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James Kent Blackburn

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LIGO LDAS Group

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California Institute of Technology
LIGO Project - MS 51-33
Pasadena CA 91125
Phone (818) 395-2129
Fax (818) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project - MS 20B-145
Cambridge, MA 01239
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

WWW: http://www.ligo.caltech.edu/

The MPI (Message Passing Interface) API's *baseline requirements*

James Kent Blackburn

California Institute of Technology
LIGO Data Analysis Group
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I. Introduction

A. General Description:

1. The mpiAPI is responsible for managing the advanced analysis processes which are based on MPI and executing in the LDAS distributed computing parallel cluster of nodes using an interpreted command language.
   a) The interpreted command language to be used is TCL/TK, which provides a command line, scripting and a graphical interface.
   b) The TCL/TK commands are extended to support low level system interfaces to the algorithms used to "communicate" the data, as well as provide greater computational performance using C++ code that utilizes the standard TCL C code API library in the form of a TCL/TK package.
2. The mpiAPI's TCL/TK script accesses the mpiAPI.rsc file containing necessary information and configuration resources to extend the command set of the TCL/TK language using the mpiAPI package, which exists as a shared object.
3. The mpiAPI will receive its commands from the managerAPI, reporting back to the managerAPI upon completion of each command. This command completion message will include the incoming identification used by the manager to track completion of sequenced commands being handled by the assistant manager levels of the managerAPI.
4. Because of the way MPI parallel jobs execute, the mpiAPI will only launch MPI jobs on the LDAS distributed computing parallel cluster of nodes and manage the job allocations based on queue configurations which can be dynamically adjusted by algorithms and / or LDAS operators.
5. The mpiAPI will also monitor the state of all MPI parallel jobs and report the status to the controlMonitorAPI using the "*Internal Lightweight Data Format*" (ILWD).

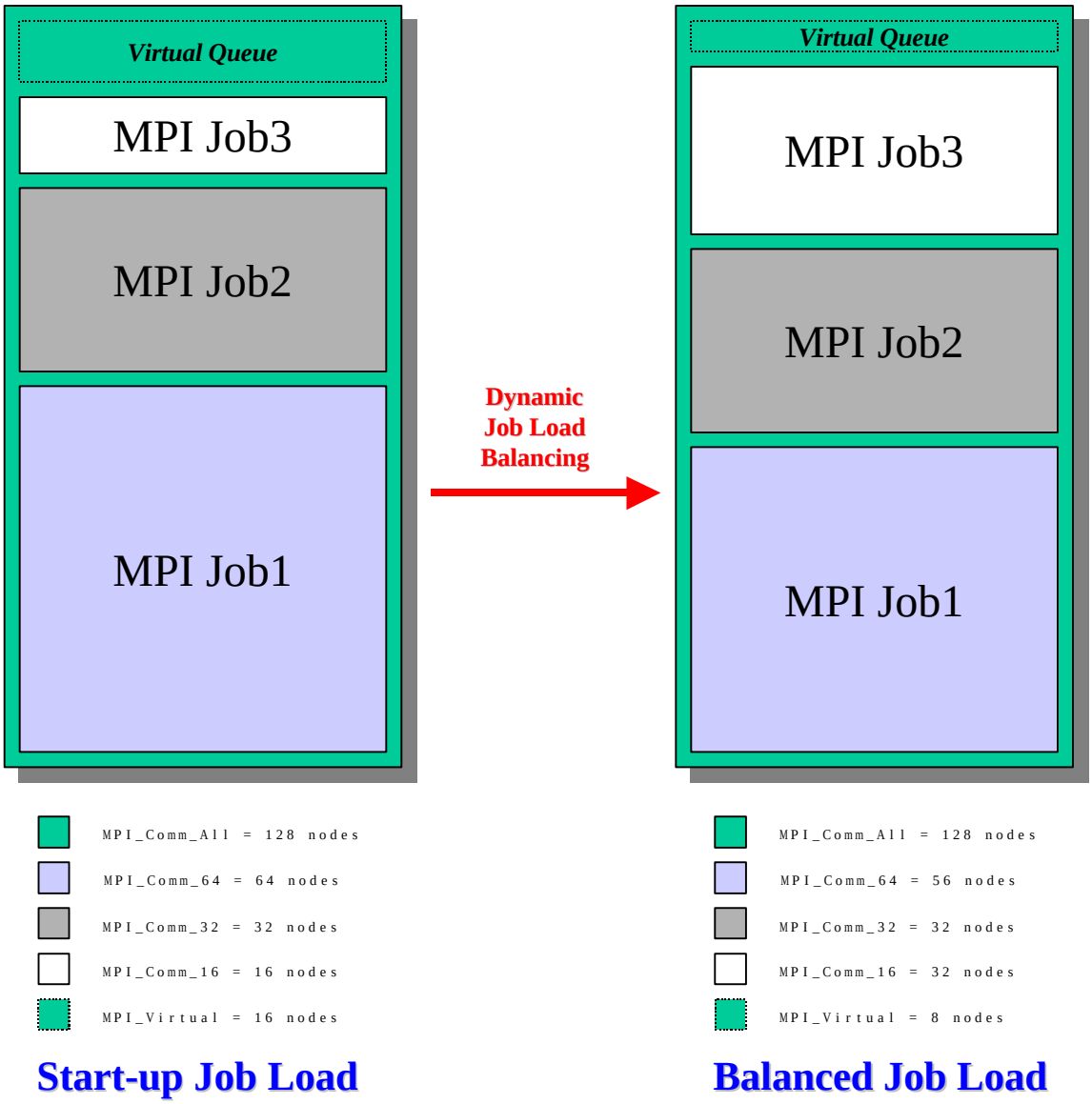
B. The mpiAPI.tcl Script's Requirements:

