queue are sorted by requested cpu time (cput). The shortest job is placed first.

5. Jobs which have been queued for more than one day will be considered *starving* and extra measures will be taken to attempt to run them.

6. Any queue whose name starts with “ded” is treated as a dedicated time queue (see discussion below). Sample dedicated_time and files are included in the installation.

7. Prime time is set to 6:00 AM - 5:30 PM. Any holiday is considered non-prime. Standard U.S. federal holidays for the year 2001 are provided in the file /usr/spool/PBS/sched_priv/holidays. These dates should be adjusted yearly to reflect your local holidays.

8. In addition, the scheduler utilizes the following attributes/ resources in making scheduling decisions:

Object	Attribute/Resource	Comparison
queue	started	= true
queue	queue_type	= execution
queue	max_running	>= number of jobs running in queue
queue	max_user_run	>= number of jobs running for a user
queue	max_group_run	>= number of jobs running for a group
job	job_state	= queued
server	max_running	>= number of jobs running
server	max_user_run	>= number of jobs running for a user
server	max_group_run	>= number of jobs running for a group
server	resources_available	>= resources requested by job

Object	Attribute/Resource	Comparison
node	loadave	< configured limit
node	arch	= type requested by job
node	host	= name or property requested by job
node	max_running	>= number of jobs running
node	max_user_run	>= number of jobs running for a user
node	max_group_run	>= number of jobs running for a group
node	resources_available	>= resources requested by job

9.2 New Scheduler Features

With each PBS Pro release, new features are added to the Standard Scheduler. This section discusses the new scheduler features available in PBS Pro 5.1, and how you may best take advantage of these changes.

9.2.1 SMP Cluster Support

The Standard Scheduler will now schedule SMP clusters in a much more efficient manner. Instead of scheduling only via load average of nodes, it will take into consideration the resources specified at the server, queue, and node level. Furthermore, the administrator can now explicitly select the resources to be considered in scheduling via a new option in the Scheduler's configuration file (`resources`). The addition of another configuration parameter (`smp_cluster_dist`) allows you to specify how nodes are selected. The available choices are `pack` (pack one node until full), `round_robin` (put one job on each node in turn), or `least_loaded` (put one job on the least loaded node).

To use this new feature requires two steps: setting resource limits via the Server, and specifying the scheduling options. Resource limits are set using the `resources_available` attribute of nodes via `qmgr` just like on the server or queues. For example, to set maximum limits on a node called "node1" to 10 CPUs and 2 GB of memory:

```
Qmgr>set node node1 resources_available.ncpus = 10
Qmgr>set node node1 resources_available.mem=2GB
```

Important: Note that by default both `resources_available.ncpus` and `resources_available.mem` are set to the physical number reported by MOM on the node.

Next, the Scheduler options need to be set. For example, to enable SMP cluster scheduler to use the “round robin” algorithm during primetime, and the “pack” algorithm during non-primetime, set the following in the Scheduler’s configuration file:

```
smp_cluster_dist: round_robin prime
smp_cluster_dist: pack        non_prime
```

Finally, specify the resources to use during scheduling (also in the Scheduler’s configuration file):

```
resources: “ncpus, mem”
```

9.2.2 Enhanced Load Balancing

The load balancing feature of PBS Pro changed with release 5.1 to allow load-balancing without oversubscribing memory. If you wish to schedule via load and not over-allocate memory, then remove "ncpus" from the Scheduler’s `resources` parameter (i.e. set `resources: “mem”`). The `load_balancing` scheduling parameter needs to be set like before. The following example illustrates this:

```
resources:        “mem”
load_balancing:   TRUE
smp_cluster_dist: pack
```

The `load_balancing_rr` parameter has been obsoleted (although it has been retained for backward compatibility). With the 5.1 Scheduler, if you want to load balance via the round robin algorithm, set the following in the Scheduler’s configuration file:

```
resources:         “”
load_balancing:    TRUE
smp_cluster_dist:  round_robin
```

9.2.3 Preemptive Scheduling

There is now the ability to preempt currently running jobs in order to run higher priority work. This is done by assigning at least one queue a priority value higher than the rest, and specifying this value to the Scheduler as the preemptive priority threshold. Queues with a priority value equal to or higher than this preemptive priority threshold are recognized as *preemptive* queues. Any jobs which are submitted to these queues are marked as *preempting*. If these jobs can not run right away, the scheduler looks for jobs to preempt, in order to run the higher priority job. A job can be preempted in several ways. The scheduler can suspend the job (i.e. sending a SIGSTOP signal), checkpoint the job (if supported by the underlying operating system), or requeue the job. Preemptive scheduling is enabled by setting several parameters in the Scheduler’s configuration file. Jobs which are preempting are not preemptable, nor are jobs utilizing advance reservations.

There are five new Scheduler parameters. The `preemptive_sched` turns preemptive scheduling on and off. You set what queue priority is preemptive with the `preempt_queue_prio` parameter. The last three set how you want to preempt work: `preempt_suspend`, `preempt_checkpoint`. and `preempt_requeue`. All of these can be set independently, but they are tried in the order: suspend, checkpoint, and then requeue. If one preemption method fails, the Scheduler tries the next. If the scheduler cannot find enough work to preempt in order to run a given job, it will not preempt any work.

Important: If using cpusets on an Origin 2K/3K, set `preempt_suspend` to `False`. If set to True, the job will be suspended, but the cpuset will not be freed, leaving the resource unavailable to other jobs.

Here is an example which enables preemptive scheduling for jobs with a priority value of 200 or greater, and with a specification of not to even try to checkpoint any preemptable jobs:

```
preemptive_sched:    TRUE    ALL
preempt_queue_prio:  200
preempt_suspend:     TRUE
preempt_checkpoint:  FALSE
preempt_requeue:     TRUE
```

Next up you need to set a queue's priority to the preemptive priority or higher:

```
# qmgr
Qmgr: set queue qname priority = 200
```

Now any jobs submitted into queue *qname* will preempt any lower priority running jobs.

9.2.4 Dynamic Consumable Resources

It is now possible to schedule resources where the number of available resources are outside of PBS's control. The Scheduler will perform a resource query to MOM to get the current availability for the resource and use that value for scheduling. These resources are specified in the Scheduler’s configuration file using the parameter, `mom_resources`. These resources are queried from every MOM in the cluster and if the MOM returns a value it will replace the `resources_available` value reported by the Server. If the MOM returns no value, the value from the Server is kept. If neither specify a value, the Scheduler sets the resource value to 0.

To use this new feature, follow these steps:

Step 1 Create new resources on the Server (`.../server_priv/resourcedef` file). See also “Defining New Resources” on page 81

Step 2 Set resource queries in mom config files. See also “Dynamic Resources” on page 93

Step 3 Set mom_resources parameter to these new resources. See below.

As an illustrative example, suppose your company has ten licenses to an expensive Astrology program, but its use is limited to a single node (named “twinkie”). Things are further complicated by the marketing department demanding you reserve two licenses for their business planning seances. You’ve been told to limit everyone else to at most eight licenses. You decide that PBS should do this, so you write a quick shell script (called `count_astro_licenses`) to query the license manager and report the total number of licenses that you want PBS to manage. (This could be useful, for example, if there are other programs outside of PBS that may use these licenses. Your script can detect this, and reduce the number that PBS should manage.). Now you are ready to configure PBS.

First you edit the Server’s resource file (`.../server_priv/resourcedef`) adding a definition for your new resource. Let’s call it “astrology”:

```
astrology   type=long  flag=qn
```

Note that the **n** flag is important in order to have the Server calculate values of `resources_assigned` for this new resource.

Next, you configure MOM to use your little shell script to query the Astrology licenses, by entering one line into the `mom_priv/config` file:

```
astrology !/usr/local/bin/count_astro_licenses
```

And finally, you edit the Scheduler configuration file, specifying this new resource that you want queried and used for scheduling:

```
mom_resources: “astrology”
```

9.2.5 New Node Attributes

The Server now supports the `max_running`, `max_user_run`, and `max_group_run` attributes for nodes. The 5.1 Standard Scheduler will honor these, thereby enforcing the max number of jobs running on a node (total, per-user, and/or per-group).

9.3 Tunable Parameters

To tune the behavior of the Standard Scheduler, change directory to `/usr/spool/PBS/sched_priv` and edit the scheduling policy configuration file `sched_config` or use the default values. This file controls the scheduling policy (the order in which jobs run). The format of the `sched_config` file is:

name: *value* [prime | non_prime | all | none]

`name` and *`value`* may not contain any white space. *`value`* can be: true | false | number | string. Any line starting with a "#" is a comment, and is ignored. A blank third word is equivalent to "`all`" which is both prime and non-primetime.

The available options for the Standard Scheduler, and the default values, are as follows.

`assign_ssinodes`

boolean: If `true`, will enable ssinode-based scheduling (i.e. support for IRIX cpusets), including updating the ncpus and memory resources to match the maximum amounts available on a given ssinode. If false, cpuset support is disabled. For more information see section 9.3.1 "Scheduler Support for SGI IRIX cpusets" on page 109.
Default: `false`

`backfill` boolean: Instead of draining the system until the starving job runs, the Scheduler will attempt to backfill smaller jobs around the starving jobs. It will first attempt to backfill other starving jobs around it, before moving onto normal jobs. The `help_starving_jobs` attribute needs to be on in conjunction with this attribute.
Default: `true all`

`backfill_prime`

boolean: Directs the scheduler not to run jobs which will overlap into primetime or non-primetime. This will drain the system before primetime or non-primetime starts, assisting with the problem where a large job is run in non-primetime right before non-primetime ends.
Default: `false all`

`by_queue` boolean: If `true`, the jobs will be run queue by queue; if `false`, the entire job pool in the Server is looked at as one large queue.

Default: `true all`

`cpus_per_ssinode`
Obsolete. See "Scheduler Support for SGI IRIX cpusets" on page 109 below.

`dedicated_prefix`
string: Queue names with this prefix will be treated as dedicated queues, meaning jobs in that queue will only be considered for execution if the system is in dedicated time as specified in the configuration file,
`/usr/spool/PBS/sched_priv/dedicated_time`.
Default: `ded`

`fair_share` boolean: This will enable the fair share algorithm. It will also turn on usage collecting and jobs will be selected based on a function of their recent usage and priority(shares). See also section 9.3.3 "Defining Fair Share" on page 110.
Default: `false all`

`half_life` time: The half life for fair share usage. Requires `fair_share` to be enabled. See also section 9.3.3 "Defining Fair Share" on page 110.
Default: `24:00:00`

`help_starving_jobs`
boolean: Setting this option will enable starving jobs support. Once jobs have waited for the amount of time given by `max_starve` they are considered starving. If a job is considered starving, then no jobs will run until the starving job can be run, unless backfilling is also specified. To use this option, the `max_starve` configuration attribute needs to be set as well. See also `backfill`.
Default: `true all`

`load_balancing`
boolean: If set, the Scheduler will load balance the jobs across a list of nodes obtained from the Server. The load balancing takes into consideration the load on each node as well as all resources specified in the "resource" list. See `smp_cluster_dist`.
Default: `false all`

`load_balancing_rr`
Obsolete. To duplicate this setting, enable `load_balancing` and set `smp_cluster_dist` to `round_robin`.

`log_filter`
integer: Defines which event types to filter from the daemon logfile. The value should be set to the bitwise OR of the event classes which should be filtered. See also section 11.10 “Use and Maintenance of Logs” on page 130.
Default: `256` (DEBUG2)

`max_starve`
time: The amount of time before a job is considered starving. This variable is used only if `help_starving_jobs` is set.
Default: `24:00:00`

`mem_per_ssinode`
Obsolete. See “Scheduler Support for SGI IRIX cpusets” on page 109 below.

