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bullx DE User's Guide

extreme computing

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Preface

This guide describes the tools and libraries provided with **bullx DE** (Development Environment) that allow the development, testing and optimal use of application programs on Bull extreme computing clusters. In addition, various Open Source and proprietary tools are described.

Note You are advised to consult the Bull Support Web site for the most up-to-date product information, documentation, firmware updates, software fixes and service offers: http://support.bull.com

Intended Readers

This guide is intended for Application Developers of **bullx supercomputer suite** clusters.

Highlighting

The following highlighting conventions are used in this guide:

Bold	Identifies the following: • Interface objects such as menu names, labels, buttons and icons. • File, directory and path names. • Keywords to which particular attention must be paid.
Italic	Identifies references such as manuals or URLs.
`monospace`	Identifies portions of program codes, command lines, or messages displayed in command windows.
< >	Identifies parameters to be supplied by the user.

```
Commands entered by the user
```

```
System messages displayed on the screen
```

WARNING
A *Warning* notice indicates an action that could cause damage to a program, device, system, or data.

Related Publications

Important **The Software Release Bulletin (SRB) delivered with your version of bullx supercomputer suite must be read first.**

- *Software Release Bulletin*, 86 A2 91FK
- *Documentation Overview*, 86 A2 90FK
- *Installation and Configuration Guide*, 86 A2 74FK
- *Extreme Pack - Installation and Configuration Guide*, 86 A2 75FK
- *bullx MC Administration Guide*, 86 A2 76FK
- *bullx MC Monitoring Guide*, 86 A2 77FK
- *bullx MC Power Management Guide*, 86 A2 78FK
- *bullx MC Storage Guide*, 86 A2 79FK
- *bullx MC InfiniBand Guide*, 86 A2 80FK
- *bullx MC Ethernet Guide*, 86 A2 82FK
- *bullx MC Security Guide*, 86 A2 81FK
- *bullx EP Administration Guide*, 86 A2 88FK
- *bullx PFS Administration Guide*, 86 A2 86FK
- *bullx MPI User's Guide*, 86 A2 83FK
- *bullx DE User's Guide*, 86 A2 84FK
- *bullx BM User's Guide*, 86 A2 85FK
- *bullx MM Argos User's Guide*, 86 A2 87FK
- *Extended Offer Administration Guide*, 86 A2 89FK
- *bullx scs 4 R4 Documentation Portfolio, 86 AP 23PA*
- *bullx scs 4 R4 Documentation Set, 86 AP 33PA*

This list is not exhaustive. Useful documentation is supplied on the Resource & Documentation CD(s) delivered with your system. You are strongly advised to refer carefully to this documentation before proceeding to configure, use, maintain, or update your system.

Chapter 1. bullx Development Environment

The Bull Extreme Computing offer development environment relies on three sets of tools:

- **Linux OS development tools**

  These tools come as part of the Linux distribution. They typically include **GNU compilers**, **gdb debugger** as well as profiling tools such as **gproof**, **oprofile** and **valgrind**.

  See the Linux OS documentation for more information on these tools.

- **bullx scs 4 Extended Offer tools**

  These tools are third party products, which are selected, validated in bullx supercomputing suite environment, distributed and fully supported by Bull. They include **Intel compilers** and **profiler tools**, **DDT** from **Alinea**, **TotalView** from **RogueWave** parallel debuggers, as well as **Vampire**.

  See the *bullx Extended Offer Administration Guide* for details regarding the installation and configuration of these third-party products for the development environment, as part of the extended offer.

- **bullx DE (Development Environment)**

  bullx DE is a component of **bullx supercomputer suite**. It includes a collection of Open Source tools that help users to develop, execute, debug, analyze and profile HPC parallel applications.

This guide describes the use of the tools and libraries provided with **bullx DE**.

Chapter 2. bullx DE User Environment

2.1 bullx DE Installation Path

The tools and libraries for the **bullx Development Environment** are installed under **/opt/bullxde**. This directory contains the following sub-directories:

debuggers	Contains **bullx DE** core offer tools for debugging applications.
mpicompanions	Contains tools and libraries used alongside **bullx MPI**.
perftools	Contains basic tools to help tune application performance or to read performance counters for a running application.
profilers	Contains application profilers.
utils	Contains utilities used by other tools.
modulefiles	Contains **bullx DE** tools module files.

2.2 Environment Modules

bullx DE uses Environment Modules to customize dynamically your shell environment in order to use a tool or a set of tools. For instance, an environment can consist of a set of compatible products including a defined release of a FORTRAN compiler, a C compiler, a debugger and mathematical libraries. In this way, you can easily reproduce trial conditions, or use only proven environments.

The Environment Modules package relies on **modulefiles** to allow dynamic modification of a user's environment. Each module file contains the information needed to configure the shell for an application. Once the Modules package is initialized, the environment can be modified on a per-module basis using the **module** command, which interprets module files. Typically, module files instruct the module command to alter or set shell environment variables such as PATH, MANPATH, etc. module files may be shared by many users on a system and users may have their own collection to supplement or replace the shared module files.

Modules can be loaded and unloaded dynamically and atomically, in a clean fashion. All popular shells are supported, including **bash**, **ksh**, **zsh**, **sh**, **csh**, **tcsh**, as well as some scripting languages such as **Perl**.

Modules are useful in managing different versions of applications. Modules can also be bundled into metamodules that will load an entire suite of different applications.

2.3 Using Modules

The following command gives the list of available modules on a cluster.

```
module avail
```

```
----------------------- /opt/modules/version -----------------------
3.1.6

------------------- /opt/modules/3.1.6/modulefiles -------------------
dot         module-info null
module-cvs  modules     use.own

---------------------- /opt/modules/modulefiles ----------------------
oscar-modules/1.0.3 (default)
```

Modules available for the user are listed under the line **/opt/modules/modulefiles**.

The command to load a module is:

```
module load module_name
```

The command to verify the loaded modules list is:

```
module list
```

Using the **avail** command, it is possible that some modules will be marked *(default)*:

```
module avail
```

These modules are those that have been loaded without the user specifying a module version number. For example, the following commands are the same:

```
module load configuration
module load configuration/2
```

The **module unload** command unloads a module.

The **module purge** command clears all the modules from the environment.

```
module purge
```

It is not possible to load modules that include different versions of **intel_cc** or **intel_fc** at the same time because they cause conflicts.

2.4 bullx DE Module Files

bullx Development Environment provides module files for all the embedded tools that help to configure the user's environment (see Sections *2.2* and 2.3).

The following command loads the **bullx DE** main module:

```
$ module load bullxde
```

Loading this module will make available the tools module; these can be listed by using the **module avail** command, as shown in the example below:

Example

```
$ module avail
```

Output

```
--------------- /opt/bullxde/modulefiles/debuggers --------------
padb/3.2

-------------- /opt/bullxde/modulefiles/utils -------------------
OTF/1.8

-------------- /opt/bullxde/modulefiles/profilers ---------------
hpctoolkit/4.9.9_3111_Bull.2

-------------- /opt/bullxde/modulefiles/perftools ---------------
bpmon/1.0_Bull.1.20101208 papi/4.1.1_Bull.2 ptools/0.10.4_Bull.4.20101203

------------ /opt/bullxde/modulefiles/mpicompanions -------------
boost-mpi/1.44.0 mpianalyser/1.1.4 scalasca/1.3.2
```

Chapter 3. Debugging Application with padb

The **padb** tool is used to trace **MPI** process stacks for running job. It is a **Job Inspection** tool used to examine and debug parallel programs, simplifying the process of gathering stack traces for compute clusters. **padb** supports a number of parallel environments and it works out-of-the-box for most clusters.

It is an Open Source (licensed under the **Lesser General Public License**) http://www.gnu.org/licenses/lgpl.html, non-interactive, command line, scriptable tool intended for use by programmers and System Administrators alike.

It supports the **RMS**, **SLURM**, and **LSF** batch schedulers. Bull has contributed in the project to support more resources managers such as **PBS Pro-MPD**, **SLURM-OpenMPI**, **LSF-MPD** and **LSF-OpenMPI**.

However, it will not diagnose problems with the wider environment, including the job launcher or runtime environment.

3.1 Installation

padb should be installed on LOGIN and COMPUTE nodes type. The following tools are pre-required: **openSSH**, **pdsh**, **Perl**, and **gdb**.

3.2 Features

The stack trace generation operation mode is supported.

3.3 padb with SLURM / bullx MPI

Bull has developed specific features to support the combination of **SLURM** and **OpenMPI** environments. Specifically, **OpenMPI** applications (compiled with **OpenMPI** libraries) should be launched using the **mpirun** command (OpenMPI launch command) within a resource managed by **SLURM** using the **salloc** command.

Some examples of job launching command combinations are shown below:

Example 1

```
salloc -w host1,host2 mpirun -n 16 ompi_appli
```

Example 2

```
salloc -w host1,host2
```

```
salloc: Granted job allocation XXXX
```

```
$ mpirun -n 16 ompi_appli
```

Example 3

```
$ salloc -w host1,host2
```

```
salloc: Granted job allocation XXXX
```

```
$ srun -n 1 mpirun -n 16 ompi_appli
```

Example 4

```
$ salloc -IN 3
```

```
salloc: Granted job allocation XXXX
```

```
$ srun -n 1 mpirun -n 16 ompi_appli
```

3.4 Using padb

Synopsis

```
padb -O rmgr=slurm -x[t] –a | jobid
```

-x Get processes stacks

-t Use tree based output for stack traces.

-a All jobs for this user

jobid Job Id obtained by the **slurm squeue** command

An environment variable can be set for the Resource Manager, for example **export PADB_RMGR=slurm**, then the **padb** command synopsis becomes simpler, as shown:

```
padb -x[t] –a | jobid
```

Examples

A short example is shown below:

```
$ salloc -p Zeus -IN 3
```

```
salloc: Granted job allocation 47136
```

```
$ mpirun -n 9 pp_sndrcv_spbl
$ squeue
```

```
JOBID PARTITION  NAMEUSER   ST TIME   NODES NODELIST(REASON)
47136 Zeus    bashsenglont R  24:47 3    inti[41-43]
```

```
$ ./padb -O rmgr=slurm -x 47136
```

```
0:ThreadId: 1
0:main() at pp_sndrcv_spbl.c:52
0:PMPI_Finalize() at ?:?
0:ompi_mpi_finalize() at ?:?
```

```
0:barrier() at ?:?
0:opal_progress() at ?:?
0:opal_event_loop() at ?:?
0:poll_dispatch() at ?:?
0:poll() at ?:?
0:ThreadId: 2
0:clone() at ?:?
0:start_thread() at ?:?
0:btl_openib_async_thread() at ?:?
0:poll() at ?:?
0:ThreadId: 3
0:clone() at ?:?
0:start_thread() at ?:?
0:service_thread_start() at ?:?
0:select() at ?:?
1:ThreadId: 1
1:main() at pp_sndrcv_spbl.c:52
1:PMPI_Finalize() at ?:?
1:ompi_mpi_finalize() at ?:?
1:barrier() at ?:?
1:opal_progress() at ?:?
1:opal_event_loop() at ?:?
1:poll_dispatch() at ?:?
1:poll() at ?:?
1:ThreadId: 2
1:clone() at ?:?
1:start_thread() at ?:?
1:btl_openib_async_thread() at ?:?
1:poll() at ?:?
1:ThreadId: 3
1:clone() at ?:?
1:start_thread() at ?:?
1:service_thread_start() at ?:?
1:select() at ?:?
2:ThreadId: 1
2:main() at pp_sndrcv_spbl.c:47
2:PMPI_Recv() at ?:?
2:mca_pml_ob1_recv() at ?:?
2:opal_progress() at ?:?
2:btl_openib_component_progress() at ?:?
2:??() at ?:?
2:ThreadId: 2
2:clone() at ?:?
2:start_thread() at ?:?
2:btl_openib_async_thread() at ?:?
2:poll() at ?:?
2:ThreadId: 3
2:clone() at ?:?
2:start_thread() at ?:?
2:service_thread_start() at ?:?
2:select() at ?:?
3:ThreadId: 1
3:main() at pp_sndrcv_spbl.c:52
3:PMPI_Finalize() at ?:?
3:ompi_mpi_finalize() at ?:?
3:barrier() at ?:?
3:opal_progress() at ?:?
3:opal_event_loop() at ?:?
3:poll_dispatch() at ?:?
3:poll() at ?:?
3:ThreadId: 2
3:clone() at ?:?
3:start_thread() at ?:?
3:btl_openib_async_thread() at ?:?
3:poll() at ?:?
3:ThreadId: 3
3:clone() at ?:?
3:start_thread() at ?:?
3:service_thread_start() at ?:?
3:select() at ?:?
4:ThreadId: 1
4:main() at pp_sndrcv_spbl.c:52
4:PMPI_Finalize() at ?:?
4:ompi_mpi_finalize() at ?:?
4:barrier() at ?:?
4:opal_progress() at ?:?
```

```
4:opal_event_loop() at ?:?
4:poll_dispatch() at ?:?
4:poll() at ?:?
4:ThreadId: 2
4:clone() at ?:?
4:start_thread() at ?:?
4:btl_openib_async_thread() at ?:?
4:poll() at ?:?
4:ThreadId: 3
4:clone() at ?:?
4:start_thread() at ?:?
4:service_thread_start() at ?:?
4:select() at ?:?
5:ThreadId: 1
5:main() at pp_sndrcv_spbl.c:52
5:PMPI_Finalize() at ?:?
5:ompi_mpi_finalize() at ?:?
5:barrier() at ?:?
5:opal_progress() at ?:?
5:opal_event_loop() at ?:?
5:poll_dispatch() at ?:?
5:poll() at ?:?
5:ThreadId: 2
5:clone() at ?:?
5:start_thread() at ?:?
5:btl_openib_async_thread() at ?:?
5:poll() at ?:?
5:ThreadId: 3
5:clone() at ?:?
5:start_thread() at ?:?
5:service_thread_start() at ?:?
5:select() at ?:?
6:ThreadId: 1
6:main() at pp_sndrcv_spbl.c:52
6:PMPI_Finalize() at ?:?
6:ompi_mpi_finalize() at ?:?
6:barrier() at ?:?
6:opal_progress() at ?:?
6:opal_event_loop() at ?:?
6:poll_dispatch() at ?:?
6:poll() at ?:?
6:ThreadId: 2
6:clone() at ?:?
6:start_thread() at ?:?
6:btl_openib_async_thread() at ?:?
6:poll() at ?:?
6:ThreadId: 3
6:clone() at ?:?
6:start_thread() at ?:?
6:service_thread_start() at ?:?
6:select() at ?:?
7:ThreadId: 1
7:main() at pp_sndrcv_spbl.c:52
7:PMPI_Finalize() at ?:?
7:ompi_mpi_finalize() at ?:?
7:barrier() at ?:?
7:opal_progress() at ?:?
7:opal_event_loop() at ?:?
7:poll_dispatch() at ?:?
7:poll() at ?:?
7:ThreadId: 2
7:clone() at ?:?
7:start_thread() at ?:?
7:btl_openib_async_thread() at ?:?
7:poll() at ?:?
7:ThreadId: 3
7:clone() at ?:?
7:start_thread() at ?:?
7:service_thread_start() at ?:?
7:select() at ?:?
8:ThreadId: 1
8:main() at pp_sndrcv_spbl.c:52
8:PMPI_Finalize() at ?:?
8:ompi_mpi_finalize() at ?:?
8:barrier() at ?:?
8:opal_progress() at ?:?
```

```
8:opal_event_loop() at ?:?
8:poll_dispatch() at ?:?
8:poll() at ?:?
8:ThreadId: 2
8:clone() at ?:?
8:start_thread() at ?:?
8:btl_openib_async_thread() at ?:?
8:poll() at ?:?
8:ThreadId: 3
8:clone() at ?:?
8:start_thread() at ?:?
8:service_thread_start() at ?:?
8:select() at ?:?
```

The following example shows **padb** with the stack tree option:

```
%./padb -O rmgr=slurm -tx 47136
```

```
 [0-1,3-8] (8 processes)

main() at pp_sndrcv_spbl.c:52
 PMPI_Finalize() at ?:?
  ompi_mpi_finalize() at ?:?
   barrier() at ?:?
    opal_progress() at ?:?
     opal_event_loop() at ?:?
      poll_dispatch() at ?:?
       poll() at ?:?
        ThreadId: 2
         clone() at ?:?
          start_thread() at ?:?
           btl_openib_async_thread() at ?:?
            poll() at ?:?
             ThreadId: 3
              clone() at ?:?
               start_thread() at ?:?
                service_thread_start() at ?:?
                 select() at ?:?
2 (1 processes)

ThreadId: 1
 ??() at ?:?
  ??() at ?:?
   ThreadId: 2
    clone() at ?:?
     start_thread() at ?:?
      btl_openib_async_thread() at ?:?
       poll() at ?:?
        ThreadId: 3
         clone() at ?:?
          start_thread() at ?:?
           service_thread_start() at ?:?
            select() at ?:?
$
```

These stacks are standard from **GDB**.