1. The mpiAPI.tcl script will provide all the functionality inherited by the genericAPI.tcl script (*i.e. help, logging, operator, jobstate & emergency sockets, etc.*).
2. The mpiAPI.tcl script will report to the managerAPI's receive socket upon completion of each command issued by the managerAPI's assistant manager

levels. This involves transmission of a message identifying the specific command completed as coded by the managerAPI (*see LIGO-T980115-0x-E for details*).

3. The mpiAPI.tcl script will validate each command received on the operator, jobstate or emergency socket as appropriate for the mpiAPI to evaluate. This includes validation of commands, command options, encryption keys and managerAPI identification indices.
4. In the event that an exception occurs while processing a command, the mpiAPI.tcl layer will report the exception to the ManagerAPI's *receive socket* along with the necessary command identification issued by the managerAPI with the specific dataConditioningAPI command.
   Note: Once reported to the managerAPI, the appropriate *assistant manager* will terminate the high level command and the userAPI that issued this high level command will be notified of the exception.
5. The mpiAPI.tcl script will be responsible for spawning MPI parallel processes using the unix "mpirun" command and all of its appropriate "options".
6. Spawned jobs will have three levels of priority associated with there processing, ***high***, ***normal***, ***low***. These priorities will be used to borrow nodes in the event that a job can not be balanced with the available number of nodes. Jobs run in the ***high*** priority can dynamically borrow nodes first from ***low*** priority jobs (and if needed from ***normal*** priority jobs). Jobs of ***normal*** priority can borrow nodes only from ***low*** priority jobs. Borrowing only occurs when the virtual queue (*see 7 & 8 below*) is empty.
7. The mpiAPI.tcl script will manage lists of node names and job queues which are used to identify the various allocations of compute nodes that can be used by each MPI parallel process. **Note:** This is intended to allow various job sizes and guarentee uniqueness in the queues assignments for MPI jobs.
8. The mpiAPI.tcl script will keep track of the node allocation needs of MPI jobs. As MPI jobs report a partial release of nodes needed to carry out an active parallel task most efficiently, the mpiAPI.tcl script will manage virtual job queues. **For example**, a MPI parallel process is started using a job queue that has 64 nodes allocated to it. The MPI parallel process "learns" that it can accomplish the task in the necessary time with minimal ideal cpu cycles after a few iterations of its main loop using 56 nodes. The MPI process continues to run in the 56 node queue but reports to the mpiAPI that 8 of the nodes in the queue are no longer needed. This increases the size of the virtual queue by 8 nodes which could be used by a different MPI parallel job to assist in bringing its process time into balance with the real time arrival of data from the interferometer, even after all of the "real" job queues may have been started up already. In the event that a MPI process was started in a job queue that was inadequate for its demands on the system, and all nodes were already allocated to existing job queues, the MPI process could request extra

nodes as they become available in the virtual queue. This in effect allows for dynamic load balancing. (*See figure below for example*). The communication