`nonprimetime_prefix`
string: Queue names which start with this prefix will be treated as non-primetime queues. Jobs within these queues will only run during non-primetime. Primetime and nonprimetime are defined in the `holidays` file.
Default: `np_`

`primetime_prefix`
string: Queue names which start with this prefix will be treated as primetime queues. Jobs will only run in these queues during primetime. Primetime and non-primetime are defined in the `holidays` file.
Default: `p_`

`preemptive_sched`
string: Enable job preemption. All jobs whose queue priority is greater than the preemption priority will force the suspension or checkpoint of lower priority jobs in order to run, if insufficient resources are available.
Default: `false all`

`preempt_queue_prio`
integer: Specifies the minimum queue priority required for a queue to be classified as a preemption queue.
Default: `150`

`preempt_suspend`
boolean: Specifies if preemptable jobs should be suspended.
Default: `true`

`preempt_checkpoint`
boolean: Specifies if preemptable jobs should be checkpointed (if supported by underlying operating system).
Default: `true`

preempt_requeue

boolean: Specifies if preemptable jobs should be requeued.
Default: true

prime_spill

time: Specifies the amount of time a job can "spill" over from non-primetime into primetime or from non-primetime into primetime. For example, if a job is in a primetime queue and it is currently primetime, but the job would cross over into non-primetime by one hour, the job would not run if prime_spill were set to less than one hour. Note, this option is only meaningful if backfill_prime is true. Also note that this option can be separately specified for prime- and non-primetime.
Default: 00:00:00

resources

string: Specifies the resources by which to schedule the system. Limits are set by setting resources_available.resourceName on the Server objects (nodes, queues, and servers). The scheduler will consider numeric (int or float) items as consumable resources and ensure that no more are assigned than are available (e.g. ncpus or mem). Any string resources will be compared using string comparisons (e.g. arch). See also section “Dynamic Consumable Resources” on page 102.
Default: “ncpus, mem” (ncpus and memory)

round_robin

boolean: If true, the queues will be cycled through in a circular fashion, attempting to run one job from each queue. If false, attempts to run all jobs from the current queue before processing the next queue.
Default: false all

smp_cluster_dist

string: Specifies how jobs should be distributed to all nodes of the cluster. Options are: pack, round_robin, and least_loaded. pack means keep putting jobs onto one node until it is “full” and then move onto the next. round_robin is to put one job on each node in turn before cycling back to the first one. least_loaded means to put the job on the lowest loaded node.
Default: pack all

sort_by

string: Selects how the jobs should be sorted. sort_by can be set to a single sort type or to multi_sort. If set to

`multi_sort`, multiple *key* fields are used. Each *key* field will be a key for the `multi_sort`. The order of the key fields decides which sort type is used first. Each sorting key is listed on a separate line starting with the word `key`
Default: `shortest_job_first`

Sort Keys	Description
fair_share	Sort based on the values in the resource group file. This should only used if strict priority sorting is needed. **Do not enable `fair_share` sorting if using the `fairshare` scheduling option.**
high_priority_first	Descending by the job priority attribute
large_walltime_first	Descending by job walltime attribute
largest_memory_first	Descending by the mem attribute
longest_job_first	Descending by the cput attribute
low_priority_first	Ascending by the job priority attribute
multi_sort	Sort on multiple keys.
no_sort	Do not sort the jobs
shortest_job_first	Ascending by the cput attribute
smallest_memory_first	Ascending by the mem attribute

The following example illustrates how to define a multi-sort using three of the above sort keys:

```
sort_by: multi_sort
key: sortest_job_first
key: smallest_memory_first
key: high_priority_first
```

`strict_fifo` boolean: If `true`, jobs will be run in a strict FIFO order. This means if a job fails to run for any reason, no more jobs will run from that queue/Server during that scheduling cycle. If `strict_fifo` is not set, large jobs can be starved, i.e., not allowed to run because a never ending series of small jobs use

the available resources. Also see the Server attribute `resources_available`, and the parameters `help_starving_jobs` and `backfill` below.
Default: `false all`

`sync_time` time: The amount of time between writing the fair share usage data to disk. Requires `fair_share` to be enabled.
Default: `1:00:00`

`unknown_shares`

integer: The amount of shares for the "unknown" group. Requires `fair_share` to be enabled. See also section 9.3.3 “Defining Fair Share” on page 110.
Default: `10`

9.3.1 Scheduler Support for SGI IRIX cpusets

As discussed earlier in this manual, PBS Pro supports the use of SGI IRIX “cpusets” (or named regions of an SGI IRIX system containing specific CPUs and associated memory). If support for SGI cpusets is desired, it needs to be enabled in the Scheduler. (See also section 4.4.1 “Installing MOM with SGI “cpuset” Support” on page 23).

In the Scheduler, cpuset support is accomplished by setting `assign_ssinodes:true` in the scheduler’s configuration file. With release 5.1 of PBS Pro, the number of CPUs and amount of memory per node board within the system are now queried directly from the MOM local to that system. This permits running clusters of SGI Origin systems with different hardware configurations managed by a single PBS Scheduler.

9.3.2 Defining Dedicated Time

The file `/usr/spool/PBS/sched_priv/dedicated_time` defines the dedicated times for the scheduler. During dedicated time, only jobs in the dedicated time queues can be run (see `dedicated_prefix` above). The format of entries is:

```
# From Date-Time   To Date-Time
# MM/DD/YYYY HH:MM MM/DD/YYYY HH:MM
# For example
04/15/2001 12:00 04/15/2001 15:30
```

9.3.3 Defining Fair Share

PBS fairshare is similar to the UNICOS implementation of fairshare. Users are put in a fairshare group file. The file is read in and a tree is created. The tree consists of groups(nodes) and users (leaves). Groups can contain groups. Every node and leaf has a number of shares associated with it. Priorities can be derived from these shares by taking a ratio of them to all the rest of the shares.

For example, say you have three nodes/leaves at one level with shares of 10, 20, and 10. The first user/group has a priority of 25% or 10/40, the second has 50% or 20/40 and so on. A node with children can establish priorities among them via shares. So if in the example above the second group (50%) is actually a group with 4 users then, each user has 1/4 of 50% or 12.5% of the machine.

If fair share or strict priority is going to be used, the resource group file `/usr/spool/PBS/sched_priv/resource_group` may need to be edited. (If all users are considered equal, this file doesn't need to be edited.) Each line of the file should use the following format:

```
name unique_ID parent_group shares
```

`name` The name of the specified user or group

`unique_id` A unique numeric identifier for the group or user (The UNIX GID or UID are recommended.)

`parent_group` The name of the parent resource group to which this user/group belongs. The root of the share tree is called `root` and is added automatically to the tree by the Scheduler.

`shares` The number shares (or priority) the user/group has in the specified resource group.

If you wish to specify how individual users should be ranked against each other, only user entries are required in the `resources_group` file, as shown the following example:

```
usr1    60      root    5
usr2    61      root    15
usr3    62      root    15
usr4    63      root    10
usr5    64      root    25
usr6    65      root    10
usr7    66      root    10
usr8    67      root    10
```

Another option is to divide shares into “group”, and then name the users who are members of each group. The following example illustrates this configuration:

```
grp1    50      root    10
grp2    51      root    20
grp3    52      root    10
grp4    53      grp1    20
grp5    54      grp1    10
grp6    55      grp2    20
usr1    60      root    5
usr2    61      grp1    10
usr3    62      grp2    10
usr4    63      grp6    10
usr5    64      grp6    10
usr6    65      grp6    20
usr7    66      grp3    10
usr8    67      grp4    10
usr9    68      grp4    10
usr10   69      grp5    10
```

9.3.4 Defining Strict Priority

Not to be confused with fair share (which considers past usage of each user and group in the selection of jobs), the Standard Scheduler offers a sorting key called “`fair_share`”. Selecting this option enables the sorting of jobs based on the priorities specified in the fair share tree (as defined above in the `resource_group` file). A simple share tree will suffice. Every user’s `parent_group` should be `root`. The amount of shares should be their desired priority. `unknown_shares` (in the scheduler’s configuration file) should be set to one. Doing so will cause everyone who is not in the tree to share one share between them, making sure everyone else in the tree will have priority over them. Lastly, `sort_by` must be set to `fair_share`.This will sort by the fair share tree which was just set up. For example:

```
usr1    60      root    5
usr2    61      root    15
usr3    62      root    15
usr4    63      root    10
usr5    64      root    25
usr6    65      root    30
```

9.3.5 Defining Primetime and Holidays

To have the scheduler utilize and enforce holidays, edit the `/usr/spool/PBS/sched_priv/holidays` file to handle prime time and holidays. The holidays file should use the UNICOS 8 holiday format. The ordering is important. Any line that begins with a "*" is considered a comment. The format of the holidays file is:

YEAR YYYY* This is the current year.
<day> <prime> <nonprime>

Day can be `weekday`, `saturday`, or `sunday`
Prime and *nonprime* are times when prime or non-prime time start. Times can either be HHMM with no colons(:) or the word "`all`" or "`none`"

<day> <date> <holiday>

Day is the day of the year between 1 and 365 (e.g. “1”)
Date is the calendar date (e.g. “Jan 1”)
Holiday is the name of the holiday (e.g. “New Year’s Day”)

```
HOLIDAYFILE_VERSION1
*
YEAR    2001
*            Prime   Non-Prime
* Day        Start   Start
*
  weekday    0600    1730
  saturday   none    all
  sunday     none    all
*
* Day of    Calendar      Company Holiday
* Year       Date         Holiday
*   1        Jan 1        New Year's Day
   15        Jan 15       Martin Luther King Day
   50        Feb 19       President's Day
  148        May 28       Memorial Day
  185        Jul 4        Independence Day
  246        Sep 3        Labor Day
  281        Oct 8        Columbus Day
  316        Nov 12       Veteran's Day
  326        Nov 22       Thanksgiving
  359        Dec 25       Christmas Day
```

Chapter 10
Example PBS Configurations

Up to this point in this manual, we have seen many examples of how to configure the individual PBS daemons, set limits, and otherwise tune a PBS installation. Those examples were used to illustrate specific points or configuration options. This chapter pulls these various examples together into configuration-specific scenarios which will hopefully clarify any remaining configuration questions. Four configuration models are discussed, each more complex than the one before it:

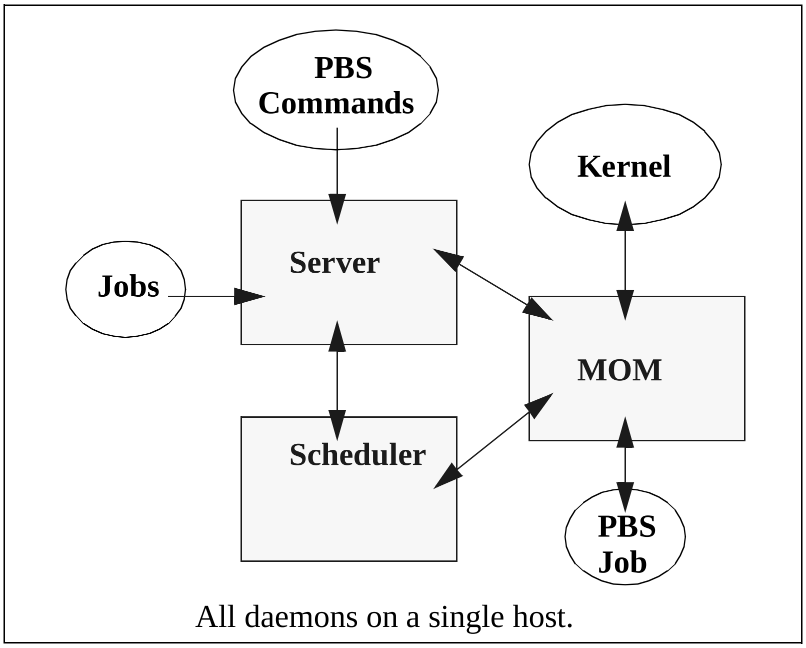
Single Node Time-sharing System
Single Node System with Separate PBS Server
Multi-node Time-sharing Cluster
Multi-node Space-sharing Cluster

For each of these possible configuration models, the following information is provided:

General description for the configuration model
Type of system the model is well suited for
Graphic illustration of the model
Contents of Server nodes file
Any required settings in Server
Contents of MOM configuration file
Required settings in Scheduler configuration file

10.1 Single Node Time-sharing System

Running PBS on a single node/host as a standalone time-sharing system is the least complex configuration. This model is most applicable to sites who have a single large Server system, or even a vector supercomputer. In this model, all three PBS daemons run on the same host, which is the same host on which jobs will be executed, as shown in the figure below.



All daemons on a single host.

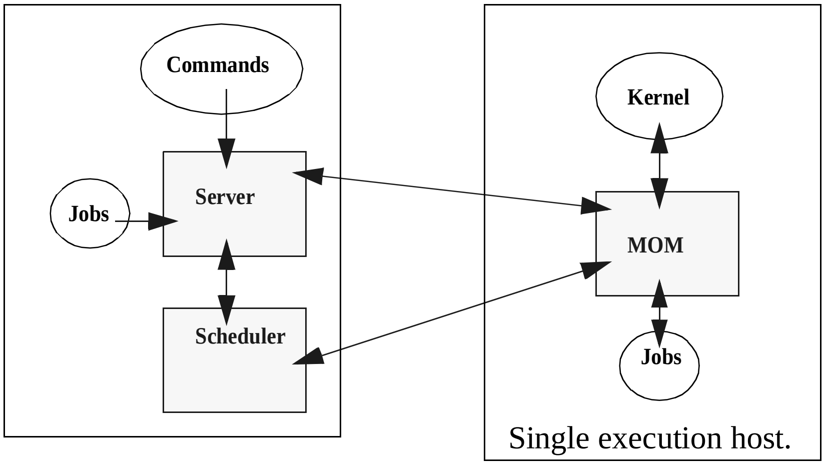
For this example, lets assume we have a 32-CPU server machine named “mars”. We want users to log into “mars” and jobs will be run via PBS on mars.

In this configuration, the default PBS `nodes` file (which should contain the name of the host the Server was installed on) is sufficient. Our example `nodes` file would contain only one entry: `mars:ts`

The default MOM and Scheduler `config` files, as well as the default queue/Server limits are also sufficient. No changes are required from the default configuration.

10.2 Single Node System with Separate PBS Server

A variation on this model would be to provide a “front-end” system that ran the PBS Server and Scheduler, and from which users submitted their jobs. Only the MOM daemon would run on our compute server mars. This model is recommended when the user load would otherwise interfere with the computational load on the Server.



Single execution host.

In this case, the PBS `nodes` file would contain the name of our compute server mars, but this may not be what was written to the file during installation, depending on which options were selected. It is possible the hostname of the machine on which the Server was installed was added to the file, in which case you would need to either manually edit the `nodes` file, or use `qmgr(1B)` to manipulate the contents to contain one node: `mars:ts`. If the default of scheduling based on available CPUs and memory meets your requirements, then no changes are required in either the MOM or Scheduler configuration files.

However, if you wish the compute node (mars) to be scheduled based on load average, the following changes are needed. Edit MOM’s `config` file so that it contains the target and maximum load averages, e.g.:

```
$ideal_load 30
$max_load 32
```

In the scheduler `config` file, the following options would need to be set:

```
load_balancing: true all
```

10.3 Multi-node Timesharing Cluster

The multi-node time-sharing cluster model is a very common configuration for PBS. In this model, there is typically a “front-end” system as we saw in the previous example, with a number of ‘back-end” compute nodes. The PBS Server and Scheduler are typically run on the front-end system, and a MOM daemon is run on each of the compute nodes, as shown in the diagram to the right.