3.5 More Information

See http://padb.pittman.org.uk and the man page for more information about **padb**.

Chapter 4. Application Analysis with bullxprof

bullxprof is a lightweight profiling tool, which launches and profiles a specified program according to the chosen experiments and dumps a profiling report onto the standard error output stream after the program's completion.

bullxprof can be seen as pertinent to the first analysis of an application as it delivers information that help targeting the program's potential 'hotspots'.

4.1 Environment

It is highly recommended to use the module file provided to have the environment set correctly before using the tools (see *Section 2.4 bullx DE Module* Files).

1. Load the **bullxprof** module file:

```
module load bullxprof/<version>
```

2. Load the MPI (**bullx MPI/OpenMPI** or **Intel MPI**) environment when profiling an MPI parallel program. The PAPI environment, needed for **hwc** profiling, is automatically loaded by the bullxprof module file.

When profiling Intel compiled application, the Intel environment must be loaded before the MPI environment.

4.2 Usage

The **bullxprof** command line is launched as follows:

```
bullxprof [ <bullxprof-options> ] "program [ <prog-args> ]"
```

In a parallel context, you can use **bullxprof** along with **mpirun** or **srun** as follows:

mpirun

```
bullxprof <bullxprof args> "mpirun <mpirun args> program <program args>"
```

srun

```
bullxprof <bullxprof args> "srun <srun args> program <program args>"
```

4.3 Command Line Options

bullxprof can be configured at run time with the following command line switches:

-d, –debug <debuglevel> Sets the tool's verbosity level: 0 (off), 1 (low), 2 (medium) and 3 (high).

-e, –experiments <exp1,exp2,...,expN>
Determines which profiling experiments will be run. Possible experiments are:

timing: application time profiling

hwc: hardware metrics profiling

mpi: MPI functions profiling

io: POSIX I/O functions profiling

mpiio: MPI I/O functions profiling

–force Forces the application profiling when multithreading is detected. This version of **bullxprof** does not support multithreading. By default, **bullxprof** will stop running when multithreading (OpenMP, pthread) is detected within the profiled binary.

-h, –help Displays the help message

-l, –list Prints the list of functions that can be instrumented

-L, –libs <lib1.so,...,libN.so>
List of shared libraries to include in the application profiling. bullxprof does not profile share libraries by default. The library full path name is needed if the library path name is not in the LD_LIBRARY_PATH environment variable.

-m, –metrics <metric1,...,metricN> Enables profiling of the selected metrics. Applies to the **hwc** experiment only. Possible metric values are:

flops: consumed GFLOPS

ibc: Instructions by Cycles

cmr: Cache Miss Rate (in %)

clr: Cache Line Reuse

-o, –output <mode1,...,modeN>
Determines report production output mode.
Possible output modes are **stdout**, **file** and **csv**.

"**stdout**" causes reports to be dumped on standard error stream.

"**file**" causes reports to be created as files in a directory named bullxprof.YYYYMMDD-HHMM-$SLURM_JOB_ID.

"**csv**" causes reports to be created as CSV files in a directory named bullxprof.YYYYMMDD-HHMM-$SLURM_JOB_ID.

-R, –region <region1,...,regionN> Enables time profiling of the selected code region. Applies to the timing experiment only. Possible regions are:

user: user code

mpi: MPI functions

io: POSIX I/O functions

mpiio: MPI I/O functions

-s Prints the reports using a smart display (time as [hours:]minutes:seconds, other values as K(ilo),M(ega) or G(iga)).

-t, –trace <tracelevel> Sets the level of detail of the profiling reports: 1 (basic), 2 (detailed) and 3 (advanced). Overrides experiment specific trace level set in configuration files.

-v Displays version and exits

4.4 Configuration

bullxprof behavior can be configured through command line options or via a configuration file. The options given as command line arguments overload the options set in a configuration file.

The configuration files are considered in this order of priority:

- A configuration file specified by the **BULLXPROF_CONF_FILE** environment variable.
- A file named **bullxprof.conf** located in the directory where the tool is launched from.
- A file named **bullxprof.conf** located in **$HOME/.bullxprof**
- A system-wide configuration file named **bullxprof.conf** located in **$BULLXPROF_HOME/etc**.
- A system-wide core configuration file named **bullxprof.core.conf** located in $BULLXPROF_HOME/etc. It is highly recommended not to modify the content of this file unless the administrator is well aware of his changes.

The following parameters may be set in a user-level configuration file:

General Configuration File Options

- app.functions.excluded=<string1,...,stringN>
Application functions to exclude from profiling.
Example: app.functions.excluded=functionA,_func_
Every function having one of the option's entry in its name will be ignored.
Caution: must not be left blank when enabled

- app.functions.whitelist=<string1,...,stringN>
Exception in the excluded application functions list. Example: app.functions.whitelist=one_func_opt
A function whose name is given as an entry of this option will not be ignored if it matches the **app.functions.excluded** option.
Caution: must not be left blank when enabled

- app.modules.excluded=<string1,...,stringN>
Application source file to exclude from profiling.
Example: app.modules.excluded=file1.c,file2.,.cpp
Every source file having one of the option's entry in its name will be ignored.
Caution: must not be left blank when enabled

- app.modules.whitelist=<string1,...,stringN>

  Exception in the excluded application source file list.
  Example: app.modules.whitelist=file2.cpp
  A source file whose name is given as an entry of this option will not be ignored if it matches the **app.functions.excluded** option.
  Caution: must not be left blank when enabled

- app.libraries=<string1,...,stringN>

  Comma-separated list of shared libraries to include in the application profiling. The library full path name is needed if the library path name is not in the LD_LIBRARY_PATH environment variable.
  Example: app.libraries=libfoo.so,/path/to/libbar.so
  Caution: must not be left blank when enabled

- bullxprof.debug=<number>

  Sets the tool's verbosity level: 0 (off), 1 (low), 2 (medium) and 3 (high).

- bullxprof.experiments=<exp1,...,expN>

  Determines which profiling experiments are to be activated.
  Possible experiments are: **timing**, **hwc**, **mpi**, **io** and **mpiio**

- bullxprof.smartdisplay=<[0|1]>

  Prints the reports using a smart display (time as [hours:]minutes:seconds, other values as K(ilo),M(ega) or G(iga)) when value is 1. Disabled otherwise.

- bullxprof.output=<mode1,...,modeN>

  Determines report production output mode. Possible output modes are **stdout**, **file** and **csv**.

  stdout causes reports to be dumped on standard error stream.

  file causes reports to be created as files in a directory named bullxprof.YYYYMMDD-HHMM-$SLURM_JOB_ID.

  csv causes reports to be created as CSV files in a directory named bullxprof.YYYYMMDD-HHMM-$SLURM_JOB_ID.

timing experiment Configuration File Options

- bullxprof.timing.tracelevel=<number> timing

  Experiment reports specific level of detail: 1 (basic), 2 (detailed) and 3 (advanced).

- bullxprof.timing.user.threshold=<float>

  Enables the display of user function statistics when percentage of user region time is over the given value. Set to 0 to disable this feature .

- bullxprof.timing.region=<region1,...,regionN>

  Enables time profiling of the selected code region. Possible regions are:

  user: user code

  mpi: MPI functions

  io: POSIX I/O functions

  mpiio: MPI I/O functions

hwc experiment Configuration File Options

- bullxprof.hwc.tracelevel=<number>

  hwc experiment reports specific level of detail: 1 (basic), 2 (detailed) and 3 (advanced).

- bullxprof.hwc.metrics=<metric1,...,metricN>

  Enables profiling of the selected metrics. Possible metric values are:

  flops: consumed GFLOPS

  ibc: Instructions by Cycles

  cmr: Cache Miss Rate (in %)

  clr: Cache Line Reuse

mpi experiment Configuration File Options

- bullxprof.mpi.tracelevel=<number>

  mpi experiment reports specific level of detail: 1 (basic), 2 (detailed) and 3 (advanced).

- bullxprof.timing.mpi.threshold=<float>

  Enables the display of MPI function statistics when percentage of MPI region time is over the given value. Set to 0 to disable this feature.

- bullxprof.mpi.functions=<function1,...,functionN>

  The list of profiled MPI functions. Supported values are selected from the following values:
  MPI_Allgather, MPI_Allgatherv, MPI_Allreduce, MPI_Alltoall, MPI_Alltoallv, MPI_Barrier, MPI_Bcast, MPI_Bsend, MPI_Bsend_init, MPI_Cancel, MPI_Cart_create, MPI_Cart_sub, MPI_Comm_create, MPI_Comm_dup, MPI_Comm_free, MPI_Comm_split, MPI_Comm_compare, MPI_Finalize, MPI_Gather, MPI_Gatherv, MPI_Get_count, MPI_Graph_create, MPI_Ibsend, MPI_Init, MPI_Intercomm_create, MPI_Intercomm_merge, MPI_Iprobe, MPI_Irecv, MPI_Irsend, MPI_Isend, MPI_Issend, MPI_Pack, MPI_Probe, MPI_Recv, MPI_Recv_init, MPI_Reduce, MPI_Reduce_scatter, MPI_Request_free, MPI_Rsend, MPI_Rsend_init, MPI_Scan, MPI_Scatter, MPI_Scatterv, MPI_Send, MPI_Send_init, MPI_Sendrecv, MPI_Sendrecv_replace, MPI_Ssend, MPI_Ssend_init, MPI_Test, MPI_Testall, MPI_Testany, MPI_Testsome, MPI_Start, MPI_Startall, MPI_Unpack, MPI_Wait, MPI_Waitall, MPI_Waitany, MPI_Waitsome

io experiment Configuration File Options

- bullxprof.io.tracelevel=<number>

  io experiment reports specific level of detail: 1 (basic), 2 (detailed) and 3 (advanced).

- bullxprof.timing.io.threshold=<float>

  Enables the display of POSIX I/O function statistics when percentage of POSIX I/O region time is over the given value. Set to 0 to disable this feature.

- bullxprof.io.functions=<function1,...,functionN>

  The list of profiled IO functions. Supported values are selected from the following values:
  open, close, creat, creat64, dup, dup2, dup3, lseek, lseek64, open64, pipe, pread, pread64, pwrite, pwrite64, read, readv, sync, fsync, fdatasync, write, writev

mpiio experiment Configuration File Options

- bullxprof.mpiio.tracelevel=<number>

  mpiio experiment reports specific level of detail: 1 (basic), 2 (detailed) and 3 (advanced).

- bullxprof.timing.mpiio.threshold=<float>

  Enables the display of MPI I/O function statistics when percentage of MPI I/O region time is over the given value. Set to 0 to disable this feature.

- bullxprof.mpiio.functions=<function1,...,functionN>

  The list of profiled MPI-IO functions. Supported values are selected from the following values:
  MPI_File_open, MPI_File_close, MPI_File_delete, MPI_File_set_size, MPI_File_preallocatePI_File_get_size, MPI_File_get_group, MPI_File_get_amode, MPI_File_set_info, MPI_File_get_info, MPI_File_set_view, MPI_File_get_view, MPI_File_read_at, MPI_File_read_at_all, MPI_File_write_at, MPI_File_write_at_all, MPI_File_iread_at,MPI_File_iwrite_at, MPI_File_read, MPI_File_read_all, MPI_File_write, MPI_File_write_all, MPI_File_iread, MPI_File_iwrite,MPI_File_seek, MPI_File_get_position, MPI_File_get_byte_offset, MPI_File_read_shared, MPI_File_write_shared, MPI_File_iread_shared, MPI_File_iwrite_shared, MPI_File_read_ordered, MPI_File_write_ordered, MPI_File_seek_shared, MPI_File_get_position_shared, MPI_File_read_at_all_begin, MPI_File_read_at_all_end, MPI_File_write_at_all_begin, MPI_File_write_at_all_end, MPI_File_read_all_begin, MPI_File_read_all_end, MPI_File_write_all_begin, MPI_File_write_all_end, MPI_File_read_ordered_begin, MPI_File_read_ordered_end, MPI_File_write_ordered_begin, MPI_File_write_ordered_end, MPI_File_get_type_extent, MPI_File_set_atomicity, MPI_File_get_atomicity, MPI_File_sync, MPI_File_set_errhandler, MPI_File_get_errhandler

4.5 Profiling reports

This section details the information contained in the different profiling reports.