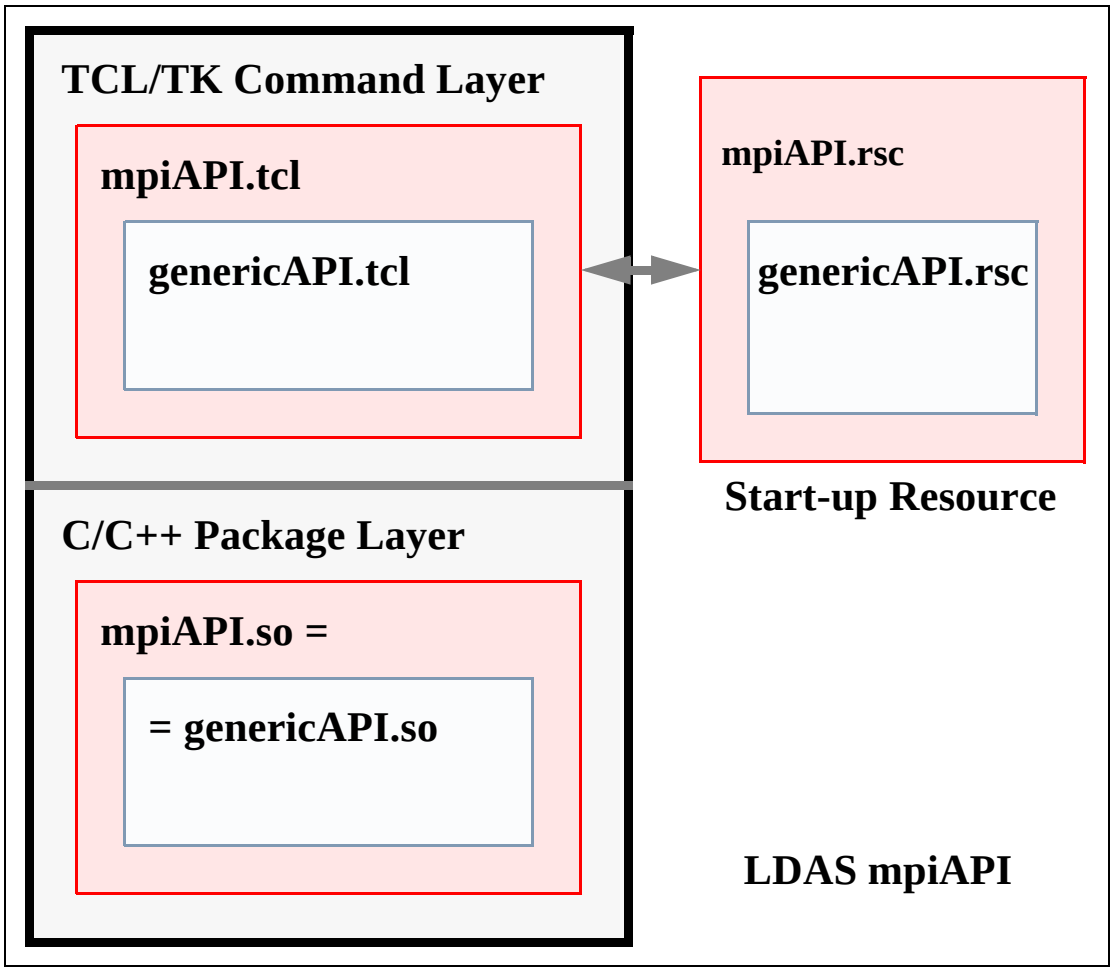
used to communicate node allocation changes to the mpiAPI will be via the jobstate socket of the mpiAPI. Each running MPI process will send commands directly to the jobstate socket containing within the body of the command, the jobid, the nodes currently being used the nodes being released and the nodes being requested. The mpiAPI will respond over the socket with a verification signal, and in the event of a request for new nodes, with a new queue for the job to grow into.