In this model, the PBS `nodes` file will need to contain the list of all the nodes in the cluster, with the timesharing attribute `:ts` appended:

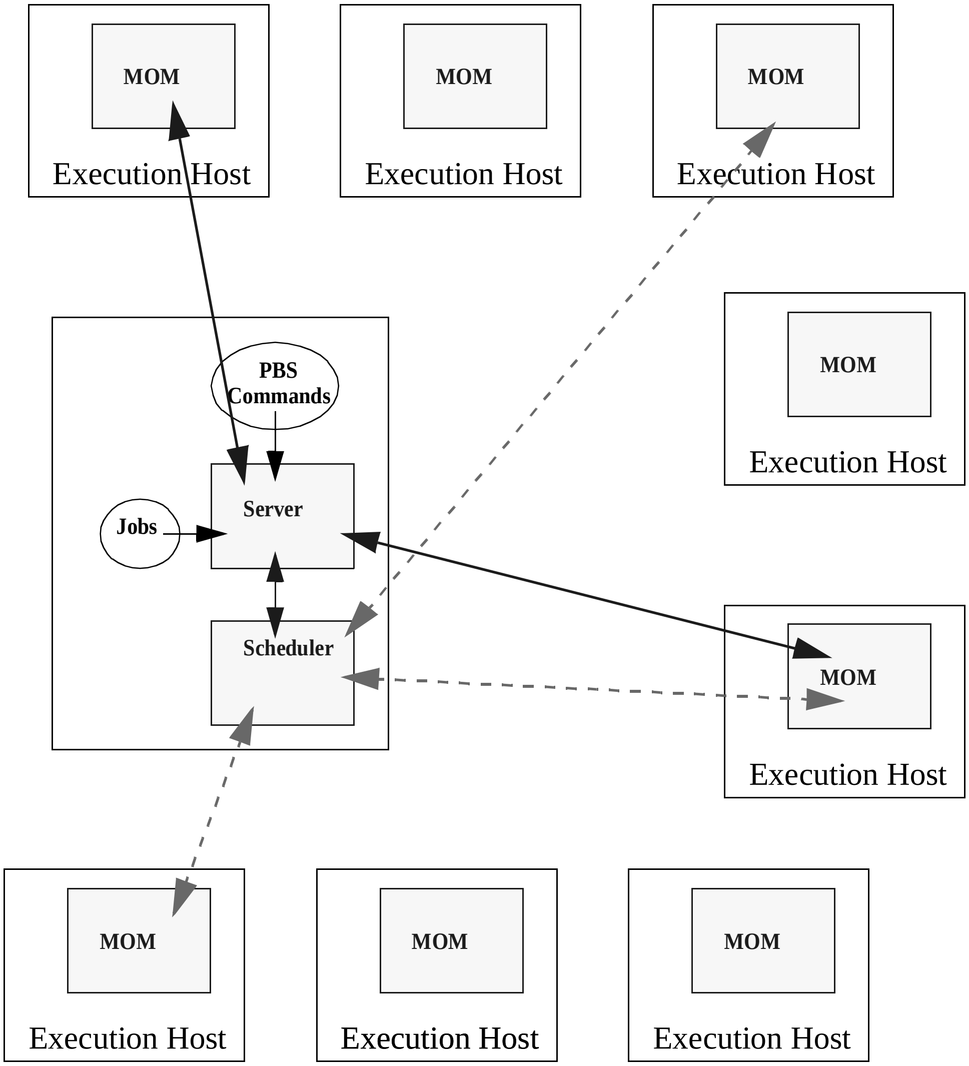
```
mercury:ts
venus:ts
earth:ts
mars:ts
jupiter:ts
saturn:ts
uranus:ts
neptune:ts
```

The MOM `config` file on each node will need two static resources added, to specify the target load for each node. If we assume each of the nodes in our planets cluster is a 32-processor system, then the following example shows what might be desirable values to add to the MOM `config` files:

```
$ideal_load 30
$max_load 32
```

Furthermore, suppose we want the Scheduler to load balance the workload across the available nodes, making sure not to run two job in a row on the same node (round robin node scheduling). We accomplish this by editing the Scheduler configuration file and enabling load_balancing:

```
load_balancing: true all
smp_cluster_dist: round_robin
```



This diagram illustrates multi-node cluster configurations wherein the Scheduler and

Server communicate with the MOMs on the compute nodes. Jobs are submitted to the Server, scheduled for execution by the Scheduler, and then transferred to a MOM when its time to be run. MOM periodically sends status information back to the Server, and answers resource requests from the Scheduler.

10.4 Multi-node Space-sharing Cluster

A variation on the time-sharing cluster is the “space-shared” cluster. In this context, space-sharing refers to assigning an entire node (or set of nodes) to a single job at a time, for the duration of the job. This is usually done in order to achieve high-throughput and predictability of runtimes for a specific application (such as message passing parallel jobs).

In this model, the PBS `nodes` file would **not** have the `:ts` appended to the node names, e.g.:

```
mercury
venus
earth
mars
jupiter
saturn
uranus
neptune
```

There would be no edits required to either the Scheduler or the MOM `config` files.

Lastly, since in this model users specify their job resource requirements using the “`-l nodes=...`” syntax of `qsub`, we need to set nodes-specific limits in the Server:

```
# qmgr
Qmgr: set server resources_default.nodes = 1
Qmgr: set server resources_default.nodect = 1
Qmgr: set server resources_default.neednodes = 1
```

Chapter 11
Administration

This chapter covers information on the maintenance and administration of PBS, and as such is intended for the PBS Manager. Topics covered include: starting and stopping PBS, security within PBS, prologue/epilogue scripts, use of accounting logs, configuration of the PBS GUIs, and using PBS with other products such as Globus.

11.1 /etc/pbs.conf

During the installation of PBS Pro, the following `/etc/pbs.conf` file was created:

```
PBS_CONF_START_SERVER=1
PBS_CONF_START_MOM=1
PBS_CONF_START_SCHED=1
PBS_HOME=/usr/spool/PBS
PBS_EXEC=/opt/pbs
PBS_SERVER=hostname.domain
PBS_SCP=path_to_scp
PBS_ENVIRONMENT=path
```

This configuration file controls which daemons are to be running on the local system, directory tree location, and various runtime configuration options. Each node in a cluster should have its own `/etc/pbs.conf` file. The following table describes the available parameters as of the current version of PBS Pro:

Parameters	Meaning
PBS_CONF_START_SERVER	set to 1 if the Server should run on this nodes
PBS_CONF_START_MOM	set to 1 if a MOM should run on this nodes
PBS_CONF_START_SCHED	set to 1 if the Scheduler should run on this node
PBS_HOME	location of PBS working directories
PBS_EXEC	location of PBS bin and sbin directories
PBS_SERVER	hostname of host running the Server
PBS_SCP	determines if scp is used
PBS_ENVIRONMENT	defaults to PBS_HOME/pbs_environment

Important: The last two parameters above are optional, the rest are required.

11.2 Starting PBS Daemons

The daemon processes, Server, Scheduler, MOM and the optional MOM Globus, must run with the real and effective uid of root. Typically the daemons are started automatically by the system upon reboot. The boot-time start/stop script for PBS is `/etc/init.d/pbs`. This script reads the `/etc/pbs.conf` file to determine which daemons should be started.

The startup script can also be run by hand to get status on the PBS daemons, and to start/stop all the PBS daemons on a given host. The command line syntax for the startup script is:

```
/etc/init.d/pbs [ status | stop | start ]
```

Alternately, you can start the individual PBS daemons manually, as discussed in the following sections. Furthermore, you may wish to change the options specified to various daemons, as discussed below.

11.2.1 Manually Starting MOM

MOM should be started at boot time. Typically there are no required options. It works best if MOM is started before the Server so she will be ready to respond to the Server’s “are you there?” ping. Start MOM with the command line:

```
/usr/pbs/sbin/pbs_mom [-p] [-r]
```

If MOM is taken down and the host system continues to run, MOM should be restarted with either of the following options:

`-p` This directs MOM to let running jobs continue to run. Because MOM is no longer the parent of the jobs, she will not be notified (**SIGCHLD**) when they die and so must poll to determine when the jobs complete. The resource usage information therefore may not be completely accurate.

`-r` This directs MOM to kill off any jobs which were left running.

Without either the `-p` or the `-r` option, MOM will assume the jobs’ processes are non-existent due to a system restart, a cold start. She will not attempt to kill the processes and will request that any jobs which where running before the system restart be requeued.

11.2.2 Manually Starting the Server

Normally the PBS Server is started from the system boot file via a line such as:

```
/usr/pbs/sbin/pbs_server [options]
```

11.2.3 Manually Starting the Scheduler

The Scheduler should also be started at boot time. If starting by hand, use the following command line:

```
/usr/pbs/sbin/pbs_sched [options]
```

There are no required options for the Standard Scheduler; available options are listed in `pbs_sched_cc` manual page.

11.2.4 Manually Starting Globus MOM

The optional Globus MOM should be started at boot time if Globus support is desired. Note that the provided startup script does not start the Globus MOM. There are no required options. If starting manually, run it with the line:

```
/usr/pbs/sbin/pbs_mom_globus [options]
```

If Globus MOM is taken down and the host system continues to run, the Globus MOM should be restarted with the -r option. This directs Globus MOM to kill off processes running on behalf of a Globus job. See the **PBS ERS** (or the `pbs_mom_globus`(1B) manual page) for a more complete explanation.

If the `pbs_mom_globus` daemon is restarted without the -r option, the assumption that will be made is that jobs have become disconnected from the Globus gatekeeper due to a system restart (cold start). Consequentially, `pbs_mom_globus` will request that any Globus jobs that were being tracked and which where running be canceled and requeued.

11.3 Stopping PBS

With the release 5.1 of PBS Pro, additional options to `qterm` are available to shutdown, selectively, or inclusively, the various PBS daemons.

`-m` directs that all `pbs_mom`s should be shutdown
`-s` directs that the `pbs_sched` should be shut down

Thus, the following command will bring down the entire PBS complex:

```
# qterm -s -m
```

Important: Note that `qterm` now defaults to `qterm -t quick.`

Also, note that the Server now does a quick shutdown upon receiving `SIGTERM`.

11.4 Start/Stop/Enable/Disable Queues

In addition to the functionality offered by `qmgr`, PBS provides separate commands for manipulating the status of queues. This section briefly describes the four commands. See the corresponding manual pages for details of use.

The `qstart` command directs that a destination should process batch jobs. If the destination is an execution queue, the Server will begin to schedule jobs that reside in the queue for execution. If the destination is a routing queue, the Server will begin to route jobs from that queue

The `qstop` command directs that a destination should stop processing batch jobs. If the destination is an execution queue, the Server will cease scheduling jobs that reside in the queue for execution. If the destination is a routing queue, the Server will cease routing jobs from that queue.

The `qenable` command directs that a destination should accept batch jobs. This command sends a Manage request to the batch Server specified on the command line. If the command is accepted, the destination will accept Queue Job requests which specify the queue.

The `qdisable` command directs that a destination should no longer accept batch jobs. If the command is accepted, the destination will no longer accept Queue Job requests which specified the disabled queue. Jobs which already reside in the queue will continue to be processed. This allows a queue to be "drained."

11.5 Security

There are three parts to security in the PBS system:

Internal security	Can the daemons be trusted?
Authentication	How do we believe a client about who it is.
Authorization	Is the client entitled to have the requested action performed.

11.6 Internal Security

A significant effort has been made to insure the various PBS daemon themselves cannot be a target of opportunity in an attack on the system. The two major parts of this effort is the security of files used by the daemons and the security of the daemons environment.

Any file used by PBS, especially files that specify configuration or other programs to be run, must be secure. The files must be owned by root and in general cannot be writable by anyone other than root.

A corrupted environment is another source of attack on a system. To prevent this type of attack, each daemon resets its environment when it starts. The source of the environment is a file named by **PBS_ENVIRONMENT** set by the configure option `--set-environ`, defaulting to *`PBS_HOME/`*`pbs_environment`. If it does not already exists, this file is created during the install process. As built by the install process, it will contain a very basic path and, if found in root's environment, the following variables: **TZ**, **LANG**, **LC_ALL**, **LC_COLLATE**, **LC_CTYPE**, **LC_MONETARY**, **LC_NUMERIC**, and **LC_TIME**. The `environment` file may be edited to include the other variables required on your system.

Important: Please note that **PATH** must be included. This value of **PATH** will be passed on to batch jobs. To maintain security, it is important that **PATH** be restricted to known, safe directories. Do NOT include "." in **PATH**. Another variable which can be dangerous and should not be set is **IFS**.

The entries in the **PBS_ENVIRONMENT** file can take two possible forms:

```
variable_name=value
variable_name
```

In the later case, the value for the variable is obtained from the daemons environment before the environment is reset.

11.6.1 Host Authentication

PBS uses a combination of information to authenticate a host. If a request is made from a client whose socket is bound to a privileged port (less than 1024, which requires root privilege), PBS believes the IP (Internet Protocol) network layer as to whom the host is. If the client request is from a non-privileged port, the name of the host which is making a client request must be included in the credential sent with the request and it must match the IP network layer opinion as to the host's identity.

11.6.2 Host Authorization

Access to the Server from another system may be controlled by an access control list (ACL).