4.5.1 Timing experiment

Sequential Program

For a sequential program, the **summary report** (produced when the trace level is set to 1) gives the following information:

process walltime	The overall execution time of the program
time	The execution time spent in a region
percentage	The percentage of walltime spent in a region

The **detailed report** (produced when the trace level is set to 2) gives the following information:

region	The region the function belongs to
number of calls	Number of times the function was called by the program
exclusive time	Time exclusively spent in the function without inner function calls
percentage	Percentage of walltime spent in the function

Parallel Program

In a MPI context, the **summary report** (produced when the trace level is set to 1) gives the following information:

process walltime	The execution time of the overall program
number of processes	Number of MPI processes
Comm/compute ratio	Ratio of time spent communicating on time spent computing

And per region – ALL, USER, MPI, MPI/IO and I/O - the following information:

Min Time[rank]	The minimum time spent in the region executing the function and the candidate process rank
Max time[rank]	The maximum time spent in the region executing the function and the candidate process rank
average time	The average time spent the function
percentage	Percentage of walltime spent in the region

The **detailed report** (produced when the trace level is set to 2) gives a per region report with the following information for each function:

Min Time[rank]	The minimum time spent in the region executing the function and the candidate process rank
Max time[rank]	The maximum time spent in the region executing the function and the candidate process rank
average time	The average time spent the function
% region	Percentage of the time spent in the region for the function
% walltime	Percentage of the walltime for the function

4.5.2 HWC experiment

hwc experiment computes hardware metrics using one or multiple **PAPI** hardware counters. The metric computation is limited to the underlying PAPI counters availability. A selected metric might not be displayed when the PAPI hardware counters needed for its computation are not available. In that case, a message is logged into the **bxprof.err** file created in the **bullxprof** launch directory.

Sequential Program

For a sequential program, the **summary report** (produced when the trace level is set to 1) gives the global value of user selected HW metrics.

The **detailed report** (produced when the trace level is set to 2) gives the user selected HW metrics values for each function. The report is dumped metric by metric.

Parallel Program

In a MPI context, the **summary report** (produced when the trace level is set to 1) gives the following information for each user selected HW metrics:

Min Value[rank]	The minimum count of the event for the overall program and the candidate process rank
Max Value[rank]	The maximum count of the event for the overall program and the candidate process rank
Average	The average count of the event for the overall program
Total	The cumulated count of the event for the overall program

4.5.3 MPI experiment

The **summary report** (produced when the trace level is set to 1) gives information about four (4) groups of MPI functions:

Point to Point	Send/Receive like MPI functions (MPI_Send, MPI_SendRecv etc.)
Collective	Collective MPI functions (e.g. MPI_Alltoall, MPI_Reduce etc.)
Synchronization	MPI_Barrier and MPI_Wait like functions
All	All MPI functions

For each group of MPI functions, the summary report gives the following information:

Max time [rank]	The maximum time spent in the functions of the group and the candidate process rank
Min time [rank]	The minimum time spent in the functions of the group and the candidate process rank
Average time	The average time spent in the functions of the group
Percentage of MPI	The percentage of time spent the MPI region.
Percentage of walltime	The percentage of walltime
Max message count [rank]	The maximum number of messages exchanged in the group and the candidate process
Min message count [rank]	The minimum number of messages exchanged in the group and the candidate process
Total message count	The total number of messages exchanged in the group
Average message count	The average number of messages exchanged in the group
Message rate	Number of messages exchanged in a second
Total volume	Total volume of data exchanged (in MB)
Average volume	Average volume of data exchanged (in MB)
Bandwidth	Volume of data exchanged in a second (in MB/s)

The **detailed report** (produced when the trace level is set to 2) gives a report for with the following information for each MPI function:

Min Time[rank]	The minimum time spent executing the MPI function and the candidate process rank
Max time[rank]	The maximum time spent executing the MPI function and the candidate process rank
average time	The average time spent in the MPI function
% region	Percentage of the MPI time for the MPI function
% walltime	Percentage of the walltime for the MPI function

4.5.4 IO experiment

Sequential Program

For a sequential program, the **summary report** (produced when the trace level is set to 1) gives the following information:

Total IO time	Total time spent executing IO functions
Total IO read time	Total time spent executing IO read-like functions
Total IO read volume	Total volume of data read (MB)
Total IO read bandwidth	Total volume of data read in a second (MB/s)
Total IO write time	Total time spent executing IO write-like and close functions

Total IO write volume Total volume of data written (MB)

Total IO write bandwidth Total volume of data written in a second (MB/s)

The detailed report (produced when the trace level is set to 2) gives for each POSIX IO function the following information:

Calls Total number of call for the IO function

Executive time Time spent executing the IO function

Percentage Percentage of walltime

Parallel Program

In a MPI context, the **summary report** (produced when the trace level is set to 1) gives information about three (3) groups of POSIX IO functions:

Read read-like functions (e.g. read, readv etc.)

Write write-like (e.g. write, pwrite etc.) and close functions

Total All POSIX IO functions

For each group of POSIX IO functions, the summary report gives the following information:

Max IO time [rank] The maximum time spent in the functions of the group and the candidate process rank

Min IO time [rank] The minimum time spent in the functions of the group and the candidate process rank

Average IO time The average time spent in the functions of the group

Percentage of IO time The percentage of time spent the MPI region.

Percentage of walltime The percentage of walltime

Max IO volume [rank] The maximum volume of IO data processed in the group and the candidate process

Min IO volume [rank] The minimum volume of IO data processed in the group and the candidate process

Total volume Total volume of data processed (in MB)

Average volume Average volume of data processed (in MB)

IO bandwidth Volume of data processed in a second (in MB/s)

The **detailed report** (produced when the trace level is set to 2) gives a report for with the following information for each POSIX IO function:

Min Time[rank] The minimum time spent executing the IO function and the candidate process rank

Max time[rank] The maximum time spent executing the IO function and the candidate process rank

average time The average time spent in the IO function

% region Percentage of the IO time for the IO function

% walltime Percentage of the walltime for the IO function

4.5.5 MPI/IO experiment

The **summary report** (produced when the trace level is set to 1) gives information about three (3) groups of MPI/IO functions:

Read	MPI_File_read like functions
Write	MPI_File_write like functions
Total	All MPI/IO functions

For each group of ll MPI/IO functions, the summary report gives the following information:

Max MPI-IO time [rank]	The maximum time spent in the functions of the group and the candidate process rank
Min MPI-IO time [rank]	The minimum time spent in the functions of the group and the candidate process rank
Average MPI-IO time	The average time spent in the functions of the group
Percentage of MPI-IO time	The percentage of time spent the MPI region.
Percentage of walltime	The percentage of walltime
Max MPI-IO volume [rank]	The maximum volume of ll MPI/IO data processed in the group and the candidate process
Min MPI-IO volume [rank]	The minimum volume of ll MPI/IO data processed in the group and the candidate process
Total volume	Total volume of data processed (in MB)
Average volume	Average volume of data processed (in MB)
MPI-IO bandwidth	Volume of data processed in a second (in MB/s)

The **detailed report** (produced when the trace level is set to 2) gives a report for with the following information for each MPI/IO function:

Min Time[rank]	The minimum time spent executing the MPI/IO function and the candidate process rank
Max time[rank]	The maximum time spent executing the MPI/IO function and the candidate process rank
average time	The average time spent in the MPI/IO function
% region	Percentage of the MPI/IO time for the MPI/IO function
% walltime	Percentage of the walltime for the MPI/IO function

Chapter 5. MPI Application Profiling

5.1 MPI Analyser

This section describes how to use the MPI Analyser profiling tool.

5.1.1 MPI Analyser Overview

mpianalyser is a profiling tool, developed by Bull for its own MPI implementation. This is a non-intrusive tool, which allows the display of data from counters that has been logged when the application runs. **mpianalyser** uses the **PMPI** interface to analyze the behavior of MPI programs.

profilecomm is a part of **mpianalyser** and is dedicated to MPI application profiling. It has been designed to be:

- Light: it uses few resources and so does not slow down the application.
- Easy to run: it is used to characterize the MPI communications in a program. Communication matrices are constructed with it. **Profilecomm** is a post-mortem tool, which does not allow on-line monitoring.

Data is collected as long as the program is running. At the end of the program, data is written into a file for future analysis.

readpfc is a tool with a command line interface which handles the data that has been collected. Its main uses are the following:

- To display the data collected.
- To export communication matrices in a format that can be used by other applications.

Data Collected

The **profilecomm** module provides the following information:

- Communication matrices
- Execution time
- Table of calls of MPI functions
- Message size histograms
- Topology of the execution environment.

Environment

The user environment can be set to use mpianalyser through the provided module files (see *Section 2.4 bullx DE Module* Files):

- **mpianalyser/1.2_link**: this module file sets the user environment for linking an MPI binary with the mpianalyser's library. Use the MPIANALYSER_LINK environment variable can be used to link the binary with mpianalyser.
- **mpianalyser/1.2_preload**: this module file sets the user environment for using mpianalyser without recompilation of your MPI dynamically linked program. Note that this module file sets the LD_PRELOAD variable that will any MPI dynamically linked program as long as this module is loaded. It is highly recommended to unload this module immediately after your profiling session.

5.1.2 Communication Matrices

The **profilecomm** library collects separately the point-to-point communications and the collective communications. It also collects the number of messages and the volume that the sender and receiver have exchanged. Finally, the library builds 4 types of communication matrices:

- Communication matrix of the number of point to point messages
- Communication matrix of the volume (in bytes) of point to point messages
- Communication matrix of the number of collective messages
- Communication matrix of the volume (in bytes) of collective messages

The volume only indicates the payload of the messages.

In order to compute the standard deviation of messages size, two other matrices are collected. They contain the sum of squared messages sizes for **point-to-point** and for collective communications.

In order to obtain precise information about messages sizes, each numeric matrix can be split into several matrices according to the size of the messages. The number of partitions and the size limits can be defined through the **PFC_PARTITIONS** environment variable. In a point-to-point communication, the sender and receiver of each message is clearly identified, this results in a well defined position in the communication matrix.

In a collective communication, the initial sender(s) and final receiver(s) are identified, but the path of the message is unknown. The **profilecomm** library disregards the real path of the messages. A collective communication is shown as a set of messages sent directly by the initial sender(s) to the final receiver(s).

Execution Time

The measured execution time is the maximum time interval between the calls to **MPI_Init** and **MPI_Finalize** for all the processes. By default, the processes are synchronized during measurements. However, if necessary, the synchronization may be by-passed using an option of the **profilecomm** library.

Call Table

The call table contains the number of calls for each profiled function of each process. For collective communications, since a call generates an unknown number of messages, the values indicated in the call table do not correspond to the number of messages.

Histograms

profilecomm collects two messages size histograms, one for point-to-point and one for collective communications. Each histogram contains the number of messages for sizes 0, 1 to 9, 10 to 99, 100 to 999, ..., 10^8 to 10^9-1 and bigger than 10^9 bytes.

5.1.3 Topology of the Execution Environment

The **profilecomm** module registers the topology of the execution environment, so that the machine and the CPU on which each process is running can be identified, and above all the intra- and inter-machine communications made visible.

5.1.4 Using profilecomm

When using **profilecomm** there are 2 separate operations – data collection, and then its analysis. To be profiled by **profilecomm**, an application must be linked with the **MPI Analyser** library.

profilecomm is disabled by default, to enable it, set the following environment variable:

```
export MPIANALYSER_PROFILECOMM=1
```

When the application finishes, the results of the data collection are written to a file (**mpiprofile.pfc** by default). By default, this file is saved in a format specific to **profilecomm**, but it is possible to save it in a text format. The **readpfc** command enables **.pfc** files to be read and analyzed.

5.1.4.1 profilecomm Options

Different options may be specified for **profilecomm** using the **PFC_OPTIONS** environment variable.

For example:

```
export PFC_OPTIONS="-f foo.pfc"
```

Some of the options that modify the behavior of **profilecomm** when saving the results in a file are below:

-f *file*, -filename *file*
Saves the result in the **file** file instead of the default file (**mpiprofile.txt** for text format files and **mpiprofile.pfc** for **profilecomm** binary format files).

-t, -text
Saves the result in a text format file, readable with any text editor or reader. This format is useful for debugging purpose but it is not easy to use beyond 10 processes.

-b, -bin
Saves the results in a **profilecomm** binary format file. This is the default format. The **readpfc** command is required to work with these files.

-s, -sync
Synchronizes the processes during the time measurements. This option is set by default.

-ns, -nosync
Does not synchronize the processes during the time measurements.

-v32, -volumic32
Use 32 bit volumic matrices. This can save memory when profiling application with a large number of processes. A process must not send more than 4GBs of data to another process.

-v64, -volumic64
Use 64 bits volumic matrices. This is the default behavior. It allows the profiling of processes which exchanges more than 4GBs of data.

Examples

To profile the **foo** program and save the results of the data collection in the default file **mpiprofile.pfc**:

```
$ MPIANALYSER_PROFILECOMM=1 srun –p my_partion –N 1 -n 4./foo
```

To save the results of the data collection in the `foo.pfc` file:

```
$ MPIANALYSER_PROFILECOMM=1 PFC_OPTIONS="-f foo.pfc" srun –p my_partion –N 1 -n
4./foo
```

To save the result of the collect in text format in the `foo.txt` file:

```
$ MPIANALYSER_PROFILECOMM=1 PFC_OPTIONS="-t -f foo.txt" srun –p my_partion –N 1 -n
4./foo
```

5.1.4.2 Messages Size Partitions

profilecomm allows the numeric matrices to be split according to the size of the messages. This feature is activated by setting the **PFC_PARTITIONS** environment variable. By default, there is only one partition, i.e. the numeric matrices are not split.
The **PFC_PARTITIONS** environment variable must be of the form **[partitions:] [limits]** in which **partitions** represents the number of partitions and **limits** is a comma separated list of sorted numbers representing the size limits in bytes.
If **limits** is not set, **profilecomm** uses the built-in default limits for the requested partition number.

Example 1

3 partitions using the default limits (1000, 1000000):

```
$ export PFC_PARTITIONS="3:"
```

Example 2

3 partitions using user defined limits (in this case, the partition number can be safely omitted):

```
$ export PFC_PARTITIONS="3:500,1000"
```

Or :

```
$ export PFC_PARTITIONS="500,1000"
```

Note **profilecomm** supports a maximum of 10 partitions only.

5.1.5 profilecomm Data Analysis

To analyze data collected with **profilecomm**, the **readpfc** command and other tools (including spreadsheets), can be used. The main features of **readpfc** are the following:

- Displaying the data contained in **profilecomm** files.
- Exporting communication matrices in standard file formats.

5.1.5.1 readpfc syntax

```
readpfc [options] [file]
```

If `file` is not specified, **readpfc** reads the default file **mpiprofile.pfc** in the current directory.

Readpfc output

The main feature of **readpfc** is to display the information contained in the seven different sections of a **profilecomm** file. These are:

- Header
- Point to point
- Collective
- Call table
- Histograms
- Statistics
- Topology

Note The header, histograms, statistics and topology sections are not included in the output when the **-t**, **-text** text format options are used.

5.1.5.2 Header Section

Displays information contained into the header of a **profilecomm** file. The more interesting fields are:

- **Elapsed Time** – indicates the length of the data collection
- **World size** - indicates the number of processes
- **Number of partitions** – indicates the number of partitions
- **Partitions limits** – indicates the list of size limits for the messages partitions (only used if there are several partitions).

The other fields are less interesting for final users but are used internally by **readpfc**.

Example

```
Header:
 Version: 2
 Flags: little-endian
 Header size: 40 bytes
 Elapsed time: 9303 us
 World size: 4
 Number of partitions: 3
 Partitions limits:  1000  1000000
 num_intsz: 4 bytes (32 bits)
 num_volsz: 8 bytes (64 bits)
```

5.1.5.3 Point to Point Communications Section

For point to point communication matrices, use the following. The number of communication messages is displayed first, then the volume. If either the **--numeric-only** or **--volumic-only** options are used then only one matrix is displayed accordingly.