C. The mpiAPI.so Package Requirements:

1. The mpiAPI.so package will not have any functionality not already provided

in the genericAPI.so package, i.e., it will only need to send and receive "Internal LDAS Lightweight Data Formats" on command from the TCL/TK layer. That is to say the mpiAPI.so package is simply the genericAPI.so package.

II. Component Layers of the LDAS mpiAPI

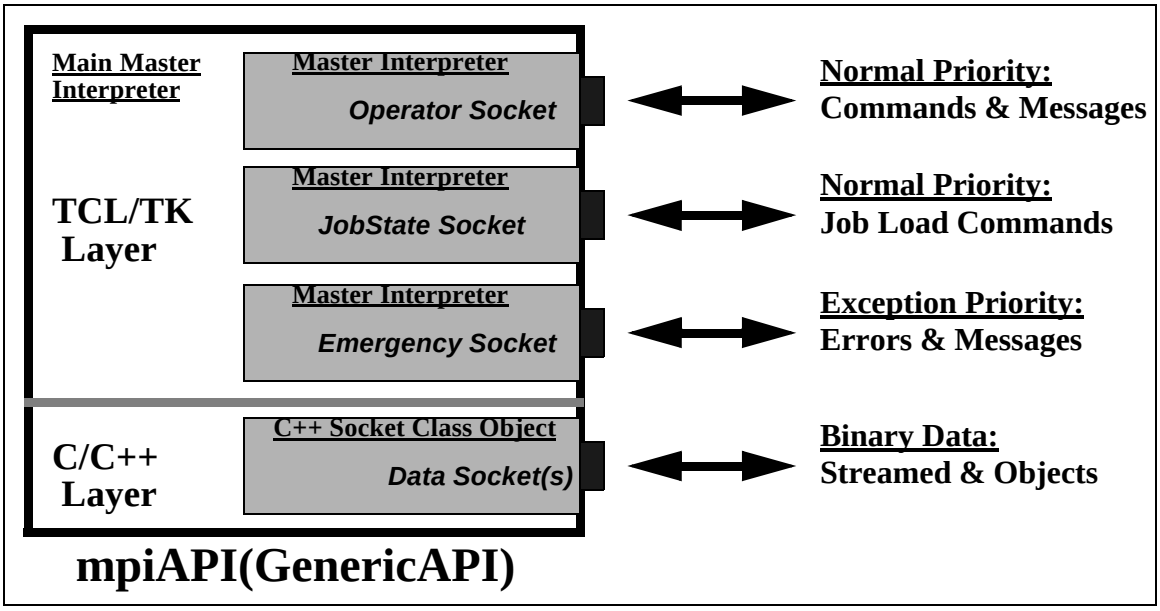


A. LDAS Distributed mpiAPI:

1. The LDAS distributed mpiAPI is made up of two major layers.
   a) TCL/TK Layer - this layer is the command layer and deals primarily with commands and/or messages and their attributes and/or parameters, as well as communicate with the underlying Package Layer through TCL/TK extensions.
   b) C/C++ Package Layer - this layer is the data engine layer and deals primarily with the binary data and the algorithms and methods needed to manipulate LIGO's data

2. The TCL/TK layer consists of two internal and two external components, designed to optimize code reuse at the level of the command language used in all LDAS API's.
   a) The mpiAPI.tcl - this TCL/TK script contains specialized TCL/TK procedures and specialized command language extensions which are particular to the mpiAPI in the LDAS architecture.
   b) The genericAPI.tcl - this TCL/TK script contains the common TCL/TK procedures and command language extensions found in all LDAS API's. the genericAPI.tcl code will be sourced in the mpiAPI.tcl script.
   c) The mpiAPI.rsc - this TCL/TK script contains the start-up and configuration defaults which are unique to the mpiAPI.
   d) The genericAPI.rsc - this TCL/TK script contains the start-up and configuration defaults which are common to each LDAS API. The genericAPI.rsc will be embedded in the mpiAPI.rsc file.
3. The C/C++ package layer consists of one internal components, developed in C++ and C to take advantage of the higher performance associated with compiled languages which is needed for the types of activities that are being carried out in this layer and loaded as shared objects.
   a) The genericAPI.so - this shared object contains the C++ classes and C interface functions needed to extend the command language set of all API's in LDAS, allowing efficiency and optimal code reuse. It will be linked into the mpiAPI.so shared object directly.