Access to `pbs_mom` is controlled through a list of hosts specified in the `pbs_mom`'s configuration file. By default, only "localhost" and the name returned by `gethostname`(2) are allowed. See the man pages `pbs_mom`(8B) for more information on the configuration file.

Access to `pbs_sched` is not limited other than it must be from a privileged port.

11.6.3 User Authentication

The PBS Server authenticates the user name included in a request using the supplied PBS credential. This credential is supplied by `pbs_iff`.

11.6.4 User Authorization

PBS as shipped does not assume a consistent user name space within the set of systems which make up a PBS cluster. However, the administrator can enable this assumption, if desired. By default, the routine `site_map_user`() is called twice, once to map the name of the requester and again to map the job owner to a name on the Server's (local) system. If the two mappings agree, the requester is considered the job owner.

If running PBS in an environment that *does* have a flat user namespace, the demonstrator can disable these checks by setting the `flatuid` Server attribute to `True` via `qmgr`:

```
# qmgr
Qmgr: set server flatuid=True
```

In either case, if a job is submitted by *UserA@hostA* PBS will allow the job to be deleted or altered by *UserA@hostB*

If `flatuid` is set to `true`, a UserA on HostX who submits a job to the PBS Server on HostY will not require a .rhosts entry on HostY for HostX, nor must HostX appear in HostY's `/etc/hosts.equiv` file.

A user may supply a name under which the job is to executed on a certain system. If one is not supplied, the name of the job owner is chosen to be the execution name-- see the `-u user_list` option of the `qsub`(1B) command. Authorization to execute the job under the chosen name is granted under the following conditions:

1. The job was submitted on the Server's (local) host and the submitter's name is the same as the selected execution name.

2. The host from which the job was submitted are declared trusted by the execution host in the `/etc/hosts.equiv` file or the submitting host and submitting user's name are listed in the execution users' `.rhosts` file. The system supplied library function, `ruserok`*()*, is used to make these checks.

If the above test to determine authorization are not sufficient to a site, the routine `site_check_user_map`*()* in the file `src/server/site_check_u.c` may be modified.

In addition to the above checks, access to a PBS Server and queues within that Server may be controlled by access control lists. (For details see "Server Attributes" on page 62 and "Queue Attributes" on page 67.)

11.6.5 Group Authorization

PBS allows a user to submit jobs and specify under which group the job should be executed. The user specifies a `group_list` attribute for the job which contains a list of group@host similar to the user list. See the `group_list` attribute under the -W option of `qsub`(1B). The PBS Server will ensure that the user is a member of the specified group by:

1. Checking if the specified group is the user's primary group in the password entry on the execution host. In this case the user's name does not have to appear in the group entry for his primary group.

2. Checking on the execution host for the user's name in the specified group entry in `/etc/group`.

The job will be aborted if both checks fail. The checks are skipped if the user does not supply a group list attribute. In this case the user's primary group from the password file will be used.

When staging files in or out, PBS also uses the selected execution group for the copy operation. This provides normal UNIX access security to the files. Since all group information is passed as a string of characters, PBS cannot determine if a numeric string is intended to be a group name or GID. Therefore when a group list is specified by the user, PBS places one requirement on the groups within a system: each and every group in which a user might execute a job MUST have a group name and an entry in `/etc/group`. If no `group_list` are ever used, PBS will use the login group and will accept it even if the group is not listed in `/etc/group`. Note, in this latter case, the `egroup` attribute value is a numeric string representing the GID rather than the group "name".

11.7 External Security

In addition to the security measures discussed above, PBS provides three levels of privilege: user, operator, and Manager. Users have user privilege which allows them to manipulate their own jobs. Manager or Operator privilege is required to set or unset attributes of the Server, queues, nodes, other peoples jobs, with the following exceptions:

Manager privilege is required to create and delete queues or nodes, and set/alter/unset:

node properties
server acl_host_enable
server acl_host_list
server acl_user_enable
server acl_users
server acl_roots
server managers
server operators
server query_other_jobs
server comment
server default_node
server node_pack

11.8 Root Owned Jobs

The Server will reject any job which would execute under the UID of zero unless the owner of the job, typically root on this or some other system, is listed in the Server attribute `acl_roots`.

11.9 Job Prologue/Epilogue Scripts

PBS provides the ability for the administrator run a site supplied script (or program) before (`prologue`) and/or after (`epilogue`) each job runs. This provides the capability to perform initialization or cleanup of resources, such as temporary directories or scratch files. The scripts may also be used to write “banners” on the job’s output files. When multiple nodes are allocated to a job, these scripts are only run by the “Mother Superior”, the pbs_mom on the first node allocated. This is also where the job shell script is run. Note that both the prologue and epilogue are run with root privilege (not as the user), and neither are included in the job session, thus the prologue cannot be used to modify the job environment or change limits on the job.

If a `prologue` or `epilogue` script is not present, MOM continues in a normal manner. If present, the script is run with root privilege. In order to be run, the script must adhere to the following rules:

- The script must be in the `/usr/spool/PBS/mom_priv` directory with the name `prologue` for the script to be run before the job and the name `epilogue` for the script to be run after the job.
- The script must be owned by root.
- The script must be readable and executable by root.
- The script cannot be writable by anyone but root.

The “script” may be either a shell script or an executable object file. Typically, a shell script should start with a line of the form:

```
#! /path/interpreter
```

For more information, see the rules described under `execve`(2) or `exec`(2) on your system.

11.9.1 Prologue and Epilogue Arguments

When invoked, the prologue is called with the following arguments:

argv[1] the job id.
argv[2] the user name under which the job executes.
argv[3] the group name under which the job executes.

The epilogue is called with the above, plus:

argv[4]	the job name.
argv[5]	the session id.
argv[6]	the requested resource limits (list).
argv[7]	the list of resources used
argv[8]	the name of the queue in which the job resides.
argv[9]	the account string, if one exists.

For both the `prologue` and `epilogue`:

envp The environment passed to the script is null.

cwd The current working directory is the user’s home directory.

input When invoked, both scripts have standard input connected to a system dependent file. Currently, this file is `/dev/null`.

output With one exception, the standard output and standard error of the scripts are connected to the files which contain the standard output and error of the job. If a job is an interactive PBS job, the standard output and error of the epilogue is pointed to `/dev/null` because the pseudo terminal connection used was released by the system when the job terminated.

11.9.2 Prologue Epilogue Time Out

To prevent an error condition within the prologue or epilogue from delaying PBS, MOM places an alarm around the scripts execution. This is currently set to 30 seconds. If the alarm sounds before the scripts has terminated, MOM will kill the script. The alarm value can be changed by changing the define of **PBS_PROLOG_TIME** within `src/resmom/prolog.c`.

11.9.3 Prologue Error Processing

Normally, the prologue script should exit with a zero exit status. MOM will record in her log any case of a non-zero exit from a script. Exit status values and their impact on the job are:

-4 The script timed out (took too long). The job will be requeued.

-3 The `wait`(2) call waiting for the script to exit returned with an error. The job will be requeued.

-2 The input file to be passed to the script could not be opened. The job will be requeued.

-1 The script has a permission error, it is not owned by root and or is writable by others than root. The job will be requeued.

0 The script was successful. The job will run.

1 The script returned an exit value of 1, the job will be aborted.

>1 The script returned a value greater than one, the job will be requeued.

The above apply to normal batch jobs. Interactive-batch jobs (`-I` option) cannot be requeued on a non-zero status. The network connection back to `qsub` is lost and cannot be re-established. Interactive jobs will be aborted on any non-zero prologue exit.

Important: The administrator must exercise great caution in setting up the prologue to prevent jobs from being flushed from the system.

Epilogue script exit values which are non-zero are logged, but have no impact on the state of the job.

11.10 Use and Maintenance of Logs

The PBS system tends to produce lots of log file entries. There are two types of logs: the event logs which record events from each PBS daemon (`pbs_server`, `pbs_mom`, and `pbs_sched`) and the PBS accounting log.

11.10.1 The Daemon Logs

Each PBS daemon maintains an event log file. The Server (`pbs_server`), Scheduler (`pbs_sched`), and MOM (`pbs_mom`) default their logs to a file with the current date as the name in the `/usr/spool/PBS/(`*`daemon`*`)_logs` directory. This location can be overridden with the "`-L pathname`" option where pathname must be an absolute path.

If the default log file name is used (no `-L` option), the log will be closed and reopened with the current date daily. This happens on the first message after midnight. If a path is given with the `-L` option, the automatic close/reopen does not take place. All daemons will close and reopen the same named log file on receipt of **SIGHUP**. The process identified (PID) of the daemon is available in its lock file in its home directory. Thus it is possible to move the current log file to a new name and send **SIGHUP** to restart the file:

```
# cd /usr/spool/PBS/DAEMON_logs
# mv current archive
# kill -HUP ‘cat ../DAEMON_priv/daemon.lock‘
#
```

The amount of output in the logs depends on the selected events to log and the presence of debug writes, turned on by compiling with `-DDEBUG`. The Server and MOM can be directed to record only messages pertaining to certain event types. The specified events are logically “or-ed”. Their decimal values are:

1	Error Events
2	Batch System/Server Events
4	Administration Events
8	Job Events
16	Job Resource Usage (hex value 0x10)
32	Security Violations (hex value 0x20)
64	Scheduler Calls (hex value 0x40)
128	Debug Messages (hex value 0x80)
256	Extra Debug Messages (hex value 0x100)

Everything turned on is of course 511. 127 is a good value to use. The event logging mask is controlled differently for the Server and MOM. The Server’s mask is set via `qmgr`(1B) setting the `log_events` attribute. This can be done at any time. MOM’s mask may be set via her configuration file with a `$logevent` entry. To have the change take effect, send MOM a **SIGHUP** signal.

To change the event logging mask of the Scheduler, set the `log_filter` parameter in the Scheduler’s config file.

11.10.2 The Accounting Log

The PBS Server daemon maintains an accounting log. The log name defaults to `/usr/`

`spool/PBS/server_priv/accounting/`*`yyyymmdd`* where *`yyyymmdd`* is the date. The accounting log files may be placed elsewhere by specifying the `-A` option on the `pbs_server` command line. The option argument is the full (absolute) path name of the file to be used. If a null string is given, then the accounting log will not be opened and no accounting records will be recorded. For example

```
# pbs_server -A ""
#
```

The accounting file is changed according to the same rules as the log files. If the default file is used, named for the date, the file will be closed and a new one opened every day on the first event (write to the file) after midnight. With either the default file or a file named with the `-A` option, the Server will close the accounting log and reopen it upon the receipt of a **SIGHUP** signal. This allows you to rename the old log and start recording again on an empty file. For example, if the current date is February 9, 2001 the Server will be writing in the file `20010209`. The following actions will cause the current accounting file to be renamed `feb9` and the Server to close the file and starting writing a new `20010209`.

```
# mv 20010209 feb9
# kill -HUP 1234     (the Server's pid)
#
```

11.11 Handling Jobs on Failed Nodes

If a job is running and the first node assigned to the job goes down, the job can be requeued (`qrerun`) or deleted (`qdel`). Neither of these actions are performed automatically because (1) it might be the network rather than the node that actually went down and the job is still running correctly, or (2) it might be that the `pbs_mom` on the node went down and the job is still running correctly. In either case, rather than waste the cycles spent so far, the administrator or user can allow the job to continue and when the network or `pbs_mom` is restarted, the work will not have been lost.

However, if the node is truly down, the administrator or user can delete the job or requeue it for execution later, by using the "`-W force`" option to `qdel` and `qrerun`, as shown below.

Important: Note, in either case, the output created by the job before the node went down will be discarded.

```
% qdel -W force 1123.veridian.com
or
% qrerun -W force 1124.veridian.com
```

11.12 xPBS GUI Configuration

PBS currently provides two Graphical User Interfaces (GUIs): xpbs (intended primarily for users) and xpbsmon (intended for PBS operators and managers). Both are built using the Tool Control Language Toolkit (TCL/tk). The first section below discusses the user GUI, `xpbs`. The following section discusses `xpbsmon`.