Example

```
Point to point:
 numeric (number of messages)
      0   1.1k      0      0 |   1.1k
   1.1k      0      0      0 |   1.1k
      0      0      0   1.1k |   1.1k
      0      0   1.1k      0 |   1.1k
```

```
 volumic (Bytes)
      0 818.8k      0      0 | 818.8k
 818.8k      0      0      0 | 818.8k
      0      0      0 818.8k | 818.8k
      0      0 818.8k      0 | 818.8k
```

If the file contains several partitions and the **-J/--**split option is set then this command displays as many numeric matrices as there are partitions. Example:

```
Point to point:
 numeric (number of messages)
 0 <= msg size < 1000
      0    800      0      0 |    800
    800      0      0      0 |    800
      0      0      0    800 |    800
      0      0    800      0 |    800

 1000 <= msg size < 1000000
      0    300      0      0 |    300
    300      0      0      0 |    300
      0      0      0    300 |    300
      0      0    300      0 |    300

 1000000 <= msg size
      0      0      0      0 |      0
      0      0      0      0 |      0
      0      0      0      0 |      0
      0      0      0      0 |      0

 volumic (Bytes)
      0 818.8k      0      0 | 818.8k
 818.8k      0      0      0 | 818.8k
      0      0      0 818.8k | 818.8k
      0      0 818.8k      0 | 818.8k
```

If the **-r/--**rate option is set then the messages rate and data rate matrices are shown instead of communications matrices. These rates are the average rates for all execution times not the instantaneous rates. Example:

```
Point to point:
 message rate (msg/s)
      0 118.2k      0      0 | 118.2k
 118.2k      0      0      0 | 118.2k
      0      0      0 118.2k | 118.2k
      0      0 118.2k      0 | 118.2k

 data rate (Bytes/s)
      0 88.01M      0      0 | 88.01M
 88.01M      0      0      0 | 88.01M
      0      0      0 88.01M | 88.01M
      0      0 88.01M      0 | 88.01M
```

5.1.5.4 Collective Section

The collective section is equivalent to the point-to-point section for collective communication matrices. Example:

```
Collective:
 numeric (number of messages)
      0    102    202    102 |    406
    102      0      0    100 |    202
    202      0      0      0 |    202
    102    100      0      0 |    202
```

```
volumic (Bytes)
     0 409.6k 421.6k 409.6k | 1.241M
12.04k      0      0    12k | 24.04k
421.6k      0      0      0 | 421.6k
12.04k 409.6k      0      0 | 421.6k
```

5.1.5.5 Call table section

This section contains the call table. If the `--ct-total-only` option is activated, only the total column is displayed. Example:

```
Call table:
                    0      1      2      3      4      5      6      7  Total
Allgather           0      0      0      0      0      0      0      0      0
Allgatherv          0      0      0      0      0      0      0      0      0
Allreduce           2      2      2      2      2      2      2      2     16
Alltoall            0      0      0      0      0      0      0      0      0
Alltoallv           0      0      0      0      0      0      0      0      0
Bcast             200    200    200    200    200    200    200    200   1.6k
Bsend               0      0      0      0      0      0      0      0      0
Gather              0      0      0      0      0      0      0      0      0
Gatherv             0      0      0      0      0      0      0      0      0
Ibsend              0      0      0      0      0      0      0      0      0
Irsend              0      0      0      0      0      0      0      0      0
Isend               0      0      0      0      0      0      0      0      0
Issend              0      0      0      0      0      0      0      0      0
Reduce            200    200    200    200    200    200    200    200   1.6k
Reduce_scatter      0      0      0      0      0      0      0      0      0
Rsend               0      0      0      0      0      0      0      0      0
Scan                0      0      0      0      0      0      0      0      0
Scatter             0      0      0      0      0      0      0      0      0
Scatterv            0      0      0      0      0      0      0      0      0
Send              1.1k   1.1k   1.1k   1.1k   1.1k   1.1k   1.1k   1.1k   8.8k
Sendrecv            0      0      0      0      0      0      0      0      0
Sendrecv_replace    0      0      0      0      0      0      0      0      0
Ssend               0      0      0      0      0      0      0      0      0
Start               0      0      0      0      0      0      0      0      0
```

5.1.5.6 Histograms Section

This section contains the message sizes histograms. It shows the number of messages whose size is zero, between 1 and 9, between 10 and 99, ..., between 10^8 and 10^9-1 and greater than 10^9.

Example:

```
Histograms of msg sizes
size   pt2pt   coll  total
   0       0      0      0
   1     800      6    806
  10    1.2k      6 1.206k
 100    1.2k    500   1.7k
1000    1.2k    500   1.7k
104        0      0      0
105        0      0      0
106        0      0      0
107        0      0      0
108        0      0      0
109        0      0      0
```

5.1.5.7 Statistics Section

This section displays statistics computed by **readpfc**. These statistics are based on the information contained in the data collection file. This section is divided into two or three sub-sections:

- The *General statistics* section contains statistics for the whole application.
- The *Per process average* section contains averages per process.
- The *Messages sizes partitions* section displays the distribution of messages among the partitions. This section is only present if there are several partitions.
- For each statistic we distinguish point to point communications from collective communications.

Example

```
General statistics:
Total time: 0.009303s  (0:00:00.009303)
                        pt2pt |       coll |      total
Messages count  |        4400 |       1012 |       5412
Volume          |    3.2752MB |  2.10822MB |  5.38342MB
Avg message size|       744B |  2.08322kB |       995B
Std deviation   |     1216.4 |     1989.1 |     1488.4
Variation coef. |     1.6341 |    0.95481 |     1.4963
Frequency msg/s |   472.966k |   108.782k |   581.748k
Throughput B/s  | 352.06MB/s | 226.62MB/s | 578.68MB/s

Per process average:
                        pt2pt |       coll |      total
Messages count  |        1100 |        253 |       1353
Volume          |     818.8kB |  527.054kB |  1.34585MB
Frequency msg/s |   118.241k |   27.1955k |   145.437k
Throughput B/s  | 88.015MB/s | 56.654MB/s | 144.67MB/s

Messages sizes partitions:
                               |   pt2pt count |    coll count  |   total
count
         0 <= sz < 1000        |  3.2e+03  73% |  5.1e+02  51% |  3.7e+03  69%
      1000 <= sz < 1000000     |  1.2e+03  27% |    5e+02  49% |  1.7e+03  31%
   1000000 <= sz               |         0   0% |         0   0% |         0   0%
```

The message sizes partitions should be examined first.

Where:

Total time	Total execution time between **MPI_Init** and **MPI_Finalize**
Messages count	Number of sent messages
Volume	Volume of sent messages (bytes)
Avg message size	Average size of messages (bytes)
Std deviation	Standard deviation of messages size
Variation coef.	Variation coefficient of messages size
Frequency msg/s	Average frequency of messages (messages per second)
Throughput B/s	Average throughput for sent messages (bytes per second)

5.1.5.8 Topology Section

This section shows the distribution of processes on nodes and processors. This distribution is displayed in two different ways:

First, for each process the node and the CPU in the node where it is running and secondly, the list of running processes for each node.

Example - 8 Processes Running on 2 Nodes

```
Topology:
8 process on 2 hosts
process hostid  cpuid
      0      0      0
      1      0      1
      2      0      2
      3      0      3
      4      1      0
      5      1      1
      6      1      2
      7      1      3

host  processes
   0  0 1 2 3
   1  4 5 6 7
```

5.1.6 Profilecomm Data Display Options

The following options can be used to display the data:

-a, --all
Displays all the information. Equivalent to **–ghimst**.

-c, --collective
Displays collective communication matrices.

-g, --topology
Displays the topology of execution environment.

-h, --header
Displays header of the **profilecomm** file.

-i, --histograms
Displays messages size histograms.

-j, --joined
Displays entire numeric matrices (i.e. not split). This is the default.

-J, --splitted
Display numeric matrices split according to messages size.

-m, --matrix, --matrices
Displays communication matrix (matrices). Equivalent to **–cp**.

-n, --numeric-only
Does not display volume matrices. This option cannot be used simultaneously with the **-v/--volumic-only** option.

-p, --p2p, --pt2pt
Displays point to point communication matrices.

-r, --rate, --throughput
Displays messages rate and data rate matrices instead of communications matrices.

-s, --statistics
Computes and displays some statistics regarding MPI communications.

-S, --scalable
Displays all scalable information; this means all information whose size is independent of number of processes. Useful when there is a great number of processes. Equivalent to **histT.**

--square-matrices
Displays the matrices containing the sum of the squared sizes of messages. These matrices are used for standard deviation computation and are useless for final users. This option is mainly provided for debugging purposes.

-t, --calltable
Displays the call table.

-T, --ct-total-only
Displays only the *Total* column of the call table. By default **readpfc** displays also one column for each process.

-v, --volumic-only
Does not display numeric matrices. This option cannot be used simultaneously with **-n/--numeric-only** option.

5.1.7 Exporting a Matrix or an Histogram

The communication matrices and the histograms can be exported in different formats that can be used by other software programs, for example spreadsheets. Three formats are available: **CSV** (Comma Separated Values), **MatrixMarket** (not available for histogram exports) and **gnuplot**.

It is also possible to have a graphical display of the matrix or the histogram, which is better for matrices with a large number of elements. Obviously, it is also possible to include the graphics in a report. Seven graphic formats are available: PostScript, Encapsulated PostScript, SVG, xfig, EPSLaTeX, PSLaTeX and PSTeX. All these formats are vectorial, which means the dimensions of the graphics can be modified if necessary.

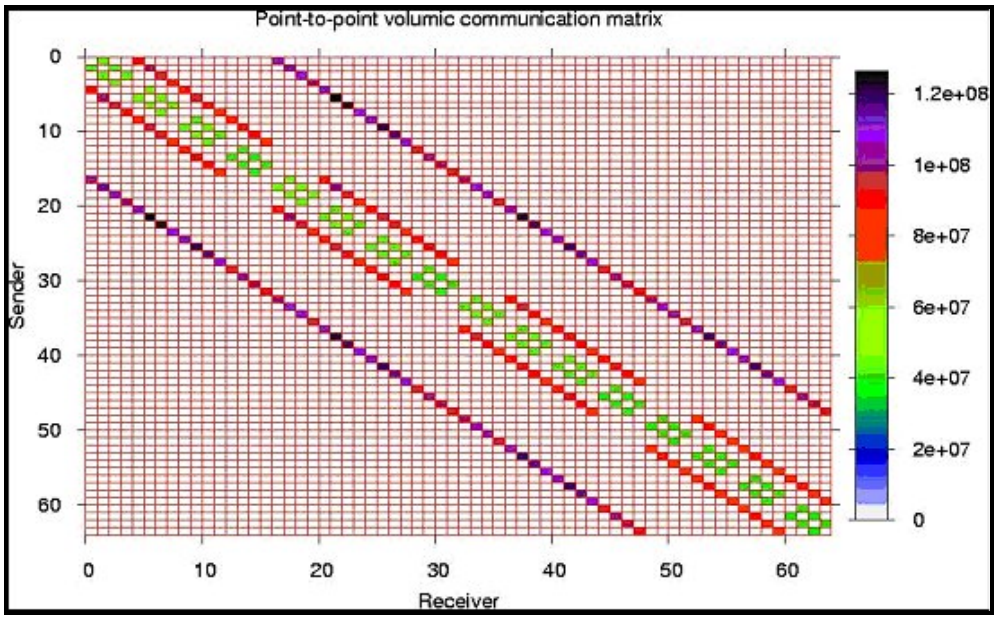


Figure 5-1. An example of a communication matrix

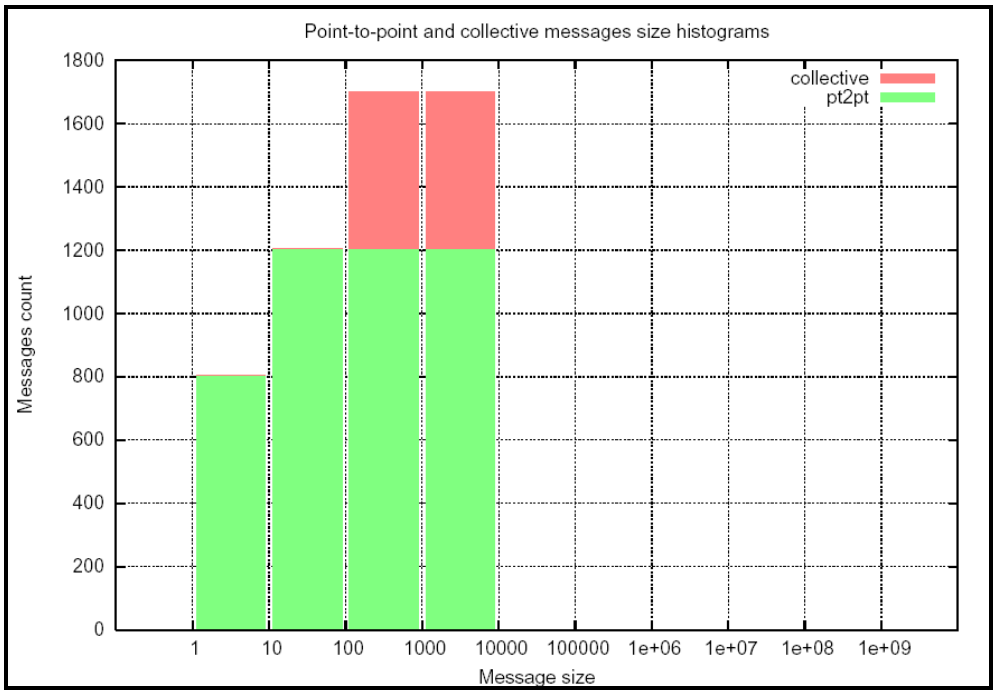


Figure 5-2. An example of a histogram

5.1.7.1 Options

The following options may be used when exporting matrices:

--csv-separator sep	Modifies CSV delimiter. Default delimiter is comma ",". Some software programs prefer a semicolon ";".
-f format, --format *format*	Chooses export format. Default format is CSV (Comma Separated Values).
help	Lists available export formats
csv	Export in CSV format
mm, market, MatrixMarket	Export in MatrixMarket format
gp, gnuplot	Export in a format used by pfcplot so that a graphical display of the matrix can be produced
ps, postscript	Export in PostScript format
eps	Export in Encapsulated PostScript format
svg	Export in Scalable Vector Graphics format
fig, xfig	Export in xfig format
epslatex	Export in LaTex and Encapsulated PostScript format
pslatex	Export in LaTex format and PostScript inline
pstex	Export in Tex format and PostScript inline

The available values are the following:

Important **When using epslatex two files are written: xxx.tex and xx.eps. The filename indicated in the –o option is the name of the Latex file.**

--logscale[=base]
Uses a logarithmic color scale. Default value for logarithm basis is 10; this basis can be modified using the **base** argument. This option is only relevant when exporting in a graphical format.

--nogrid
Does not display the grid on a graphical representation of the matrix.