III. Communications in dataConditioningAPI from GenericAPI



A. Socket Based Communications in mpiAPI:

1. The genericAPI will provide the mpiAPI with an internet socket within the TCL/TK layer that is the primary communication port for commands and messages of a normal priority. This port is commonly referred to as the *Operator Socket* to reflect its association with normal operations. Requirements on this socket are that defined by the genericAPI. The genericAPI will also provide the mpiAPI with an internel socket within the TCL/TK layer for exception priority messages. This port is commonly referred to as the *Emergency Socket* to reflect its association with exception handling. The mpiAPI will also have a unique internet server socket within the TCL/TK layer that will be used to receive requests to load balance the queues being managed by the mpiAPI. This JobState Socket will be notified when an MPI job has excess nodes which it does not need. It will also be used by MPI jobs to request additional nodes (if available) for increasing MPI job performance.
2. The genericAPI will provide the mpiAPI with dynamic TCP/IP sockets within the C/C++ layer that is used to communicate all data (*typically binary data*) in the form of streamed binary data or distributed C++ class objects using the ObjectSpace C++ Component Series Socket Library. This port is commonly referred to as the *Data Socket* to reflect its primary duty in communicating data sets. Requirements on these sockets are defined by the genericAPI.

IV. Software Development Tools

A. TCL/TK:

1. TCL is a string based command language. The language has only a few fundamental constructs and relatively little syntax making it easy to learn. TCL is designed to be the glue that assembles software building blocks into applications. It is an interpreted language, but provides run-time tokenization of commands to achieve near to compiled performance in some cases. TK is an TCL integrated (as of release 8.x) tool-kit for building graphical user interfaces. Using the TCL command interface to TK, it is quick and easy to build powerful user interfaces which are portable between Unix, Windows and Macintosh computers. As of release 8.x of TCL/TK, the language has native support for binary data.

B. C and C++:

1. The C and C++ languages are ANSI standard compiled languages. C has been in use since 1972 and has become one of the most popular and powerful compiled languages in use today. C++ is an object oriented super-set of C which only just became an ANSI/ISO standard in November of 1997. It provided facilities for greater code reuse, software reliability and maintainability than is possible in traditional procedural languages like C and FORTRAN. LIGO's data analysis software development will be dominated by C++ source code.

C. SWIG:

1. SWIG is a utility to automate the process of building wrappers to C and C++ declarations found in C and C++ source files or a special *interface file* for API's to such languages as TCL, PERL, PYTHON and GUIDE. LDAS will use the TCL interface wrappers to the TCL extension API's.

D. Make:

1. Make is a standard Unix utility for customizing the build process for executables, objects, shared objects, libraries, etc. in an efficient manor which detects the files that have changed and only rebuilds components that depend on the changed files. The Make facility is being extended using AutoConfig, AutoMake and LibTools, all from the public domain.

E. CVS:

1. CVS is the Concurrent Version System. It is based on the public domain (and is public domain itself) software version management utility RSC. CVS is based on the concept of a software source code repository from which multiple software developers can check in and out components of a software from any point in the development history.

F. Documentation:

1. DOC++ is a documentation system for C/C++ and Java. It generates LaTeX or HTML documents, providing for sophisticated online browsing. The documents are extracted directly from the source code files. Documents are hierarchical and structured with formatting and references.
2. TclDOC is a documentation system for TCL/TK. It generates structured HTML documents directly from the source code, providing for a similar online browsing system to the LDAS help files. Documents include a hypertext linked table of contents and a hierarchical structured format.