11.12.1 xpbs

xpbs provides a user-friendly point-and-click interface to the PBS commands. To run `xpbs` as a regular, non-privileged user, type:

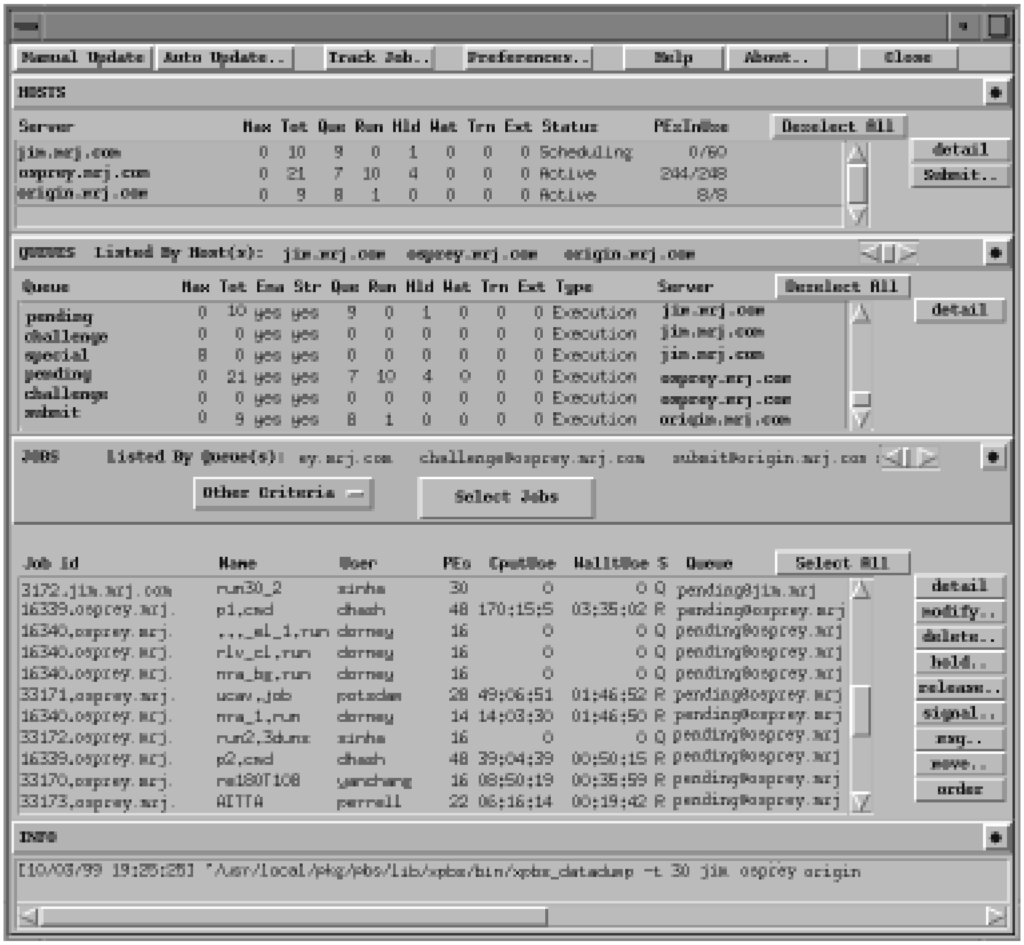
```
% setenv DISPLAY your_workstation_name:0
% xpbs
```

To run `xpbs` with the additional purpose of terminating PBS Servers, stopping and starting queues, or running/rerunning jobs, then run:

```
% xpbs -admin
```

Running `xpbs` will initialize the X resource database from various sources in the following order:

1. The RESOURCE_MANAGER property on the root window (updated via `xrdb`) with settings usually defined in the `.Xdefaults` file



```
Server              Max Tot Que Run Hld Wat Trn Ext Status      PEsInUse
jim.mrj.com           0  10   9   0   1   0   0   0 Scheduling      0/60
osprey.mrj.com        0  21   7  10   4   0   0   0 Active        244/248
origin.mrj.com        0   9   8   1   0   0   0   0 Active          8/8
```

QUEUES Listed By Host(s): jim.mrj.com osprey.mrj.com origin.mrj.com

```
Queue          Max Tot Ena Str Que Run Hld Wat Trn Ext Type      Server
pending          0  10 yes yes   9   0   1   0   0   0 Execution jim.mrj.com
challenge        0   0 yes yes   0   0   0   0   0   0 Execution jim.mrj.com
special          8   0 yes yes   0   0   0   0   0   0 Execution jim.mrj.com
pending          0  21 yes yes   7  10   4   0   0   0 Execution osprey.mrj.com
challenge        0   0 yes yes   0   0   0   0   0   0 Execution osprey.mrj.com
submit           0   9 yes yes   8   1   0   0   0   0 Execution origin.mrj.com
```

JOBS Listed By Queue(s): ey.mrj.com challenge@osprey.mrj.com submit@origin.mrj.com

```
Job Id              Name          User      PEs  CputUse  WalltUse S Queue
3172.jim.mrj.com    run30_2       sinha      30        0         0 Q pending@jim.mrj
16339.osprey.mrj.   p1.cmd        dhesh      48 170:15:5  03:35:02 R pending@osprey.mrj
16340.osprey.mrj.   ...._ml_1.run dorney     16        0         0 Q pending@osprey.mrj
16340.osprey.mrj.   rlv_cl.run    dorney     16        0         0 Q pending@osprey.mrj
16340.osprey.mrj.   nra_bg.run    dorney     16        0         0 Q pending@osprey.mrj
33171.osprey.mrj.   ucav.job      potsdam    28 49:06:51  01:46:52 R pending@osprey.mrj
16340.osprey.mrj.   nra_1.run     dorney     14 14:03:30  01:46:50 R pending@osprey.mrj
33172.osprey.mrj.   run2.3dunx    sinha      16        0         0 Q pending@osprey.mrj
16339.osprey.mrj.   p2.cmd        dhesh      48 39:04:39  00:50:15 R pending@osprey.mrj
33170.osprey.mrj.   ra180T108     yancheng   16 08:50:19  00:35:59 R pending@osprey.mrj
33173.osprey.mrj.   AITTA         perrell    22 06:16:14  00:19:42 R pending@osprey.mrj
```

```
[10/08/99 19:28:28] "/usr/local/pkg/pbs/lib/xpbs/bin/xpbs_datadump -t 30 jim osprey origin
```

2. Preference settings defined by the system administrator in the global `xpbsrc` file

3. User's `~/.xpbsrc` file-- this file defines various X resources like fonts, colors, list of PBS hosts to query, criteria for listing queues and jobs, and various view states. See XPBS Preferences section below for a list of resources that can be set.

The system administrator can specify a global resources file to be read by the GUI if a personal `.xpbsrc` file is missing: `/usr/pbs/lib/xpbs/xpbsrc`. Keep in mind that within an Xresources file (Tk only), later entries take precedence. For example, suppose in your `.xpbsrc` file, the following entries appear in order:

```
xpbsrc*backgroundColor: blue
*backgroundColor: green
```

The later entry "green" will take precedence even though the first one is more precise and longer matching. The things that can be set in the personal preferences file are fonts, colors, and favorite Server host(s) to query.

11.12.2 XPBS Preferences

The resources that can be set in the X resources file, `~/.xpbsrc`, are:

*defSeverFile name of file containing the name of the default PBS Server host

*serverHosts list of Server hosts (space separated) to query by `xpbs`. A special keyword/entry PBS_DEFAULT_SERVER will substitute the hostname obtained from the resource defServerFile.

*timeoutSecs specify the number of seconds before timing out waiting for a connection to a PBS host.

*xtermCmd the xterm command to run driving an interactive PBS session.

*labelFont font applied to text appearing in labels.

*fixlabelFont font applied to text that label fixed-width widgets such as listbox labels. This must be a fixed-width font.

*textFont font applied to a text widget. Keep this as fixed-width font.

*backgroundColor the color applied to background of frames, buttons, entries, scrollbar handles.

*foregroundColor the color applied to text in any context (under selection, insertion, etc...).

*activeColor the color applied to the background of a selection, a selected command button, or a selected scroll bar handle.

*disabledColor color applied to a disabled widget.
*signalColor color applied to buttons that signal something to the user about a change of state. For example, the color of the button when returned output files are detected.

*shadingColor a color shading applied to some of the frames to emphasize focus as well as decoration.

*selectorColor the color applied to the selector box of a radiobutton or checkbutton.

*selectHosts list of hosts (space separated) to automatically select/highlight in the HOSTS listbox. A special keyword/entry PBS_DEFAULT_SERVER will substitute the hostname obtained from the resource defServerFile.

*selectQueues list of queues (space separated) to automatically select/highlight in the QUEUES listbox.

*selectJobs list of jobs (space separated) to automatically select/highlight in the JOBS listbox.

*selectOwners list of owners checked when limiting the jobs appearing on the Jobs listbox in the main `xpbs` window. Specify value as "Owners: <list_of_owners>". See `-u` option in `qselect`(1B) for format of <list_of_owners>.

*selectStates list of job states to look for (do not space separate) when limiting the jobs appearing on the Jobs listbox in the main `xpbs` window. Specify value as "Job_States: <states_string>". See `-s` option in `qselect`(1B) for format of <states_string>.

*selectRes list of resource amounts (space separated) to consult when limiting the jobs appearing on the Jobs listbox in the main `xpbs` window. Specify value as "Resources: <res_string>". See `-l` option in `qselect`(1B) for format of <res_string>.

*selectExecTime the Execution Time attribute to consult when limiting the list of jobs appearing on the Jobs listbox in the main `xpbs` window. Specify value as "Queue_Time: <exec_time>". See `-a` option in `qselect`(1B) for format of <exec_time>.

*selectAcctName the name of the account that will be checked when limiting the jobs appearing on the Jobs listbox in the main `xpbs` window. Specify value as "Account_Name: <account_name>". See `-A` option in `qselect`(1B) for format of <account_name>.

*selectCheckpoint the checkpoint attribute relationship (including the logical operator) to consult when limiting the list of jobs appearing on the Jobs listbox in the main `xpbs` window. Specify value as "Checkpoint: <checkpoint_arg>". See `-c` option in `qselect`(1B) for format of <checkpoint_arg>.

*selectHold the hold types string to look for in a job when limiting the jobs appearing on the Jobs listbox in the main `xpbs` window. Specify value as "Hold_Types: <hold_string>". See -h option in `qselect`(1B) for format of <hold_string>.

*selectPriority the priority relationship (including the logical operator) to consult when limiting the list of jobs appearing on the Jobs listbox in the main `xpbs` window. Specify value as "Priority: <priority_value>". See `-p` option in `qselect(1B)` for format of <priority_value>.

*selectRerun the rerunnable attribute to consult when limiting the list of jobs appearing on the Jobs listbox in the main `xpbs` window. Specify value as "Rerunnable: <rerun_val>". See -r option in `qselect`(1B) for format of <rerun_val>.

*selectJobName name of the job that will be checked when limiting the jobs appearing on the Jobs listbox in the main `xpbs` window. Specify value as "Job_Name: <jobname>". See -N option in `qselect`(1B) for format of <jobname>.

*iconizeHostsView a boolean value (true or false) indicating whether or not to iconize the HOSTS region.

*iconizeQueuesView a boolean value (true or false) indicating whether or not to iconize the QUEUES region.

*iconizeJobsView a boolean value (true or false) indicating whether or not to iconize the JOBS region.

*iconizeInfoView a boolean value (true or false) indicating whether or not to iconize the INFO region.

*jobResourceList a curly-braced list of resource names as according to architecture known to xpbs. The format is as follows:
{ <arch-type1> resname1 resname2 ... resnameN }
{ <arch-type2> resname1 resname2 ... resnameN }
. . .
{ <arch-typeN> resname1 resname2 ... resnameN }

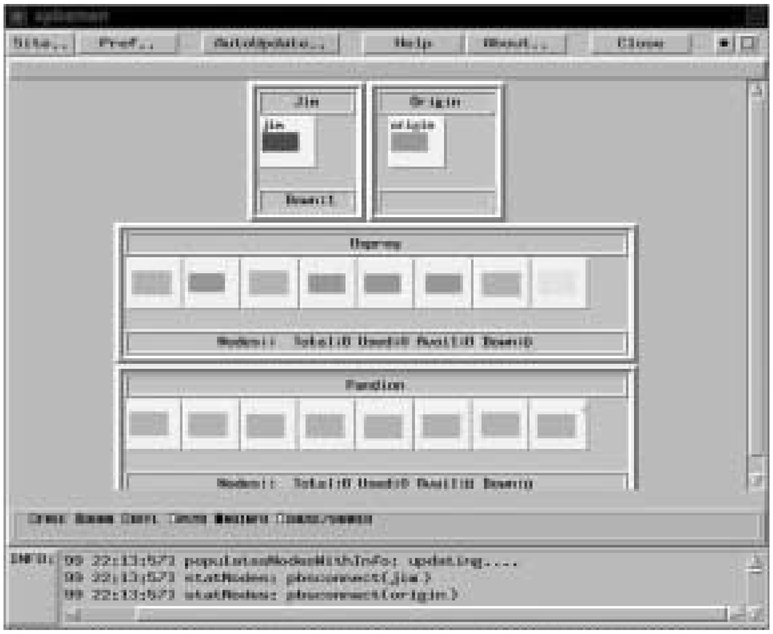
11.12.3 XPBS and PBS Commands

xpbs calls PBS commands as follows:

xPBS Button	PBS Command
detail (Hosts)	qstat -B -f <selected server_host(s)>
terminate	qterm <selected server_host(s)>
detail (Queues)	qstat -Q -f <selected queue(s)>
stop	qstop <selected queue(s)>
start	qstart <selected queue(s)>
enable	qenable <selected queue(s)>
disable	qdisable <selected queue(s)>
detail (Jobs)	qstat -f <selected job(s)>
modify	qalter <selected job(s)>
delete	qdel <selected job(s)>
hold	qhold <selected job(s)>
release	qrls <selected job(s)>
run	qrun <selected job(s)>
rerun	qrerun <selected job(s)>
signal	qsig <selected job(s)>
msg	qmsg <selected job(s)>
move	qmove <selected job(s)>
order	qorder <selected job(s)>

11.13 xpbsmon GUI Configuration

xpbsmon is the node monitoring GUI for PBS. It is used for graphically displaying information about execution hosts in a PBS environment. Its view of a PBS environment consists of a list of sites where each site runs one or more Servers, and each Server runs jobs on one or more execution hosts (nodes).



```
09 22:13:57] populateNodesWithInfo: updating....
09 22:13:57] statNodes: pbsconnect(jim)
09 22:13:57] statNodes: pbsconnect(origin)
```

The system administrator needs to define the site's information in a global X resources file, */usr/pbs/lib/*`xpbsmon/xpbsmonrc` which is read by the GUI if a personal `.xpbsmonrc` file is missing. A default `xpbsmonrc` file usually would have been created already during installation, defining (under *sitesInfo resource) a default site name, list of Servers that run on a site, set of nodes (or execution hosts) where jobs on a particular Server run, and the list of queries that are communicated to each node's `pbs_mom.` If node queries have been specified, the host where `xpbsmon` is running must have been given explicit permission by the `pbs_mom` daemon to post queries to it. This is done by including a `$restricted` entry in the MOM's config file.