-o file, --output *file*
Specifies the file name for an export file. The default filenames are **out.csv**, **out.mm, out.dat, out.ps, out.svg, out.fig** or **out.tex**, according to export format. This option is only available with the –x option.

--palette *pal*
Uses a personalized colored palette. This option is only relevant when exporting in a graphical format. This palette must be compatible with the **`defined`** function of gnuplot, for instance:
`--palette '0 "white", 1 "red", 2 "black"'` or `--palette '0 "#0000ff", 1 "#ffff00", 2 "ff0000"'`

--title *title*
Uses a personalized title for a graphical display. The default title is *Point-to-point/collective numeric/volumic communication* matrix, according to the exported matrix.

-x object, *--export object*
Exports a communication matrix or histogram specified by the ***object*** argument. Values for **object** are the following:

help	List of available matrices and histograms
pn[.part], np[.part]	Point-to-point numeric communication matrix. The optional item part is the partition number for split matrices. If part is not set, the entire matrix (i.e. the sum of the split matrices) is exported.
pv, vp	Point to point volumic communication matrix
cn[.part], nc[.part]	Collective numeric communication matrix
cv, vc	Collective volumic communication matrix
ph, hp	Point-to-point messages size histogram
ch, hc	Collective messages size histogram
th, ht	Total messages size histogram (collective and point-to-point)
ah, ha	Both point-to-point and collective messages size histograms (all histograms)

Other options

-H, --help, --usage	Displays help messages
-q, --quiet	Does not display help warning messages (error messages continue to be displayed).
-V, --version	Displays program version.

Examples

- To display all information available in **foo.pfc** file, enter:

```
$ readpfc -a foo.pfc
```

This will give information similar to that below

```
Header:
 Version: 2
 Flags: little-endian
 Header size: 40 bytes
 Elapsed time: 9303 us
 World size: 4
 Number of partitions: 3
 Partitions limits:  1000  1000000
 num_intsz: 4 bytes (32 bits)
 num_volsz: 8 bytes (64 bits)
[...]
Topology:
4 process on 1 hosts
process hostid  cpuid
      0      0      0
      1      0      1
      2      0      2
      3      0      3

host  processes
   0  0 1 2 3
```

- To display a point to point numerical communication matrix:

```
$ readpfc -pn foo.pfc
```

```
Point to point:
 numeric (number of messages)
      0   1.1k      0      0 |   1.1k
   1.1k      0      0      0 |   1.1k
      0      0      0   1.1k |   1.1k
      0      0   1.1k      0 |   1.1k
```

- To export the collective volumic communication matrix in CSV format in the default file:

```
$ readpfc –x cv foo.pfc
```

```
Warning: No output file specified, write to default (out.csv).
```

```
$ ls out.csv
```

```
out.csv
```

- To export the first part (small messages) of point to point numerical communication matrices in PostScript format in the foo.ps file:

```
$ readpfc -x np.0 -f ps -o foo.ps foo.pfc
$ ls foo.ps
```

```
foo.ps
```

5.1.7.2 pfcplot, histplot and gnuplot

The **pfcplot** script converts matrices into graphic using **gnuplot**. It is generally used by **readpfc**, but can be used directly by the user who wants more flexibility. The matrix must be exported with the **–f gnuplot** option to be read by **pfcplot**.

For more details enter:

```
man pfcplot
```

Users who have particular requirements can invoke **gnuplot** directly. To do this the matrix must be exported with **gnuplot** format or with CSV format, choosing space as the separator.

Important **Due to the limitations of gnuplot, one null line and one null column are added to the exported matrix in gnuplot format.**

Histplot is the equivalent of **pfcplot** for histograms. Like **pfcplot**, it can be used directly by users but it is not user-friendly. More details are available from the man page:

```
man histplot
```

5.2 Scalasca

This section describes how to use the Scalasca performance analysis toolset.

5.2.1 Scalasca Overview

Scalasca (Scalable Performance Analysis of Large-Scale Applications) is an Open-Source performance-analysis toolset that has been specifically designed for use on large-scale systems. It is also well adapted for small and medium-scale HPC platforms. Scalasca supports incremental performance-analysis procedures that integrate runtime summaries with in-depth studies of concurrent behavior via event tracing, adopting a strategy of successively refined measurement configurations. A distinctive feature is the ability to identify wait states that occur, for example, due to unevenly distributed workloads. Such wait states can lead to poor performance, especially when trying to scale communication-intensive applications to large processor counts.

The current version of Scalasca supports the performance analysis of applications based on the MPI, OpenMP, and hybrid programming constructs (OpenMP and hybrid with restrictions) most widely used in highly scalable HPC applications written in C, C++ and Fortran on a wide range of current HPC platforms. The user can choose between generating a summary report (profile) with aggregate performance metrics for individual function call-paths, and/or generating event traces recording individual runtime events. Scalasca allows switching between both options to occur, without re-compiling or re-linking.

Summarization is particularly useful, as it presents an overview of performance behavior and of local metrics such as those derived from hardware counters. In addition, it can also be used to optimize the instrumentation for later trace generation. When tracing is enabled, each process generates a trace file containing records for all the process local events.

Following program termination, Scalasca loads the trace files into main memory and analyzes them in parallel, using as many CPUs as have been used for the target application itself. During the analysis, Scalasca searches for characteristic patterns indicating wait states and related performance properties, classifies detected instances by category and quantifies their significance. The result is a pattern-analysis report similar in structure to the summary report, but enriched with higher-level communication and synchronization inefficiency metrics.

5.2.2 Scalasca Usage

Using Scalasca consists in loading a module file, which will set the different paths for binaries and libraries.

The Scalasca package provides three module files:

- **scalasca/<version>_bullxmpi -gnu**
  This module file is to be loaded to use Scalasca with applications compiled with bullxMPI or any OpenMPI based MPI implementation and using GNU compilers.
- **scalasca/<version>_bullxmpi -intel**
  This module file is to be loaded to use Scalasca with applications compiled with bullxMPI or any OpenMPI based MPI implementation and using Intel compilers.
- **scalasca/<version>_intelmpi**
  This module file is to be loaded to use Scalasca with applications compiled with Intel MPI and Intel compilers.

To be able to use Scalasca with an application, the first step is to recompile the application to get it instrumented.

In addition to an almost automatic approach using compiler-inserted instrumentation, semi-automatic **POMP** and manual instrumentation approaches are also supported.

Manual instrumentation can be used either to augment automatic instrumentation with region or phase annotations, which can improve the structure of analysis reports – or if other instrumentations fail.

Once the application instrumented, next steps are execution measurement collection and analysis, and analysis report examination.

Use the **scalasca** command with appropriate action flags to **instrument** application object files and executables, **analyze** execution measurements, and interactively **examine** measurement/analysis experiment archives:

Note The PDT-based source-code instrumentation is not supported by this integrated version of Scalasca.

http://www.vi-hps.org/upload/material/tw11/Scalasca.pdf

5.2.3 More Information

For a full workflow example and more about the application performance analysis, see: http://www.vi-hps.org/upload/material/tw11/Scalasca.pdf

For more information on Scalasca concepts and projects, see: http://www.scalasca.org.

5.3 xPMPI

xPMPI is a framework allowing the use of multiple **PMPI** tools. PMPI is the MPI profiling layer defined by the MPI standard to allow the interception of MPI function calls. By definition, only one tool can intercept a function and forward the call to the real implementation library. xPMPI is a framework that acts as a PMPI multiplexer by intercepting the MPI function calls and forwards the call to a chain of patched PMPI tools.

5.3.1 Supported tools

xPMPI allows the combination of the following PMPI tools:

IPM

IPM is a portable profiling tool for parallel codes. It provides a low-overhead performance profile of the performance aspects and resource utilization in a parallel program. Communication, computation, and IO are the primary focus.

At the end of a run, IPM dumps a text-based report where aggregate wallclock time, memory usage and flops are reported along with the percentage of wallclock time spent in MPI calls, as shown in the following example:

```
##IPMv0.983############################################################
#
# command : ./TF (completed)
# host : dakar1/x86_64_Linux mpi_tasks : 4 on 1 nodes
# start : 09/14/12/11:28:37 wallclock : 5.381077 sec
# stop : 09/14/12/11:28:42 %comm : 7.15
# gbytes : 9.64523e-01 total gflop/sec : 0.00000e+00 total
#
###########################################################################
# region : * [ntasks] = 4
#
# [total] <avg> min max
# entries 4 1 1 1
# wallclock 21.517 5.37924 5.3785 5.38108
# user 25.47 6.3675 6.29 6.44
# system 0.88 0.22 0.16 0.26
# mpi 1.53893 0.384732 0.0103738 0.53211
# %comm 7.14973 0.192783 9.89294
# gflop/sec 0 0 0 0
# gbytes 0.964523 0.241131 0.241112 0.241161
#
#
# [time] [calls] <%mpi> <%wall>
# MPI_Allreduce 0.769333 72 49.99 3.58
# MPI_Send 0.628268 637 40.83 2.92
# MPI_Barrier 0.0887964 432 5.77 0.41
# MPI_Bcast 0.048476 148 3.15 0.23
# MPI_Irecv 0.00139042 563 0.09 0.01
# MPI_Reduce 0.00099695 16 0.06 0.00
# MPI_Wait 0.000902604 560 0.06 0.00
# MPI_Gather 0.000289791 8 0.02 0.00
# MPI_Recv 0.000234257 74 0.02 0.00
# MPI_Comm_size 0.00013079 991 0.01 0.00
# MPI_Waitall 3.91998e-05 1 0.00 0.00
# MPI_Probe 3.63181e-05 3 0.00 0.00
# MPI_Comm_rank 3.54093e-05 232 0.00 0.00
###########################################################################
```

Note In the context of xPMPI, the user applications have not to be recompiled. Hardware counters profiling is not supported by this integrated version of IPM.

mpiP

mpiP is a lightweight profiling library for MPI applications. Because it only collects statistical information about MPI functions, mpiP generates considerably less overhead and much less data than tracing tools. All the information captured by mpiP is task-local. It only uses communication during report generation, typically at the end of the experiment, to merge results from all of the tasks into one output file.

Note In the context of xPMPI, the user applications have not to be recompiled.

At the end of the run, mpiP generates a **.mpiP** report file in the current directory (default). We suggest modifying this default to your favorite directory, setting the environment variable MPIP as follows:

```
export MPIP="-f /myhome/myfavourite/the_appli"
```

See http://mpip.sourceforge.net/#mpiP_Output for a complete description of the results.

Should you want to influence the mpiP runtime and customize the generated report, more options are available with the environment variable MPIP there:
http://mpip.sourceforge.net/#Runtime_Configuration

5.3.2 xPMPI Configuration

The combination of tools can be managed with a configuration file indicating which tools are activated and their order of execution.

```
#####################################################################
#
# XPMPI configuration file
#
#####################################################################
module mpiP
module ipm
```

The keyword **module** declares that the tool is activated. The tools are chained in their order of declaration.

A default configuration file is installed in the following location:

/opt/bullxde/mpicompanions/xPMPI/etc/xpmpi.conf

A user-defined configuration file can be specified with the PNMPI_CONF environment file.

```
export PNMPI_CONF=<path to user defined configuration file>
```

5.3.3 xPMPI Usage

Using xPMPI consists in loading a module file. The environment will be set to allow the tool to intercept MPI functions call without changing the application regular launch process.

Do not forget to unload the module file to disable the use of xPMPI after a profiling session.

Chapter 6. Analyzing Application Performance

Different tools are available to monitor the performance of your application, and to help identify problems and to highlight where performance improvements can be made. These include:

- **PAPI,** an open source tool
- **Bull Performance Monitor (bpmon)**, a Linux command line single node performance monitoring tool, which uses the **PAPI** interface to access the hardware performance events (counters) of most processors.
- **HPCToolkit**, an open source tool based on **PAPI** and included in the **bullx supercomputer suite** delivery.
- **Bull-Enhanced HPCToolkit**, based on the current HPCToolkit, it provides added value for HPC users needing profile based performance analysis in order to optimize their running software applications
- **Open|SpeedShop** an open source multi platform Linux performance tool

6.1 PAPI

PAPI (Performance API) is used for the following reasons:

- To provide a solid foundation for cross-platform performance analysis tools
- To present a set of standard definitions for performance metrics on all platforms
- To provide a standard API among users, vendors and academics

PAPI supplies two interfaces:

- A high-level interface, for simple measurements
- A low-level interface, programmable, adaptable to specific machines and linking the measurements

PAPI should only be used by specialists interested in optimizing scientific programs. These specialists can focus on code sequences using PAPI functions.
PAPI tools are all open source tools.

6.1.1 High-level PAPI Interface

The high-level API provides the ability to start, stop and read the counters for a specified list of events. It is particularly well designed for programmers who need simple event measurements, using PAPI preset events.
Compared with the low-level API the high-level is easier to use and requires less setup (additional calls). However, this ease of use leads to a somewhat higher overhead and the loss of flexibility.

Note Earlier versions of the high-level API are not thread safe. This restriction has been removed with PAPI 3.

Below is a simple code example using the high-level API:

```
#include <papi.h>

#define NUM_FLOPS 10000
#define NUM_EVENTS 1

main()
{
int Events[NUM_EVENTS] = {PAPI_TOT_INS};
long_long values[NUM_EVENTS];

/* Start counting events */
if (PAPI_start_counters(Events, NUM_EVENTS) != PAPI_OK)
   handle_error(1);

/* Defined in tests/do_loops.c in the PAPI source distribution */
do_flops(NUM_FLOPS);

/* Read the counters */
if (PAPI_read_counters(values, NUM_EVENTS) != PAPI_OK)
   handle_error(1);

printf("After reading the counters: %lld\n",values[0]);

do_flops(NUM_FLOPS);

/* Add the counters */
if (PAPI_accum_counters(values, NUM_EVENTS) != PAPI_OK)
   handle_error(1);
printf("After adding the counters: %lld\n", values[0]);

/* double a,b,c; c+= a* b; 10000 times  */
do_flops(NUM_FLOPS);

/* Stop counting events */
if (PAPI_stop_counters(values, NUM_EVENTS) != PAPI_OK)
   handle_error(1);

printf("After stopping the counters: %lld\n", values[0]);
}
```

Possible Output:

```
After reading the counters: 441027
After adding the counters: 891959
After stopping the counters: 443994
```

Note that the second value (after adding the counters) is approximately twice as large as the first value (after reading the counters). This is because **PAPI_read_counters** resets and leaves the counters running, then **PAPI_accum_counters** adds the current counter value into the **values** array.

6.1.2 Low-level PAPI Interface

The low-level API manages hardware events in user-defined groups called **Event Sets**. It is particularly well designed for experienced application programmers and tool developers who need fine-grained measurements and control of the PAPI interface. Unlike the high-level interface, it allows both PAPI preset and native event measurements.

The low-level API features the possibility of getting information about the executable and the hardware, and to set options for multiplexing and overflow handling. Compared with high-level API, the low-level API increases efficiency and functionality.