It is not recommended to manually update the *sitesInfo value in the `xpbsmonrc` file as its syntax is quite cumbersome. The recommended procedure is to bring up `xpbsmon`, click on "Pref.." button, manipulate the widgets in the Sites, Server, and Query Table dialog boxes, then click "Close" button and save the settings to a `.xpbsmonrc` file. Then copy this file over to the */usr/pbs/*`lib/xpbsmon/` directory.

11.14 pbsnodes Command Changes

With PBS Pro release 5.1 changes have been made to the `pbsnodes` command to make it safer for the Administrator and more friendly for the user.

The `-d` option is now required to make the listed nodes down and clear "down" from the unlisted nodes. This will require a change to any scripts that use this feature of the command. If executed without the `-d` option with a list of nodes, the command will now display the status of the list of nodes.

Summary of new behavior of the `pbsnodes` command:

Command Usage	Action
`pbsnodes`	prints the command usage syntax (new)
`pbsnodes node1 node2`	prints the status of nodes node1 and node2 (new)
`pbsnodes -d`	clears "down" from all nodes (new)
`pbsnodes -d node1 node2`	clears "down" from all nodes **except** node1 and node2 which are marked down (new)

All other options behave the same as in previous versions. See the `pbsnodes(1B)` man page for detailed usage.

11.15 PBS Pro on Scyld Beowulf Clusters

Running PBS Pro under Scyld Computing Corporation’s Beowulf operating system is a bit different from normal clusters. Given Scyld’s single system image, there needs to be only a single MOM running within the cluster, rather than on each node. When `pbs_mom` starts on the master node, the ownership of all the compute nodes is changed to 'root'. Each time a job runs, the ownership of the nodes chosen for the job will be changed to the user running the job.

The Scyld kernel allows processes running on the compute nodes to be tracked on the master node so `pbs_mom` can directly set limits and track usage. The `ncpus` resource is reported as the total number of CPUs reported on all the compute nodes configured. The actual number of CPUs available will vary as nodes run jobs, go down or otherwise become unavailable. Since ownership is assigned on a node rather than cpu basis, if you have multi-cpu nodes, there may be unused CPUs if a job asks for a number of nodes that is not an even multiple of the number of CPUs per node. The physmem resource is the sum of physical memory on all the compute nodes.

Information on running jobs on Scyld Beowulf clusters is given in section “Running Jobs on Scyld Beowulf Clusters” of the **PBS User Guide**.

Chapter 12
Problem Solving

The following is a list of common problems and recommended solutions. Additional information is always available online at the PBS website, www.pbspro.com. The last section in this chapter gives important information on how to get additional assistance from the Veridian PBS Support staff.

12.1 Clients Unable to Contact Server

If a client command (such as `qstat` or `qmgr`) is unable to connect to a Server there are several possibilities to check. If the error return is `15034`, “`No server to connect to`”, check (1) that there is indeed a Server running and (2) that the default Server information is set correctly. The client commands will attempt to connect to the Server specified on the command line if given, or if not given, the Server specified by **`SERVER_NAME`** in `/etc/pbs.conf`.

If the error return is `15007`, “`No permission`”, check for (2) as above. Also check that the executable `pbs_iff` is located in the search path for the client and that it is setuid root. Additionally, try running `pbs_iff` by typing:

```
pbs_iff -t server_host 15001
```

Where *`server_host`* is the name of the host on which the Server is running and `15001` is the port to which the Server is listening (if started with a different port number, use that number instead of 15001). Check for an error message and/or a non-zero exit status. If pbs_iff exits with no error and a non-zero status, either the Server is not running or was installed with a different encryption system than was pbs_iff.

12.2 Nodes Down

The PBS Server determines the state of nodes (up or down), by communicating with MOM on the node. The state of nodes may be listed by two commands: qmgr and pbsnodes.

```
% qmgr
Qmgr: list node @active

% pbsnodes -a
Node jupiter
        state = down, state-unknown
        properties = sparc, mine
        ntype = cluster
```

A node in PBS may be marked "down" in one of two substates. For example, the state above of node "jupiter" shows that the Server has not had contact with MOM since the Server came up. Check to see if a MOM is running on the node. If there is a MOM and if the MOM was just started, the Server may have attempted to poll her before she was up. The Server should see her during the next polling cycle in 10 minutes. If the node is still marked "down, state-unknown" after 10+ minutes, either the node name specified in the Server's node file does not map to the real network hostname or there is a network problem between the Server's host and the node.

If the node is listed as

```
% pbsnodes -a
Node jupiter
        state = down
        properties = sparc, mine
        ntype = cluster
```

Then the Server has been able to ping MOM on the node in the past, but she has not responded recently. The Server will send a "ping" PBS message to every free node each ping cycle, 10 minutes. If a node does not acknowledge the ping before the next cycle, the Server will mark the node down.

On an IBM SP, a node may also be marked down if MOM on the node believes that the node is not connected to the high speed switch. When the Server receives an acknowledgment from MOM on the node, the node will again be marked up (free).

12.3 Requeueing a Job “Stuck” on a Down Node

Once a job is "running" it will be in that state until the Server hears otherwise from MOM. However, if the (first) node for a job fails/crashes/hangs, then MOM cannot tell the Server that the job is done. You have two options of how to handle this situation.

If you wish to have PBS simply remove the hung job from the system, use the “`-Wforce`” option to qdel:

```
% qdel -Wforce jobID
```

If instead you want PBS to requeue the job, and have it immediately eligible to run again, use the “`-Wforce`” option to qrerun:

```
% qrerun -Wforce jobID
```

The `-Wforce` option is required as a safe-guard since both actions are extraordinary.

12.4 Non Delivery of Output

If the output of a job cannot be delivered to the user, it is saved in a special directory: `/usr/spool/PBS/undelivered` and mail is sent to the user. The typical causes of non-delivery are:

1. The destination host is not trusted and the user does not have a `.rhost` file.
2. An improper path was specified.
3. A directory in the specified destination path is not writable.
4. The user’s `.cshrc` on the destination host generates output when executed.
5. The path specified by **`PBS_SCP`** in `/etc/pbs.conf` is incorrect.
6. The `/usr/spool/PBS/spool` directory on the execution host does not have the correct permissions. This directory must have mode 1777 (`drwxrwxrwxt`).

These are explained in the “Delivery of Output Files” section of the **PBS User Guide**.

12.5 Job Cannot be Executed

If a user receives a mail message containing a job id and the line "Job cannot be executed", the job was aborted by MOM when she tried to place it into execution. The complete reason can be found in one of two places, MOM's log file or the standard error file of the user's job.

If the second line of the message is "See Administrator for help", then MOM aborted the job before the job's files were set up. The reason will be noted in MOM's log. Typical reasons are a bad user/group account, checkpoint/restart file (Cray or SGI), or a system error.

If the second line of the message is "See job standard error file", then MOM had created the job's file and additional messages were written to standard error. This is typically the result of a bad resource request.

12.6 Running Jobs with No Active Processes

On very rare occasions, PBS may be in a situation where a job is in the Running state but has no active processes. This should never happen as the death of the job's shell should trigger MOM to notify the Server that the job exited and end of job processing should begin. If this situation is noted, PBS offers a way out. Use the qsig command to send SIGNULL, signal 0, to the job. If MOM finds there are no processes then she will force the job into the exiting state.

12.7 Dependent Jobs and Test Systems

If you have users running on a test batch system using an alternative port number, -p option to pbs_server, problems may occur with job dependency if the following requirements are not observed:
For a test system, the job identifier in a dependency specification must include at least the first part of the host name.

The colon in the port number specification must be escaped by a back-slash. This is true for both the Server and current Server sections. For example:

```
23.test_host\:17000
23.old_host@test_host\:17000
23.test_host\:17000@diff_test_host\:18000
```

On a shell line, the back slash itself must be escaped from the shell, so the above become:

```
23.test_host\\:17000
23.old_host@test_host\\:17000
23.test_host\\:17000@diff_test_host\\:18000
```

These rules are not documented on the qsub/qalter man pages since the likelihood of the general user community finding themselves setting up dependencies with jobs on a test system is small and the inclusion would be generally confusing.

12.8 Getting Help

If the material in the PBS manuals is unable to help you solve a particular problem, you may need to contact the PBS Support team for assistance. First, be sure to check the Customer Login area of the PBS Pro website, which has a number of ways to assist you in resolving problems with PBS. The two most frequently used are: the Tips & Advice page and the Submit Problem Report page.

The PBS Pro support team can also be reached directly via email and phone:

Email: support@pbspro.com	Phone: 650-967-4675

Important: When contacting PBS Pro Support, please provide as much of the following information as possible:

PBS SiteID
Output of the following commands:

```
qstat -Bf
qstat -Qf
pbsnodes -a
```

If the question pertains to a certain type of job, include:

```
qstat -f job_id
```

If the question is about scheduling, also send your:
`(PBS_HOME)/sched_priv/sched_config` file.

To expand, renew, or change your PBS support contract, contact our Sales Department. (See contact information on the inside front cover of this manual.)

Chapter 13
Customizing PBS

This chapter addresses several ways that PBS can be customized for your site. While having the source code is the first step, there are specific actions other than modifying the code you can take.

13.1 Shell Invocation

When PBS starts a job, it invokes the user's login shell (unless the user submitted the job with the `-S` option). PBS passes the job script which is a shell script to the login process in one of two ways depending on how PBS was installed.

1. Name of Script on Standard Input
The default method (PBS built with --enable-shell-pipe) is to pass the name of the job script to the shell program. This is equivalent to typing the script name as a command to an interactive shell. Since this is the only line passed to the script, standard input will be empty to any commands. This approach offers both advantages and disadvantages:

+ Any command which reads from standard input without redirection will get an EOF.

+ The shell syntax can vary from script to script, it does not have to match the syntax for the user's login shell. The first line of the script, even before any #PBS directives, should be

`#!/`*`shell`* where *`shell`* is the full path to the shell of choice, `/bin/sh`, `/bin/csh`, ...

The login shell will interpret the `#!` line and invoke that shell to process the script.

- An extra shell process is run to process the job script.

- If the script does not include a `#!` line as the first line, the wrong shell may attempt to interpret the script producing syntax errors.

- If a non-standard shell is used via the -S option, it will not receive the script, but its name, on its standard input.

2. Script as Standard Input
The alternative method for PBS (built with `--disable-shell-invoke`), is to open the script file as standard input for the shell. This is equivalent to typing:

```
% /path/shell < script
```

This also offers advantages and disadvantages:

+ The user's script will always be directly processed by the user's login shell.

+ If the user specifies a non-standard shell (any old program) with the -S option, the script can be read by that program as its input.

- If a command within the job script reads from standard input, it may read lines from the script depending on how far ahead the shell has buffered its input. Any command line so read will not be executed by the shell. A command that reads from standard input with out explicit redirection is generally unwise in a batch job.

The choice of shell invocation methods is left to the site. It is recommended that all PBS execution servers (pbs_mom) within that site be built to use the same shell invocation method.

13.2 Additional Build Options

Two header files within the subdirectory `src/include` provide additional configuration control over the Server and MOM. The modification of any symbols in the two files should not be undertaken lightly.

13.2.1 pbs_ifl.h

This header file contains structures, symbols and constants used by the API, libpbs.a, and the various commands as well as the daemons. Very little here should ever be changed. Possible exceptions are the following symbols. They must be consistent between all batch systems which might interconnect.

PBS_MAXHOSTNAME

Defines the length of the maximum possible host name. This should be set at least as large as MAXHOSTNAME which may be defined in `sys/params.h.`

PBS_MAXUSER

Defines the maximum possible length of a user login name.

PBS_MAXGRPN

Defines the maximum possible length of a maximum possible group name.

PBS_MAXQUEUENAME

Defines the maximum possible length of a maximum possible PBS queue name.

PBS_USE_IFF

If this symbol is set to zero (0), before the library and commands are built, the API routine `pbs_connect`() will not attempt to invoke the program `pbs_iff` to generate a secure credential to authenticate the user. Instead, a clear text credential will be generated. This credential is completely subject to forgery and is useful only for debugging the PBS system. You are strongly advised against using a clear text credential.

PBS_BATCH_SERVICE_PORT

Defines the port number at which the Server listens.

PBS_MOM_SERVICE_PORT

Defines the port number at which MOM, the execution mini-server, listens.

PBS_SCHEDULER_SERVICE_PORT
Defines the port number at which the Scheduler listens.

13.2.2 server_limits.h

This header file contains symbol definitions used by the Server and by MOM. Only those that *might* be changed are listed here. These should be changed with care. It is strongly recommended that no other symbols in `server_limits.h` be changed. If server_limits.h is to be changed, it may be copied into the include directory of the *target* (build) tree and modified before compiling.

NO_SPOOL_OUTPUT
If defined, directs MOM to not use a spool directory for the job output, but to place it in the user's home directory while the job is running. This allows a site to invoke quota control over the output of running batch jobs.

PBS_BATCH_SERVICE_NAME
This is the service name used by the Server to determine to which port number it should listen. It is set to pbs in quotes as it is a character string. Should you wish to assign PBS a service port in `/etc/services` change this string to the service name assigned. You should also update PBS_SCHEDULER_SERVICE_NAME as required.

PBS_DEFAULT_ADMIN
Defined to the name of the default administrator, typically "root". Generally only changed to simplify debugging.

PBS_DEFAULT_MAIL
Set to user name from which mail will be sent by PBS. The default is "adm". This is overridden if the Server attribute `mail_from` is set.

PBS_JOBBASE
The length of the job id string used as the basename for job associated files stored in the spool directory. It is set to 11, which is 14 minus the 3 characters of the suffixes like `.JB` and `.OU`. Fourteen is the guaranteed length for a file name under POSIX.

PBS_MAX_HOPCOUNT
Used to limit the number of hops taken when being routed from

queue to queue. It is mainly to detect loops.

PBS_NET_MAX_CONNECTIONS

The maximum number of open file descriptors and sockets supported by the Server.

PBS_NET_RETRY_LIMIT

The limit on retrying requests to remote Servers.

PBS_NET_RETRY_TIME

The time between network routing retries to remote queues and for requests between the Server and MOM.

PBS_RESTAT_JOB

To refrain from over burdening any given MOM, the Server will wait this amount of time (default 30 seconds) between asking her for updates on running jobs. In other words, if a user asks for status of a running job more often than this value, the prior data will be returned.

PBS_ROOT_ALWAYS_ADMIN

If defined (set to 1), “root” is an administrator of the batch system even if not listed in the `managers` attribute.

PBS_SCHEDULE_CYCLE

The default value for the elapsed time between scheduling cycles with no change in jobs queued. This is the initial value used by the Server, but it can be changed via `qmgr(`1B).

13.3 Site Modifiable Source Files

It is safe to skip this section until you have played with PBS for a while and want to start tinkering.

Certain functions of PBS appear to be likely targets of widespread modification by sites for a number of reasons. When identified, the developers of PBS have attempted to improve the easy of modification in these areas by the inclusion of special *site specific modification routines* The distributed default version of these files build a private library, libsite.a, which is included in the linking phase for the Server and for MOM.

13.3.1 Server Modifiable Files

`site_allow_u.c`

The routine in this file, `site_allow_u`() provides an additional point at which a user can be denied access to the batch system (Server). It may be used instead of or in addition to the Server `acl_user` list.

`site_alt_rte.c`

The function `site_alt_router`() allows a site to add decision capabilities to job routing. This function is called on a per-queue basis if the queue attribute `alt_router` is true. As provided, `site_alt_router`() just invokes the default router, `default_router`().

`site_check_u.c`

There are two routines in this file.

The routine `site_check_user_map`() provides the service of authenticating that the job owner is privileged to run the job under the user name specified or selected for execution on the Server system.

The routine `site_acl_check`() provides the site with the ability to restrict entry into a queue in ways not otherwise covered. For example, you may wish to check a bank account to see if the user has the funds to run a job in the specific queue.

`site_map_usr.c`

For sites without a common user name/uid space, this function, `site_map_user`() provides a place to add a user name mapping function. The mapping occurs at two times. First to determine if a user making a request against a job is the job owner, see “User Authorization”. Second, to map the submitting user (job owner) to an execution uid on the local machine.

`site_*_attr_*.h`

These files provide a site with the ability to add local attributes to the Server, queues, and jobs. The files are installed into the target tree “include” subdirectory during the first make. As delivered, they contain only comments. If a site wishes to add attributes, these files can be *carefully* modified.

The files are in three groups, by Server, queue, and job. In each group are `site_*_attr_def.h` files which are used to defined the name and support functions for the new attribute or attributes, and `site_*_attr_enum.h` files which insert a enumerated label into the set for the corresponding parent object. For Server, queue, node attributes, there is also an additional file that defines if the qmgr(1) command will include the new attribute in the set “printed” with the print server, print queue, or print nodes sub-commands.

site_resc_attr_def.h

This file allows a site to add local resources. It is included into the Server’s resc_def_all.c file at compile time.

You should note that just adding attributes will have no effect on how PBS processes jobs. The main usage for new attributes would be in providing new Scheduler controls and/or information. The scheduling algorithm will have to be modified to use the new attributes. If you need MOM to do something different with a job, you will still need “to get down and dirty” with her source code.

13.3.2 MOM Modifiable Files

site_mom_chu.c

If a Server is sending jobs to more than one MOM, additional checking for execution privilege may be required at MOM’s level. It can be added in this function site_mom_chkuser().

site_mom_ckp.c

Provide post-checkpoint, site_mom_postchk() and pre-restart site_mom_prerst() “user exits” for the Cray and SGI systems.

site_mom_jset.c

The function site_job_setup() allows a site to perform specific actions once the job session has been created and before the job runs.

Chapter 14
Alternate Schedulers

PBS provides a separate process to determine which jobs should be placed into execution. This is a flexible mechanism by which you may implement a very wide variety of policies. The Scheduler uses the standard PBS API to communicate with the Server and an additional API to communicate with the PBS resource monitor, `pbs_mom`. Should the provided Schedulers be insufficient to meet your site's needs, it is possible to implement a replacement Scheduler using the provided APIs which will enforce the desired policies. This chapter discusses the alternate schedulers included in the source release of PBS, and provides information on customizing an existing scheduler, or developing a new PBS scheduler.

14.1 Scheduling Policy

The first generation UNIX batch system, NQS, and many of the other workload management systems use various queue-based controls to limit or schedule jobs. Queues would be turned on and off to control job ordering over time or have a limit of the number of running jobs in the queue.

While PBS supports multiple queues and the queues have some of the "job scheduling" attributes used by other batch systems, the PBS Server does not by itself run jobs or enforce any of the restrictions implied by these queue attributes. In fact, the Server will happily run a *held* job that resides in a *stopped* queue with a zero limit on running jobs, if it is directed to do so. The direction may come from the operator, administrator, or the Scheduler. In fact, the Scheduler is nothing more than a client with administrator privilege.

If you chose to implement your site scheduling policy using a multiple-queue queue-based scheme, you may do so. The Server and queue attributes used to control job scheduling may be adjusted by a client with privilege, such as `qmgr`(8B), or by a program of your own creation. However, the controls are actually used by in the Scheduler, not the Server. The Scheduler must check the status of the Server and queues, as well as the jobs, determining the setting of the Server and queue controls. It then must use the settings of those controls in its decision making.

Another possibility is the “whole pool” approach, wherein all jobs are in a single pool (single queue). The Scheduler evaluates each job on its merits and decides which, if any, to run. The policy can easily include factors such as time of day, system load, size of job, etc. Ordering of jobs in the queue need not be considered. The PBS team believes that this approach is superior for two reasons:

1. Users are not tempted to lie about their requirements in order to “game” the queue policy.

2. The scheduling can be performed against the complete set of current jobs resulting in better fits against the available resources.

14.2 Scheduler – Server Interaction

In developing a scheduling policy, it may be important to understand when and how the Server and the Scheduler interact. The Server always initiates the scheduling cycle. When scheduling is active within the Server, the Server opens a connection to the Scheduler and sends a command indicating the reason for the scheduling cycle. The reasons or events that trigger a cycle are:

SCH_SCHEDULE_NEW
A job newly becomes eligible to execute. The job may be a new job in an execution queue, or a job in an execution queue that just changed state from held or waiting to queued.

SCH_SCHEDULE_TERM
An executing job terminates.

SCH_SCHEDULE_TIME
The time interval since the prior cycle specified by the Server attribute `schedule_iteration` is reached.

SCH_SCHEDULE_CMD

The Server attribute `scheduling` is set or reset to true. If set true, even if it's previous value was true, the Scheduler will be cycled. This provides the administrator/operator a means to force a scheduling cycle.

SCH_SCHEDULE_RECYC

If the Scheduler was cycled and it requested one and only one job to be run, then the Scheduler will be recycled by the Server. This event is a bit abstruse. It exists to "simplify" a Scheduler. The Scheduler only need worry about choosing the one best job per cycle. If other jobs can also be run, it will get another chance to pick the next job. Should a Scheduler run none or more than one job in a cycle it is clear that it need not be recalled until conditions change and one of the other events trigger the next cycle.

SCH_SCHEDULE_FIRST

If the Server recently recovered, the first scheduling cycle, resulting from any of the above, will be indicated uniquely.

Once the Server has contacted the Scheduler and sent the reason for the contact, the Scheduler then becomes a privileged client of the Server. As such, it may command the Server to perform any action allowed to a Manager.

When the Scheduler has completed all activities it wishes to perform in this cycle, it will close the connection to the Server. While a connection is open, the Server will not attempt to open a new connection.

Note that the Server contacts the Scheduler to begin a scheduling cycle only if scheduling is active in the Server. This is controlled by the value of the Server attribute `scheduling`. If set true, scheduling is active and `qstat -B` will show the Server status as Active. If `scheduling` is set false, then the Server will not contact the Scheduler and the Server's status is shown as Idle. When started, the Server will recover the value for `scheduling` as it was set when the Server shut down. The value may be changed in two ways: the -a option on the pbs_server command line, or by setting `scheduling` to `true` or `false` via `qmgr`.

One point should be clarified about job ordering: Queues "are" and "are not" FIFOs. What is meant is that while jobs are ordered first in – first out in the Server and in each queue. That fact does **not** imply that running them in that order is mandated, required, or even desirable. That is a decision left completely up to site policy and implementation. The

Server will maintain the order across restarts solely as a aid to sites that wish to use a FIFO ordering in some fashion.

14.3 Creating a New Scheduler

PBS provides two different interfaces for creating custom scheduler modules: the C programming language, and the Tool Command Language (TCL). This sections gives a high-level overview of each. For detailed information, consult the PBS External Reference Specification.

14.4 Tcl-Based Scheduling

The provided Tcl based Scheduler framework uses the basic Tcl interpreter with some extra commands for communicating with the PBS Server and Resource Monitor. The scheduling policy is defined by a script written in Tcl. A number of sample scripts are provided in the source directory `src/scheduler.tcl/sample_scripts`. The Tcl based Scheduler works, very generally, as follows:

1. On start up, the Scheduler reads the initialization script (if specified with the -i option) and executes it. Then, the body script is read into memory. This is the file that will be executed each time a “schedule” command is received from the Server. It then waits for a “schedule” command from the Server.

2. When a schedule command is received, the body script is executed. No special processing is done for the script except to provide a connection to the Server. A typical script will need to retrieve information for candidate jobs to run from the Server using `pbsselstat` or `pbsstatjob`. Other information from the Resource Monitor(s) will need to be retrieved by opening connections with `openrm`(3B) and submitting queries with `addreq`(3B) and getting the results with `getreq`(3B). The Resource Monitor connections must be closed explicitly with `closerm`(3B) or the Scheduler will eventually run out of file descriptors. When a decision is made to run a job, a call to `pbsrunjob`(3B) must be made.

3. When the script evaluation is complete, the Scheduler will close the TCP/IP connection to the Server.

14.4.1 Tcl-Based Scheduling Advice

The Scheduler does not restart the Tcl interpreter for each cycle. This gives the ability to carry information from one cycle to the next. It also can cause problems if variables are not initialized or "unset" at the beginning of the script when they are not expected to contain any information later on.

System load average is frequently used by a script. This number is obtained from the system kernel by pbs_mom. Most systems smooth the load average number over a time period. If one scheduling cycle runs one or more jobs and the next scheduling cycle occurs quickly, the impact of the newly run jobs will likely not be reflected in the load average. This can cause the load average to shoot way up especially when first starting the batch system. Also when jobs terminate, the delay in lowering the load average may delay the scheduling of additional jobs. The Scheduler redirects the output from “stdout” and “stderr” to a file. This makes it easy to generate debug output to check what your script is doing. It is advisable to use this feature heavily until you are fairly sure that your script is working well.

14.4.2 Implementing a Tcl Scheduler

The best advice is study the examples found in src/scheduler.tcl/sample_scripts. Then once you have modified or written a Scheduler body script and optionally an initialization script, place them in the directory `/usr/spool/PBS/sched_priv` and invoke the Scheduler by typing:

```
    pbs_sched [-b script] [-i init_script]
```

See the `pbs_sched_tcl`(8B) man page for more information.

14.5 C-Based Scheduling

The C based Scheduler is similar in structure and operation to the Tcl Scheduler except that C functions are used rather than Tcl scripts:

1. On start up, the Scheduler calls `schedinit(argc, argv)` one time only to initialize whatever is required to be initialized.

2. When a schedule command is received, the function `schedule`*(*`cmd`, `connector`*)* is invoked. All scheduling activities occur

within that function.

3. Upon return to the main loop, the connection to the Server is closed.

Several working Scheduler code examples are provided in the samples subdirectory. The following sections discuss certain of the sample schedulers including the default Scheduler Standard. The sources for the samples are found in `src/scheduler.cc/samples` under the scheduler type name, for example `src/scheduler.cc/samples/Standard`.

14.5.1 SGI_Origin Scheduler

This is a highly specialized Scheduler for managing a cluster of SGI Origin2000 systems, providing integrated support for Array Services (for MPI programs), and NODEMASK (to pin applications via software to dynamically created regions of nodes within the system). The scheduling algorithm includes an implementation of static backfill and dynamically calculates NODEMASKs on a per-job basis. (See the README file in the scheduler.cc/samples/sgi_origin directory for details of the algorithm.)

Another special scheduler, sgi_origin_cpuset, will take advantage of Origin2000 systems that use CPUSET. This pins a job's processes to a set of CPUs, both memory-wise and cpu-wise. Be sure to add --enable-cpuset to the configure option. (See the `README` file and `docs/` files in `scheduler.cc/samples/sgi_origin_cpuset` directory for more details).

14.5.2 Installing the SGI_ORIGIN Scheduler

Step 1 As discussed in the build overview, run configure with the following options:

```
--set-sched=cc --set-sched-code=sgi_origin
```
or
```
--set-sched-code=sgi_origin_cpuset
```

If you wish to enable Scheduler use of the NODEMASK facility, then also add the configure option `--enable-nodemask`.