An Event Set is a user-defined group of hardware events (preset or native) which, all together, provide meaningful information. The users specify the events to be added to the Event Set and attributes such as the counting domain (user or kernel), whether or not the events are to be multiplexed, and whether the Event Set is to be used for overflow or profiling. PAPI manages other Event Set settings such as the low-level hardware registers to use, the most recently read counter values and the Event Set state (running / not running).

Following is a simple code example using the low-level API. It applies the same technique as the high-level example.

```
#include <papi.h>
#include <stdio.h>

#define NUM_FLOPS 10000

main()
{
int retval, EventSet=PAPI_NULL;
long_long values[1];

/* Initialize the PAPI library */
retval = PAPI_library_init(PAPI_VER_CURRENT);
if (retval != PAPI_VER_CURRENT) {
  fprintf(stderr, "PAPI library init error!\n");
  exit(1);
}

/* Create the Event Set */
if (PAPI_create_eventset(&EventSet) != PAPI_OK)
    handle_error(1);

/* Add Total Instructions Executed to our Event Set */
if (PAPI_add_event(EventSet, PAPI_TOT_INS) != PAPI_OK)
    handle_error(1);

/* Start counting events in the Event Set */
if (PAPI_start(EventSet) != PAPI_OK)
    handle_error(1);

/* Defined in tests/do_loops.c in the PAPI source distribution */
do_flops(NUM_FLOPS);

/* Read the counting events in the Event Set */
if (PAPI_read(EventSet, values) != PAPI_OK)
    handle_error(1);

printf("After reading the counters: %lld\n",values[0]);

/* Reset the counting events in the Event Set */
if (PAPI_reset(EventSet) != PAPI_OK)
  handle_error(1);

do_flops(NUM_FLOPS);
```

```
/* Add the counters in the Event Set */
if (PAPI_accum(EventSet, values) != PAPI_OK)
   handle_error(1);
printf("After adding the counters: %lld\n",values[0]);

do_flops(NUM_FLOPS);

/* Stop the counting of events in the Event Set */
if (PAPI_stop(EventSet, values) != PAPI_OK)
    handle_error(1);

printf("After stopping the counters: %lld\n",values[0]);
 }
```

Possible output:

```
After reading the counters: 440973
After adding the counters: 882256
After stopping the counters: 443913
```

Note that `PAPI_reset` is called to reset the counters, because `PAPI_read` does not reset the counters. This lets the second value (after adding the counters) to be approximately twice as large as the first value (after reading the counters).

For more details, please refer to PAPI man and documentation, which are installed with the product in **/usr/share** directory.

6.1.3 Collecting FLOP Counts on Sandy Bridge Processors

Floating Point OPerations (FLOP) performance events are very machine type sensitive. The focus here will be the Sandy Bridge processor. Here are some general insights:

1. Users think in terms of how many computing operations are done as a count of many numbers are added, subtracted, compared, multiplied or divided.
2. Hardware engineers think in terms of how many instructions are done that add, subtract, compare, multiply or divide.

Three types of operations are provided on these machines:

1. Scalar – One operand per register
2. Packed in 128-bit Register – 4 single precision numbers or 2 double precision numbers
3. Packed in 256-bit Register – 8 single precision numbers or 4 double precision numbers

The FLOP performance events collected by PAPI are influenced by these three types of operations. The performance events count one for each instruction regardless of the number of operations done. To compensate for this PAPI has defined several presets that compute the user expected number of FLOPs by collecting several performance events and multiplying each one by the proper constant. The PAPI Wiki has a very interesting page that goes into great detail on this topic:
http://icl.cs.utk.edu/projects/papi/wiki/PAPITopics:SandyFlops

The PAPI Floating Point Preset Events are as below:

PRESET Event	Description
PAPI_FP_INS	Count of Scalar Operations
PAPI_FP_OPS	same as above
PAPI_SP_OPS	Count of all Single Precision Operations
PAPI_DP_OPS	Count of all Double Precision Operations
PAPI_VEC_SP	Count of all Single Precision Vector Operations
PAPI_VEC_DP	Count of all Double Precision Vector Operations

The following table is from the website. The table shows how single and double precision operand operations are computed for total operations and for vector operations from the raw event counts.

PRESET Event	Definition
PAPI_FP_INS	SSE_SCALAR_DOUBLE + SSE_FP_SCALAR_SINGLE
PAPI_FP_OPS	same as above
PAPI_SP_OPS	FP_COMP_OPS_EXE:SSE_FP_SCALAR_SINGLE + 4*(FP_COMP_OPS_EXE:SSE_PACKED_SINGLE) + 8*(SIMD_FP_256:PACKED_SINGLE)
PAPI_DP_OPS	FP_COMP_OPS_EXE:SSE_SCALAR_DOUBLE + 2*(FP_COMP_OPS_EXE:SSE_FP_PACKED_DOUBLE) + 4*(SIMD_FP_256:PACKED_DOUBLE)
PAPI_VEC_SP	4*(FP_COMP_OPS_EXE:SSE_PACKED_SINGLE) + 8*(SIMD_FP_256:PACKED_SINGLE)
PAPI_VEC_DP	2*(FP_COMP_OPS_EXE:SSE_FP_PACKED_DOUBLE) + 4*(SIMD_FP_256:PACKED_DOUBLE))

6.2 Bull Performance Monitor (bpmon)

The **Bull Performance Monitor** tool (**bpmon**) is a Linux command line single node performance monitoring tool, which uses the **PAPI** interface to access the hardware performance events (counters) of most processors. It is possible to monitor a single thread or the entire system with **bpmon**.

The set of events that can be measured depends on the underlying processor. In general, **bpmon** gives access to all processor-specific performance events.

bpmon can monitor the performance of the application or the node(s). Command execution performance can be monitored by **bpmon.** For example, the command below gives the following output.

bpmon Syntax

bpmon –e INSTRUCTIONS_RETIRED,LLC_MISSES,MEM_LOAD_RETIRED:L3_MISS,MEM_UNCORE_RETIRED:LOCAL_DRAM,MEM_UNCORE_RETIRED:REMOTE_DRAM /opt/hpctk/test_cases/llclat -S -l 4 -i 256 -r 200 -o r

Output

```
Run a single copy of the test on the current thread
Started Timing Reads
Command is <Reads> with Range <200 MB> and Stride <256 B> with Average Time
<63.533 ns>

Elapsed Time of Run of Current Thread is 37.880739086

+-------------------------------------------------------------+
| BPMON Single Thread Event Results                           |
+-------------------------------------------------------------+
Event Description                     Event Count
INSTRUCTIONS_RETIRED                  10807933019
LLC_MISSES                              537361852
MEM_LOAD_RETIRED:L3_MISS                536834525
MEM_UNCORE_RETIRED:LOCAL_DRAM           536834304
MEM_UNCORE_RETIRED:REMOTE_DRAM                 67

Elapsed time: 37.893312 seconds
```

6.2.1 bpmon Reporting Mode

For all, or a subset, of node processors **bpmon** provides two reporting modes.

6.2.1.1 Processor Performance Reporting

Processor performance reporting lists a set(s) of performance events in tables, with one row per processor specified and the different performance events in columns. This can be set to repeat the reporting at regular intervals, as shown in the example below.

```
#
# Experiment to measure L3 Cache Performance on each Processor without using
Uncore Events
#
# INSTRUCTIONS_RETIRED     measures Total Instructions Executed
# LLC_MISSES         measures L3 Cache Misses
# MEM_LOAD_RETIRED:L3_MISS  measures L3 Data Cache Load Misses
# MEM_UNCORE_RETIRED:LOCAL_DRAM  measures L3 Data Cache Load Misses Satisfied from
Local DRAM
# MEM_UNCORE_RETIRED:REMOTE_DRAM measures L3 Data Cache Load Misses Satisfied from
Remote DRAM
#
run-time=30
event=INSTRUCTIONS_RETIRED,LLC_MISSES,MEM_LOAD_RETIRED:L3_MISS,MEM_UNCORE_RETIRED:
LOCAL_DRAM,MEM_UNCORE_RETIRED:REMOTE_DRAM
report=event
```

A command example with its output is shown below.

```
<Run from Terminal 1> ./llclat -l 10 -c 4
<Run from Terminal 2> sudo bpmon -c
/opt/bullxde/perftools/bpmon/share/doc/bpmon/examples/l3crw
```

Output

```
Update in: 30 seconds, ctrl-c to exit

+-------------------------------------------------------------+
| BPMON CPU Event Results |
+-------------------------------------------------------------+
CPU  INSTRUCTIONS_RETIRE   LLC_MISSES   MEM_LOAD_RETIRED  MEM_UNCORE_RETIRED  MEM_UNCORE_RETIRED
#                                              :L3_MISS         :LOCAL_DRAM         :REMOTE_DRAM
0             11874471347   184298321          181306087           86188440            95116786
1             11864491632   183240206          180310779           83212538            97097821
2             11856905044   183105309          180369962           83542631            96827232
3             11856505436   183098942          180344484           83470335            96873988
4                 3292691        5589               1032                367                 528
5                  401016        2342                466                195                 176
6                 2594262         981                217                 50                 121
7                  101785         594                150                147                   0
8              11848325273   182436818          179645809           83339429            96306262
9              11895706265   182414051          179770963           81956916            97813529
10             11861415833   183430836          180686147           82165023            98520942
11             11867024890   183864157          181035165           84138310            96896833
12                       0           0                  0                 0                   0
13                  254712        2169                 06                138                 203
14                388438371        5205                664                286                 220
15                  6051685        2067                933                839                  93
ALL            95325980242  1465907587         1443473264          668015644           775454734


run_time completed. ...bpmon has terminated!!
```

6.2.1.2 Memory Usage Reporting

The second report type is a Memory Utilization Report built into **bpmon**. This report shows the percentages of memory references made to a different socket from the one where the core is executing. This report can also be repeated at a periodic rate.

A command example with its output is shown below.

```
<Run from Terminal 1> ./llclat -l 10 -c 4
<Run from Terminal 2> sudo bpmon --report memory --run-time 30
```

Output

```
Update in: 30 seconds, ctrl-c to exit
+--------------------------------+
| BPMON Memory Utilization Report |
+--------------------------------+
                    Hyper-    CPU  CPU  Instruction  Memory Read    Local  Remote
Board  Socket Core  Thread CPU  Mhz  Used  Rate (MIPS)  Bandwidth(MBPS) Loads  Loads
-------------------------------------------------------------------------------------------
0    0    0   0   0 2933.3  100.0%    104      515.72   45.8%  54.2%
0    0    1   0   1 2933.3  100.0%    104      516.83   46.0%  54.0%
0    0    2   0   2 2933.3  100.0%    105      521.48   45.4%  54.6%
0    0    3   0   3 2933.3  100.0%    105      519.10   45.6%  54.4%
0    1    0   0   4 1600.1  0.2%      47        0.01   20.4%  79.6%
0    1    1   0   5 1609.1  0.0%      173       0.01   85.9%  14.1%
0    1    2   0   6 1601.1  0.0%      1        0.00   61.9%  38.1%
0    1    3   0   7 1600.8  0.0%      514       0.04   -n/a-  -n/a-
0    0    0   1   8 2933.3  100.0%    104      514.00   45.6%  54.4%
0    0    1   1   9 2933.3  100.0%    106      522.72   45.4%  54.6%
0    0    2   1   10 2933.3  100.0%    105      520.98   45.2%  54.8%
0    0    3   1   11 2933.3  100.0%    104      517.43   45.5%  54.5%
0    1    0   1   12 1613.7  0.0%       0        0.00   -n/a-  -n/a-
0    1    1   1   13 1602.7  0.0%     425        0.01   19.0%  81.0%
0    1    2   1   14 1637.4  0.0%      16        0.00    6.4% 93.6%
0    1    3   1   15 1601.2  0.0%    1492        0.02   92.9% 7.1%
-------------------------------------------------------------------------------------------
Totals for 16 CPUs :      36332.1 50.0%    3505      4148.37   45.6%  54.4%


run_time completed. ...bpmon has terminated!!
```

See The **bpmon** man page or help file for more information.

6.2.2 BPMON PAPI CPU Performance Events

The **PAPI** mechanism used by **bpmon** enables the review of both PAPI preset events and processor native events.

PAPI Preset Events

PAPI preset events are the same for all hardware platforms and are derived by addition or subtraction of native events. However, if the platform processor's native events do not support the information collection required, then some presets may not exist.

PAPI preset events offer the safest source of information for users who are not expert on the processor's native events. **bpmon** allows users to generate a list of available PAPI preset events, from which the event counts to be used can be chosen.

PAPI Processor Native Events

bpmon allows the user to generate a list of the processor's native events supported by PAPI. The user can then review the list and choose which ones to use.

See *Intel64 and IA-32 Architectures Software Developers Manual, Volume 3B: System Programming Guide, Part 2, (document order number 253669)* for details of performance events available for Intel processors.

6.2.3 BPMON with the Bull Coherent Switch

The Bull Performance Monitor tool (**BPMON**) includes the ability to report performance monitor events from the Bull Coherent Switch (**BCS**). The **BCS** is the Bull hardware that interfaces memory traffic between the four mainboard sockets and the next mainboard in multi-mainboard bullx supernode systems. These performance events provide an insight into the non-uniform memory architecture (**NUMA**) related behavior of the system.

The BCS capability is provided by adding a BCS component to the PAPI used with BPMON and a BCS driver to provide an interface to the BCS hardware performance monitor. The BCS performance monitor can collect counts for up to four BCS events simultaneously.

Here is an example using the **Traffic Identification** performance event. Four Incoming Traffic events are collected, two for Remote memory and two for Local memory:

1. BCS_PE_REM_Incoming_Traffic[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=1,NIDM=0x01] counts the number of CPU reads that are satisfied from a Remote node.
2. BCS_PE_REM_Incoming_Traffic[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=1,NIDM=0x01] counts the number of CPU writes that are satisfied from a Remote node.
3. BCS_PE_LOM_Incoming_Traffic[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=0,NIDM=0x18] counts the number of CPU reads that are satisfied from the Local node.
4. BCS_PE_LOM_Incoming_Traffic[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=0,NIDM=0x18] counts the number of CPU writes that are satisfied from the Local node.

Command example

```
bpmon -e
BCS_PE_REM_Incoming_Traffic[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=1,NIDM=0x01],
BCS_PE_REM_Incoming_Traffic[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=1,NIDM=0x01],
BCS_PE_LOM_Incoming_Traffic[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=0,NIDM=0x18],
BCS_PE_LOM_Incoming_Traffic[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=0,NIDM=0x18]
./llclat -r 200 -l 1 -o r -S
```

./llclat -r 200 -l 1 -o r -S is the command being measured. This test generates 128M L3 Cache Read Misses. Only this workload must run on the system under test, so that the measurement results can be related to the workload, as BCS events cannot be limited to a specific process in the way that the CPU events can.

In this example, **REM Incoming Traffic** from one BCS should be equal to the **LOM Incoming Traffic** from another BCS.

The command above gives the following output:

```
+-------------------------------------------------------------+
| BPMON Single Thread Event Results |
+-------------------------------------------------------------+
Event Description                                        Event Count
BCS_PE_REM_Incoming_Traffic                              448530917
[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=1,NIDM=0x01]
BCS_PE_REM_Incoming_Traffic                              483451
[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=1,NIDM=0x01]
BCS_PE_LOM_Incoming_Traffic                              448466650
[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=0,NIDM=0x18]
BCS_PE_LOM_Incoming_Traffic                              476911
[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=0,NIDM=0x18]

Elapsed time: 76.024967 seconds
```

6.3 Open|SpeedShop

This section describes the **Open|SpeedShop** performance tool.

6.3.1 Open|SpeedShop Overview

Open|SpeedShop is an open source multi-platform Linux performance tool, which is initially targeted to support performance analysis of applications running on both single node and large scale IA64, IA32, EM64T, and AMD64 platforms.

Open|SpeedShop is explicitly designed with usability in mind and is for application developers and computer scientists. The base functionality includes:

- Sampling Experiments
- Support for Callstack Analysis
- Hardware Performance Counters
- MPI Profiling and Tracing
- I/O Profiling and Tracing
- Floating Point Exception Analysis

In addition, Open|SpeedShop is designed to be modular and extensible. It supports several levels of plug-ins which allow users to add their own performance experiments.

6.3.2 Open|SpeedShop Usage

Using Open|SpeedShop consists in loading a module file, which will set the different paths for binaries and libraries and some environment variables required for a proper usage.

The Open|SpeedShop package provides two module files:

- **openspeedshop/<version>_bullxmpi**
  This module file is to be loaded to use Open|SpeedShop with applications compiled with bullxMPI or any OpenMPI based MPI implementation.
- **openspeedshop/<version>_intelmpi**
  This module file is to be loaded to use Open|SpeedShop with applications compiled with Intel MPI.

This integrated version of Open|SpeedShop has been configured to use the **offline** mode of operation which links the performance data collection modules with your application and collects the performance data you specify.

6.3.3 More Information

See the documentation available from http://www.openspeedshop.org for more details on using Open|SpeedShop.

Convenience commands are provided as a very simple syntax and an easier way to invoke the **offline** functionality:

http://www.openspeedshop.org/wp/wp-content/uploads/2013/03/OSSQuickStartGuide2012.pdf

Man pages are available for the Open|SpeedShop invocation command **openss** and **every convenience script**.

Extensive information about how to use the Open|SpeedShop experiments and how to view the performance information in informative ways is provided here:

http://www.openspeedshop.org/wp/wp-content/uploads/2013/04/OpenSpeedShop_202_User_Manual_v13.pdf

6.4 HPCToolkit

HPCToolkit provides a set of profiling tools to help improve the performance of the system. These tools perform profiling operations on executables and display information in a user-friendly way.

An important advantage of HPCToolkit over other profiling tools is that it does not require the use of compile-time profiling options or re-linking of the executable.

Note In this chapter, the term 'executable' refers to a **Linux** program file, in **ELF** (Executable and Linking Format) format.

HPCToolkit is designed to:

- *Work at binary level to ensure language independence*
  This enables HPCToolkit to support the measurement and analysis of multi-lingual codes using external binary-only libraries.
- *Profile instead of adding code instrumentation*
  Sample-based profiling is less intrusive than code instrumentation, and uses a modest data volume.
- *Collect and correlate multiple performance metrics*
  Typically, performance problems cannot be diagnosed using only one type of event.
- *Compute derived metrics to help analysis*
  Derived metrics, such as the bandwidth used for the memory, often provide insights that will indicate where optimization benefits can be achieved.
- *Attribute costs very precisely*
  HPCToolkit is unique in its ability to associate measurements in the context of dynamic calls, loops, and inlined code.

6.4.1 HPCToolkit Workflow

The HPCToolkit design principles led to the development of a general methodology, resulting in a workflow that is organized around four different capabilities:

- **Measurement** of performance metrics during the execution of an application
- **Analysis** of application binaries to reveal the program structure
- **Correlation** of dynamic performance metrics with the structure of the source code
- **Presentation** of performance metrics and associated source code

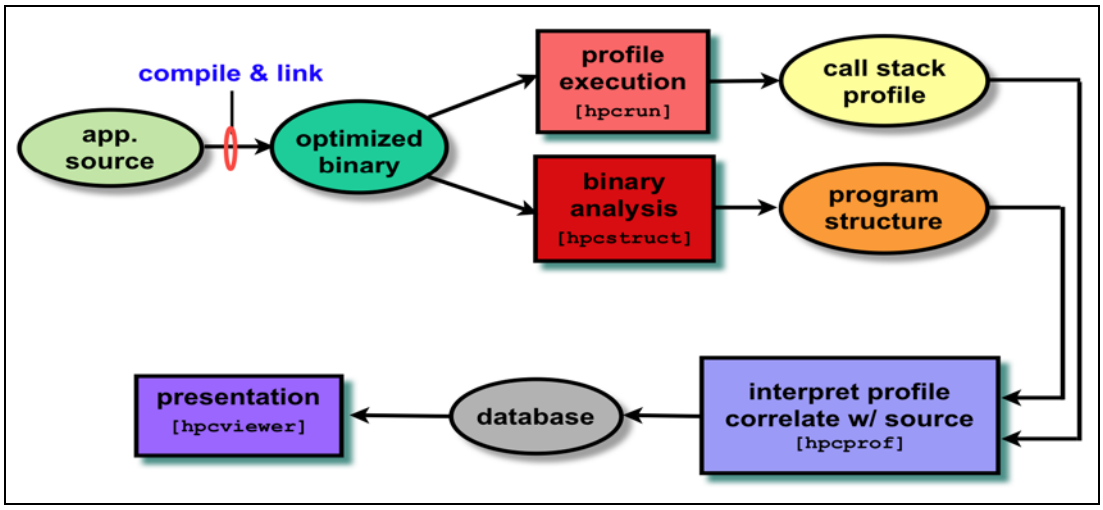


Figure 6-1. HPCToolkit Workflow

As shown in the workflow diagram above, firstly, one compiles and links the application for a production run, using full optimization. Then, the application is launched with the **hpcrun** measurement tool; this uses statistical sampling to produce a performance profile. Thirdly, **hpcstruct** is invoked, this tool analyzes the application binaries to recover information about files, functions, loops, and inlined code. Fourthly, **hpcprof** is used to combine performance measurements with information about the program structure to produce a performance database. Finally, it is possible to examine the performance database with an interactive viewer, called **hpcviewer**.

6.4.2 HPCToolkit Tools

The tools included in the **HPCToolkit** are:

6.4.2.1 hpcrun

hpcrun uses event-based sampling to *measure* program performance. Sample events correspond to periodic interrupts induced by an interval timer, or overflow of hardware performance counters, measuring events such as cycles, instructions executed, cache misses, and memory bus transactions. During an interrupt, **hpcrun** attributes samples to calling contexts to form *call path profiles*. To accurately measure code from 'black box' vendor compilers, **hpcrun** uses on-the-fly binary analysis to enable stack unwinding of fully optimized code *without compiler support*, even code that lacks frame pointers and uses optimizations such as tail calls. **hpcrun** stores sample counts and their associated calling contexts in a *calling context tree* (CCT).

hpcrun-flat, the flat-view version of **hpcrun**, *measures* the execution of an executable by a statistical sampling of the hardware performance counters to create flat profiles. A flat profile is an IP histogram, where IP is the instruction pointer.

6.4.2.2 hpcstruct

hpcstruct *analyzes* the application binary to determine its static program structure. Its goal is to recover information about procedures, loop nests, and inlined code. For each procedure in the binary, **hpcstruct** parses its machine code, identifies branch instructions, builds a control flow graph, and then uses interval analysis to identify loop nests within the control flow. It combines this information with compiler generated line map information in a way that allows **HPCToolkit** to correlate the samples associated with machine instructions to the program's procedures and loops. This correlation is possible even in the presence of optimizations such as inlining and loop transformations such as fusion, and compiler-generated loops from scalarization of **Fortran 90** array operations or array copies induced by Fortran 90's calling conventions.

6.4.2.3 hpcprof

hpcprof *correlates* the raw profiling measurements from **hpcrun** with the source code abstractions produced by **hpcstruct**. **hpcprof** generates high level metrics in the form of a performance database called the **Experiment** database, which uses the Experiment XML format for use with **hpcviewer**.

hpcprof-flat is the flat-view version of hpcprof and correlates measurements from **hpcrun-flat** with the program structure produced by **hpcstruct**.

hpcproftt *correlates* flat profile metrics with either source code structure or object code and generates textual output suitable for a terminal. **hpcproftt** also generates textual dumps of profile files.

hpcprof-mpi correlates the call path profiling metrics (in parallel) produced by **hpcrun** with the source code structure created by **hpcstruct**. It produces an **Experiment** database for use with the **hpcviewer** or **hpctraceviewer** tool. **hpcprof-mpi** is especially designed for analyzing and attributing measurements from large-scale executions.

6.4.2.4 hpcviewer

hpcviewer *presents* the Experiment database produced by **hpcprof**, **hpcprof-flat** or **hpcprof-mpi** so that the user can quickly and easily view the performance databases generated.

6.4.2.5 Display Counters

The **hpcrun** tool uses the hardware counters as parameters. To know which counters are available for your configuration, use the **papi_avail** command. The **hpcrun** and **hpcrun-flat** tools will also give this information.

```
papi_avail
```

```
Available events and hardware information.
--------------------------------------------------------------------
Vendor string and code  : GenuineIntel (1)
Model string and code   : 32 (1)
CPU Revision : 0.000000
CPU Megahertz: 1600.000122
CPU's in this Node : 6
Nodes in this System: 1
Total CPU's  : 6
Number Hardware Counters : 12
Max Multiplex Counters   : 32
--------------------------------------------------------------------
The following correspond to fields in the PAPI_event_info_t structure.
Name    Code   Avail Deriv Description (Note)
PAPI_TOT_CYC 0x8000003b Yes  No  Total cycles
PAPI_L1_DCM0 x80000000 Yes  No  Level1 data cache  misses
PAPI_L1_ICM0 x80000001 Yes  No  Level 1  instruction cache misses
PAPI_L2_DCM0 x80000002 Yes  YesLevel 2 data cache misses
...
PAPI_FSQ_INS 0x80000064 No  NoFloating point square root instructions
PAPI_FNV_INS 0x80000065 No  NoFloating point inverse instructions
PAPI_FP_OPS 0x80000066 Yes  NoFloating point operations
--------------------------------------------------------------------
Of 103 possible events, 60 are available, of which 17 are derived.
```

The following counters are particularly interesting: **PAPI_TOT_CYC** (number of CPU cycles) and **PAPI_FP_OPS** (number of floating point operations).

See For more information on the display counters, use the **papi_avail -d** command.

6.4.3 More information about HPCToolkit

See

- The **HPCToolkit** web at http://www.hpctoolkit.org for more information regarding **HPCToolkit**.
- The *HPCToolkit User's Manual*, at http://hpctoolkit.org/manual/HPCToolkit-users-manual.pdf for more detailed information, including Quick Start, FAQ and Troubleshooting **HPCToolkit**.

6.5 Bull-Enhanced HPCToolkit

Bull-Enhanced HPCToolkit is an application performance profiling tool for HPC users. It is based on the current HPCToolkit open-source product, which was designed and built by Rice University, TX, USA. The Bull-Enhanced HPCToolkit provides added value for HPC users needing profile based performance analysis in order to optimize their running software applications.

See Section *6.4 HPCToolkit* for more information about the HPCToolkit.

The Bull-Enhanced HPC Toolkit contains three main components:

1. History Component - see section 6.5.1
2. Viewing Component - see section 6.5.2
3. HPCToolkit Wrappers- see section 6.5.3

6.5.1 History Component

The History Component provides a means to store information related to a test run in a repository. This facility allows the user to keep a history of test runs so that they can be enhanced with added value, viewed, or compared at a later time. This component consists of the following parts:

- History Repository
- History Repository Environment Variables
- Passport Library
- Passport Manager Application

6.5.1.1 History Repository

The History Repository is a database whose entries are code passports from many different test runs. Each execution of the user's program, which may occur across multiple nodes, results in one code passport in the History Repository.

Data in the History Repository is stored in a file structure which is grouped first by project and then by code passports within a project. A code passport contains all of the results from running a single test including environment information such as compiler version, compilation platform, surrounding software distributions; program structure information; and performance information, including raw performance profiles and performance databases.

A repository name represents a set of data within a repository. This set may be a single file, many files, or even all of the files in the repository. The fields in a repository name support glob style pattern matching to provide a friendly way to specify the desired set of repository files.

History Repository naming convention

<repo name> :: <project>:<code passport>:<test tool>:<data origin>:<file path>

<project> :: string
identifies the user or group running test provided by user when bhpcstart is run

<code passport> :: <simple passport>.yyyymmdd.hhmmss
timestamp added when passport created

<simple passport> :: string
identifies application and/or test being run provided by user when bhpcstart is run

<test tool> :: string
name of tool that generated the test results bhpcstruct, bhpcrun, bhpcprof, bhpcprof-mpi

<data origin> :: <system>.<rank>

<system> :: string
system generating test results

<rank> :: string
mpi rank of process generating test results not present if not an mpi job

<file path> :: string
file or directory pathname relative to <data_origin> often just a simple file name

<pathname> :: string
path to a file outside of the repository that may be absolute or relative

6.5.1.2 History Repository Environment Variables

The Bull HPCToolkit extension uses an environment variable to define the location of the History Repository. The environment variable BHPCTK_REPO_ROOT must be set to the path name of the repository root. In this release it is a requirement that the repository root path be locally accessible from all nodes used in the test run.

The environment variable allows multiple repositories on the same system; it also allows multiple users to share the same repository.

BHPCTK_REPO_ROOT is used by the passport library to locate the History Repository when applications that use it are run.

6.5.1.3 Passport Library

This library provides an API to manage the History Repository and the information found in the code passports stored within the repository. The library is responsible for reading the environment variable BHPCTK_REPO_ROOT to find out where the repository is located.

6.5.1.4 Passport Manager Application

This application is a utility that can be used to access the data in a history repository. Data in the history repository is stored in a file structure which is grouped first by project and then by code passports within a project. A code passport contains all of the results from running a single test.

The Passport Manager tools are accessed with the command **bhpcpm**.

Usage

bhpcpm ACTION <repository name> [OPTION [<pathname>]]

A required ACTION field is used to specify the desired function.
An optional OPTION field is used along with the ACTION to achieve the desired result.

Note Both fields can be entered with a '-' and a single letter or a '–' and a word.
An asterisk '*' is a wild card used for all occurrences of an item.

To display the help information for the Passport Manager Application, enter:

```
bhpcpm -h
```

or

```
bhpcpm --help
```

6.5.2 Viewing Component

The enhanced Bull HPCToolkit viewer, **bhpcveiwer** adds new features to the Rice University GUI based **hpcviewer**, **which** currently displays the contents of the performance database.