Step 2 Review:
`scheduler.cc/samples/sgi_origin/toolkit.h`
(or `scheduler.cc/samples/sgi_origin_cpuset/`

toolkit.h) editing any variables necessary, such as the value of SCHED_DEFAULT_CONFIGURATION.

Step 3 Build and install PBS.

Step 4 Change directory into /usr/spool/PBS/sched_priv and edit the Scheduler configuration file "config" (see below). This file controls the scheduling policy used to determine which jobs are run and when. The comments in the config file explain what each option is. If in doubt, the default option is generally acceptable.

14.5.3 Configuring the SGI_Origin Scheduler

The /usr/spool/PBS/sched_priv/sgi_origin/config file contains the following tunable parameters, which control the policy implemented by the Scheduler. Comments are allowed anywhere in the file, and begin with a ’#’ character. Any non-comment lines are considered to be statements, and must conform to the syntax:

<option> <argument>

See the README and config files for a description of the options listed below, and the type of argument expected for each of the options. Arguments must be one of:

Argument Type	Argument Description
boolean	A boolean value. Either 0 (false/off) or 1 (true/on)
domain	A registered domain name, e.g. “veridian.com”
integer	An integral (typically non-negative) decimal value.
pathname	A valid pathname (i.e. “/usr/local/pbs/pbs_acctdir”).
real	A real valued number (i.e. the number 0.80).
string	An uninterpreted string passed to other programs.
time_spec	A string of the form HH:MM:SS (i.e. 00:30:00).

Argument Type	Argument Description
queue_spec	The name of a PBS queue. Either ’queue@exechost’ or just ’queue’. If the hostname is not specified, it defaults to the name of the local host machine.
variance	Negative and positive deviation from a value. The syntax is ’-mm%,+nn%’ (i.e. ’-10%,+15%’ for minus 10 percent and plus 15% from some value).

Syntactical errors in the configuration file are caught by the parser, and the offending line number and/or configuration option/argument is noted in the Scheduler logs. The Scheduler will not start while there are syntax errors in its configuration files.

Before starting up, the Scheduler attempts to find common errors in the configuration files. If it discovers a problem, it will note it in the logs (possibly suggesting a fix) and exit.

The following is a complete list of the recognized options:

Parameter	Type
AVOID_FRAGMENTATION	<boolean>
BATCH_QUEUES	<queue_spec>[,<queue_spec>...]
DECAY_FACTOR	<real>
DEDICATED_QUEUE	<queue_spec>
DEDICATED_TIME_CACHE_SECS	<integer>
DEDICATED_TIME_COMMAND	<pathname>
ENFORCE_ALLOCATION	<boolean>
ENFORCE_DEDICATED_TIME	<boolean>
ENFORCE_PRIME_TIME	<boolean>
EXTERNAL_QUEUES	<queue_spec>[,<queue_spec>...]
FAKE_MACHINE_MULT	<integer>

Parameter	Type
HIGH_SYSTIME	<integer>
INTERACTIVE_LONG_WAIT	<time_spec>
MAX_DEDICATED_JOBS	<integer>
MAX_JOBS	<integer>
MAX_QUEUED_TIME	<time_spec>
MAX_USER_RUN_JOBS	<integer>
MIN_JOBS	<integer>
NONPRIME_DRAIN_SYS	<boolean>
OA_DECAY_FACTOR	<real>
PRIME_TIME_END	<time_spec>
PRIME_TIME_SMALL_NODE_LIMIT	<integer>
PRIME_TIME_SMALL_WALLT_LIMIT	<time_spec>
PRIME_TIME_START	<time_spec>
PRIME_TIME_WALLT_LIMIT	<time_spec>
SCHED_ACCT_DIR	<pathname>
SCHED_HOST	<hostname>
SCHED_RESTART_ACTION	<string>
SERVER_HOST	<hostname>
SMALL_JOB_MAX	<integer>
SMALL_QUEUED_TIME	<time_spec>
SORT_BY_PAST_USAGE	<boolean>
SPECIAL_QUEUE	<queue_spec>
SUBMIT_QUEUE	<queue_spec>
SYSTEM_NAME	<hostname>

Parameter	Type
TARGET_LOAD_PCT	<integer>
TARGET_LOAD_VARIANCE	<variance>
TEST_ONLY	<boolean>
WALLT_LIMIT_LARGE_JOB	<time_spec>
WALLT_LIMIT_SMALL_JOB	<time_spec>

See the following files for detailed explanation of these options:

```
src/scheduler.cc/samples/sgi_origin/README
src/scheduler.cc/samples/sgi_origin/config
```

14.5.4 CRAY T3E Scheduler

This is a highly specialized Scheduler for the Cray T3E MPP system. The supporting code of this Scheduler (configuration file parser, reading of external files, limits specification, etc.) is based on the previously discussed SGI Origin Scheduler (see section 14.5.1 “SGI_Origin Scheduler” on page 162).

The scheduling algorithm is an implementation of a priority-based system wherein jobs inherit an initial priority from the queue that they are first submitted to, and then the priority is adjusted based on a variety of factors. These factors include such variables as: length of time in queue, time of day, length of time requested, number of nodes and/or amount of memory requested, etc. (See the README file in the scheduler.cc/samples/cray_t3e directory for details of the algorithm and configuration options.)

14.5.5 Installing the CRAY_T3E Scheduler

Step 1 As discussed in the build overview, run configure with the following options:

```
--set-sched=cc --set-sched-code=cray_t3e
```

If you wish to enable Scheduler use of the PEMASK facility, then also add the configure option --enable-pemask.

Step 2 Review the header file in src/scheduler.cc/samples/sgi_origin/toolkit.h editing any variables necessary, such as the value of SCHED_DEFAULT_CONFIGURATION.

Step 3 Build and install PBS.

Step 4 Change directory into `/usr/spool/PBS/sched_priv` and edit the Scheduler configuration file "`config`" (see below). This file controls the scheduling policy used to determine which jobs are run and when. The comments in the configuration file explain what each option is. If in doubt, the default option is generally acceptable.

14.5.6 Configuring the Cray T3E Scheduler

The `/usr/spool/PBS/sched_priv/cray_t3e/configfile` contains the following tunable parameters, which control the policy implemented by the Scheduler. Comments are allowed anywhere in the file, and begin with a '#' character. Any non-comment lines are considered to be statements, and must conform to the syntax:

<option> <argument>

See the `README` and `config` files for a description of the options listed below, and the type of argument expected for each of the options. Possible arguments are the same as those available for the SGI_Origin Scheduler (see section 14.5.3 "Configuring the SGI_Origin Scheduler" on page 163).

Syntactical errors in the configuration file are caught by the parser, and the offending line number and/or configuration option/argument is noted in the Scheduler logs. The Scheduler will not start while there are syntax errors in its configuration files. Before starting up, the Scheduler attempts to find common errors in the configuration files. If it discovers a problem, it will note it in the logs (possibly suggesting a fix) and exit. The available options to this scheduler are the same as for the SGI_Origin scheduler. (See section 14.5.3 "Configuring the SGI_Origin Scheduler" on page 163). Full a detailed explanation of each option, see the following files:

14.6 Scheduling and File Staging

A decision must be made about when to begin to stage-in files for a job. The files must be available before the job executes. The amount of time that will be required to copy the files is unknown to PBS, that being a function of file size and network speed. If file instaging is not started until the job has been selected to run when the other required resources are available, either those resources are "wasted" while the stage-in occurs, or another job is started which takes the resources away from the first job, and might prevent it from running. If the files are staged in well before the job is otherwise ready to run, the files may take up valuable disk space need by running jobs.

PBS provides two ways that file in-staging can be initiated for a job. If a run request is received for a job with a requirement to stage in files, the staging operation is begun and when completed, the job is run. Or, a specific stage-in request may be received for a job, see `pbs_stagein`(3B), in which case the files are staged in but the job is not run. When the job is run, it begins execution immediately because the files are already there.

In either case, if the files could not be staged-in for any reason, the job is placed into a wait state with a “execute at” time **PBS_STAGEFAIL_WAIT** 30 minutes in the future. A mail message is sent to the job owner requesting that s/he look into the problem. The reason the job is changed into wait state is to prevent the Scheduler from constantly retrying the same job which likely would keep on failing.

Figure 5.0 in Appendix B of the PBS ERS shows the (sub)state changes for a job involving file in staging. The Scheduler may note the substate of the job and chose to perform pre-staging via the pbs_stagein() call. The substate will also indicate completeness or failure of the operation. The Scheduler developer should carefully chose a stage-in approach based on factors such as the likely source of the files, network speed, and disk capacity.

Appendix A: Error Codes

The following table lists all the PBS error codes, their textual names, and a description of each.

Error Name	Error Code	Description
PBSE_NONE	0	No error
PBSE_UNKJOBID	15001	Unknown Job Identifier
PBSE_NOATTR	15002	Undefined Attribute
PBSE_ATTRRO	15003	Attempt to set READ ONLY attribute
PBSE_IVALREQ	15004	Invalid request
PBSE_UNKREQ	15005	Unknown batch request
PBSE_TOOMANY	15006	Too many submit retries
PBSE_PERM	15007	No permission
PBSE_BADHOST	15008	Access from host not allowed
PBSE_JOBEXIST	15009	Job already exists
PBSE_SYSTEM	15010	System error occurred
PBSE_INTERNAL	15011	Internal Server error occurred

Error Name	Error Code	Description
PBSE_REGROUTE	15012	Parent job of dependent in route queue
PBSE_UNKSIG	15013	Unknown signal name
PBSE_BADATVAL	15014	Bad attribute value
PBSE_MODATRRUN	15015	Cannot modify attrib in run state
PBSE_BADSTATE	15016	Request invalid for job state
PBSE_UNKQUE	15018	Unknown queue name
PBSE_BADCRED	15019	Invalid Credential in request
PBSE_EXPIRED	15020	Expired Credential in request
PBSE_QUNOENB	15021	Queue not enabled
PBSE_QACESS	15022	No access permission for queue
PBSE_BADUSER	15023	Bad user - no password entry
PBSE_HOPCOUNT	15024	Max hop count exceeded
PBSE_QUEEXIST	15025	Queue already exists
PBSE_ATTRTYPE	15026	Incompatible queue attribute type
PBSE_QUEBUSY	15027	Queue Busy (not empty)
PBSE_QUENBIG	15028	Queue name too long
PBSE_NOSUP	15029	Feature/function not supported
PBSE_QUENOEN	15030	Cannot enable queue, needs add def
PBSE_PROTOCOL	15031	Protocol (ASN.1) error
PBSE_BADATLST	15032	Bad attribute list structure
PBSE_NOCONNECTS	15033	No free connections
PBSE_NOSERVER	15034	No Server to connect to
PBSE_UNKRESC	15035	Unknown resource
PBSE_EXCQRESC	15036	Job exceeds Queue resource limits
PBSE_QUENODFLT	15037	No Default Queue Defined

Error Name	Error Code	Description
PBSE_NORERUN	15038	Job Not Rerunnable
PBSE_ROUTEREJ	15039	Route rejected by all destinations
PBSE_ROUTEEXPD	15040	Time in Route Queue Expired
PBSE_MOMREJECT	15041	Request to MOM failed
PBSE_BADSCRIPT	15042	(qsub) Cannot access script file
PBSE_STAGEIN	15043	Stage In of files failed
PBSE_RESCUNAV	15044	Resources temporarily unavailable
PBSE_BADGRP	15045	Bad Group specified
PBSE_MAXQUED	15046	Max number of jobs in queue
PBSE_CKPBSY	15047	Checkpoint Busy, may be retries
PBSE_EXLIMIT	15048	Limit exceeds allowable
PBSE_BADACCT	15049	Bad Account attribute value
PBSE_ALRDYEXIT	15050	Job already in exit state
PBSE_NOCOPYFILE	15051	Job files not copied
PBSE_CLEANEDOUT	15052	Unknown job id after clean init
PBSE_NOSYNCMSTR	15053	No Master in Sync Set
PBSE_BADDEPEND	15054	Invalid dependency
PBSE_DUPLIST	15055	Duplicate entry in List
PBSE_DISPROTO	15056	Bad DIS based Request Protocol
PBSE_EXECTHERE	15057	Cannot execute there
PBSE_SISREJECT	15058	Sister rejected
PBSE_SISCOMM	15059	Sister could not communicate
PBSE_SVRDOWN	15060	Request rejected -server shutting down
PBSE_CKPSHORT	15061	Not all tasks could checkpoint

Error Name	Error Code	Description
PBSE_UNKNODE	15062	Named node is not in the list
PBSE_UNKNODEATR	15063	Node-attribute not recognized
PBSE_NONODES	15064	Server has no node list
PBSE_NODENBIG	15065	Node name is too big
PBSE_NODEEXIST	15066	Node name already exists
PBSE_BADNDATVAL	15067	Bad node-attribute value
PBSE_MUTUALEX	15068	State values are mutually exclusive
PBSE_GMODERR	15069	Error(s) during global mod of nodes
PBSE_NORELYMOM	15070	Could not contact MOM
PBSE_NOTSNODE	15071	No time-shared nodes
Resource monitor specific error codes		
PBSE_RMUNKNOWN	15201	Resource unknown
PBSE_RMBADPARAM	15202	Parameter could not be used
PBSE_RMNOPARAM	15203	A parameter needed did not exist
PBSE_RMEXIST	15204	Something specified didn't exist
PBSE_RMSYSTEM	15205	A system error occurred
PBSE_RMPART	15206	Only part of reservation made

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