New **bhpcveiwer** features include:

- Display of the History Repository database
  This provides a graphic display of all the files and directories in the history repository database.
- Context menu items to perform operations on tree objects
  This allows the user to select one or more tree objects and perform some operation on the objects selected. The kinds of operations to be supported include:
  - Opening files to see contents,
  - Loading an experiment database into the hpcviewer perspective
  - Comparing the content of two selected files in a side by side display that highlights differences,
  - Comparing all objects in two selected directories to provide a list of the files in those directories that are different, with the ability to see each file's differences by opening one of the files in that list.,
  - Import and Export tar files
  - Delete the selected projects and/or code passports
  - Merge Application files and System files
    The objective of the merge utility is to create one application or system file for each bhpcrun/<system_name>.<rank#>/application or system file with the same content. Files with the same content will be merged into one file and header information will be added to the merged files to track which process ranks contain the same content.
- Preference page to control the History Repository display
  This provides controls that affect the History Repository Explorer View.
- Preference page to control the Grouping Options for the new views
  This provides controls that affect the Grouped Metrics View and the Raw Metrics View.

- A Group Metrics view
  The idea behind creating the grouped metrics view is that, in any large run some of the processes will behave differently than other processes. The approach is to separate the processes into groups of processes which generated similar behavior. The analyst can decide that one group is running correctly and another running incorrectly. After doing the grouping the user will have a few sets of processes that behaved differently from one another. This view only needs to present one set of data for each group and the analyst only needs to compare the performance differences between the groups and not all the processes.
- A Raw Metrics view
  This view shows the raw metric values for all of the processes at one program scope.
- Additional Grouping Features
  The grouping tool features include:
  - Algorithm to provide an initial optimum number of groups
    The grouping mechanism as a default has an algorithm that chooses the optimum number of groups.
    Or the user may specify the number of groups.
  - Automatic hotspot detection
    This helps the analyst focus on the program scopes that are of the most value to analyze and highlights them using different colors that may be chosen by the user.
  - Grouping properties view.
    The grouping properties are the results of the grouping tool and principally show the processes that are part of each group.
- Updates to take advantage of information in the performance database

Syntax

To run the enhanced Bull HPCToolkit viewer application, use the **bhpcviewer** command.

```
bhpcviewer
```

See The **bhpcviewer** application Help menu and then Bull Extensions Manual for more information about the **bhpcviewer**.

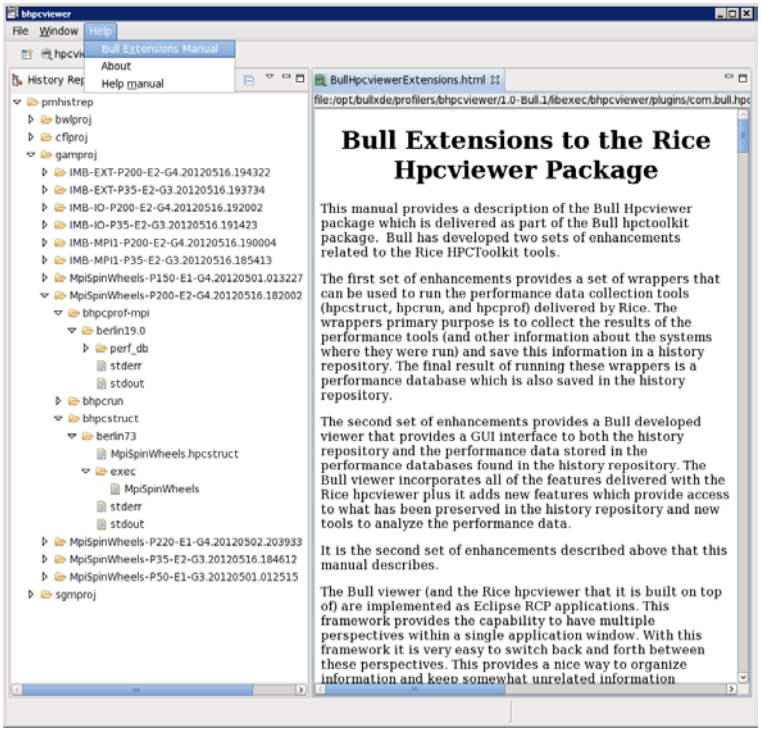


Figure 6-2. bhpcviewer - Bull Extensions Manual page

6.5.3 HPCToolkit Wrappers

Wrapper commands or scripts primary purpose is to run another command or script. They provide pre- and post-processing as well as support for configuration control of the arguments of both the wrapper and the script it runs. Often, the input and output files for the wrappers are obtained from or written to the History Repository.

The **bhpcstruct**, **bhpcrun**, **bhpcprof** and **bhpcprof-mpi** wrappers can be invoked as **CLIs** along with **bhpcstart**, **bhpcstop** and **bhpcclean.**

Command line help

Each of **Bull-Enhanced HPCToolkit** command-line wrappers will generate a help message summarizing the tool's usage, arguments and options.

To display the help information for the wrappers, enter:

```
<wrapper_name> -h
```

or

```
<wrapper_name> --help
```

6.5.3.1 Start Component: bhpcstart

When the **bhpcstart** wrapper is run, it will set the environment used by a test case. A test case consists of running several scripts, each of which collects some of the data related to the test. When the test is finished the **bhpcstop** script should be run.
This wrapper can be used to create a new code passport or to set an existing code passport to be the current one used by other scripts.

- Creating a new one is accomplished by providing a project name and a simple code passport name (one without a date/time stamp).
- Setting an existing code passport to be the current is done by providing the project name and the full code passport name (including data/time stamp).

Once the **bhpcstart** script is run, all other scripts that reference the current project and code passport only require the project name of the repository name.

6.5.3.2 Stop Component: bhpcstop

When the **bhpcstop** wrapper is run, it will clear the current code passport name for the input project to stop future scripts from putting more data into this code passport.

6.5.3.3 Clean Component: bhpcclean

When the bhpcclean wrapper is run, it will remove the hpcrun metrics data collected from a previous run of the bhpcrun script. A user may wish to do this after they create a code passport and then run the bhpcrun script, if he finds that the bhpcrun used incorrect parameters or that the wrong versions of software were installed on some of the systems.

A user must run this script before they will be allowed to rerun bhpcrun. This is necessary because another run of bhpcrun when there is already data collected will cause the test case to contain invalid data. To be able to present consistent data, all of the information must have come from the same test run.

6.5.3.4 Compilation Component: bhpcstruct

This component is a wrapper around the HPCToolkit **hpcstruct** component.
For MPI applications, **bhpcstruct** must be installed on all possible target nodes where the test will be executed.

The **bhpcstruct** wrapper performs these actions:

- Collect special metrics from the program structure to create the program summary
- Execute the **hpcstruct** component to create the program structure
- Collect information to create the program environment
- Call the Passport Library to write program structure metrics and environment information to the specified code passport in the designated History Repository location.
  - The scope tree produced by hpcstruct
    <project>.<code passport>.bhpcstruct.<system>.<test case name>.hpcstruct
  - The executable of the test case
    <project>.<code passport>.bhpcstruct.<system>.exec.<test case name>
  - Standard Error and Standard Output
    <project>.<code passport>.bhpcstruct.<system>.stdout
    <project>.<code passport>.bhpcstruct.<system>.stderr

6.5.3.5 Parallel Manager Component: bhpcrun

This component is a wrapper around the HPCToolkit **hpcrun** component.
For MPI applications, **bhpcrun** must be installed on all possible target nodes where the test will be executed.

bhpcrun must preserve the node name, process name, and MPI rank (for MPI processes) used during sample collection to allow tying of abnormal samples back to the node and/or process on which they occurred.

The **bhpcrun** wrapper performs these actions:

- Collect environment information for the system we are running on
- Collect dynamic libraries used by application
- Execute the hpcrun component to execute a test case
- Collect and store the performance profile data generated from a single invocation of hpcrun on one or more nodes.
- Call the Passport Library to write the performance profile to the specified code passport in the designated History Repository location.
  - The performance profile
    <project>.<code passport>.bhpcrun.<data origin>.<test case name>-xxx.hpcrun
    <project>.<code passport>.bhpcrun.<data origin>.<test case name>-xxx .hpctrace
    <project>.<code passport>.bhpcrun.<data origin>.<test case name>-xxx.log
  - The application executable location
    <project>.<code passport>.bhpcrun.<data origin>.application
  - The dynamic libraries
    <project>.<code passport>.bhpcrun.<data origin>.libraries
  - Standard Error and Standard Output
    <project>.<code passport>.bhpcrun.<data origin>.stdout
    <project>.<code passport>.bhpcrun.<data origin>.stderr
  - Environment information for the system
    <project>.<code passport>.bhpcrun.<data origin>.sys_type
    <project>.<code passport>.bhpcrun.<data origin>.variables

The user may also provide optional scripts to perform tasks at specified points during the execution of the **bhpcrun** script. The optional prologue script will be executed by **bhpcrun** prior to execution of the hpcrun script, and the optional epilogue script will be executed as the last step in the **bhpcrun** script. The optional data script will be executed just after the hpcrun script has completed but prior to the move of the profile data into the History Repository, allowing the user to manipulate the profile data prior to its insertion. In addition, a maximum run time value can be provided to limit the execution time of the **bhpcrun** test run.

6.5.3.6 Hotplot Component: bhpcprof

This component is a wrapper around the HPCToolkit **hpcprof** component. It provides an interface that can be used to add value to a performance database.

The **bhpcprof** wrapper performs these actions:

- Collect the information from the code passport that would normally be used by hpcprof to build a performance database.
- Optionally call a user-provided command/script to allow the user to modify the set of data to be passed to hpcprof.
- Execute the hpcprof component to build a performance database as an XML file intended to be displayed by the GUI viewer.
- Call the Passport Library to write the performance database created by hpcprof to the specified code passport in the designated History Repository location.
  - The performance database and supporting files
    <project>.<code passport>.bhpcprof.<data origin>.perf_db.callpath.xml
    <project>.<code passport>.bhpcprof.<data origin>.perf_db.experiment-1.mdb
    <project>.<code passport>.bhpcprof.<data origin>.perf_db.experiment.mt
    <project>.<code passport>.bhpcprof.<data origin>.perf_db.experiment.xml
  - The performance database source files
    <project>.<code passport>.bhpcprof.<data origin>.perf_db.src.xxx
    <project>.<code passport>.bhpcprof.<data origin>.perf_db.src.usr.xxx
  - Standard Error and Standard Output
    <project>.<code passport>.bhpcprof.<data origin>.stdout
    <project>.<code passport>.bhpcprof.<data origin>.stderr

6.5.3.7 Hotplot Component: bhpcprof-mpi

This component is a wrapper around the HPCToolkit **hpcprof-mpi** component. It provides an interface that can be used to add value to a performance database.

The **bhpcprof-mpi** wrapper performs these actions:

- Collect the information from the code passport that would normally be used by hpcprof-mpi to build a performance database.
- Optionally call a user-provided command/script to allow the user to modify the set of data to be passed to hpcprof-mpi.
- Execute the hpcprof-mpi component to build a performance database as an XML file intended to be displayed by the GUI viewer.
- Call the Passport Library to write the performance database created by hpcprof-mpi to the specified code passport in the designated History Repository location.
  - The performance database and supporting files
    <project>.<code passport>.bhpcprof-mpi.<data origin>.perf_db.callpath.xml
    <project>.<code passport>.bhpcprof-mpi.<data origin>.perf_db.experiment-1.mdb
    <project>.<code passport>.bhpcprof-mpi.<data origin>.perf_db.experiment.mt
    <project>.<code passport>.bhpcprof-mpi.<data origin>.perf_db.experiment.xml
  - The performance database source files
    <project>.<code passport>.bhpcprof-mpi.<data origin>.perf_db.src.xxx
    <project>.<code passport>.bhpcprof-mpi.<data origin>.perf_db.src.usr.xxx
  - Standard Error and Standard Output
    <project>.<code passport>.bhpcprof-mpi.<data origin>.stdout
    <project>.<code passport>.bhpcprof-mpi.<data origin>.stderr

6.5.4 Test Case

Test cases are identified by a project name and code passport name. The project name is provided by the user running the test as a way to separate his tests from tests run by people on other projects. It will be provided by the user to all of the scripts run as part of the test case.

The code passport name represents a single test run by the user. It is possible to run the same test many times which should create many code passports. When the same test is run many times, it would be good to be able to recognize that they are all different runs of the same test. For this reason, the user provides a string to the start script, which will be used to create a unique code passport name to be used for this test case. The unique name is created by the passport manager by appending a date/time stamp to the user provided string.

The passport manager will also keep track of the current code passport (string plus date/time stamp) being used for each project. This allows scripts run following the **bhpcstart** script to get the code passport name being used for the current test from the passport manager so it does not need to be provided by the user to any other scripts run for the test case. When the **bhpcstop** script is run, it will clear the current code passport name to stop future scripts from putting more data into this code passport. The user needs to create a new code passport (or set an existing one to be current again) before running additional scripts.

6.5.4.1 Test run work flow

The work flow is similar to the classical Toolkit, however, the input and output files for the Toolkit components are obtained from or written to a **code passport**, as outlined below:

1. One must initialize the BHPCTK_REPO_ROOT environment variable with the path name of the History Repository repository root.
2. One invokes the start component (**bhpcstart**) with a project name and a simple or full code passport name. A code passport is created if a partial name is entered and the last code passport name file is created for the project.
3. One invokes the compilation component (**bhpcstruct**), which in turn invokes the classic hpcstruct tool to perform binary analysis. bhpcstruct writes the program structure to the code passport.
4. One launches an application with the parallel manager component (**bhpcrun**), which in turn invokes the classic hpcrun tool to execute the binary with statistical sampling. bhpcrun collects performance profiles from the one or more nodes on which the binary was executed and adds them to the code passport. It also collects environment information about the executable on that system. This includes the executables size and build date plus the environment variables that were set and list of dynamic libraries used by the executable on that node.
5. One invokes the hotplot component (**bhpcprof** or **bhpcprof-mpi**), which in turn invokes the classic hpcprof or hpcprof-mpi tool to correlate the performance data with the source structure, creating a performance database. This database is then added to the code passport.
6. One invokes the stop component (**bhpcstop**) with a project name. The last code passport name file is deleted for the project.

7. A sample bash script test case to run an MPI MpiSpinWheels job (**/opt/hpctk/test_cases/MpiSpinWheels**) is displayed below:

```
export BHPCTK_REPO_ROOT=/home/hpctk/pmhistrep

bhpcstart -ndemoproj:MpiSpinWheels

bhpcstruct -ndemoproj -T/opt/hpctk/test_cases/MpiSpinWheels

mpirun --mca btl tcp,self -np 8 -x $BHPCTK_REPO_ROOT -host sulu,bones -
bynode -display-map bhpcrun -ndemoproj -e PAPI_TOT_CYC@1000000 -e
PAPI_TOT_INS@1000000 -H --trace -T/opt/hpctk/test_cases/MpiSpinWheels

mpirun --mca btl tcp,self -np 1 -host bones -x $BHPCTK_REPO_ROOT -bynode
-display-map bhpcprof-mpi -ndemoproj

bhpcstop -ndemoproj
```

The bhpcviewer **Repository** Perspective of the code passport (MpiSpinWheels.20120713.143757) data created by the above example is displayed below.

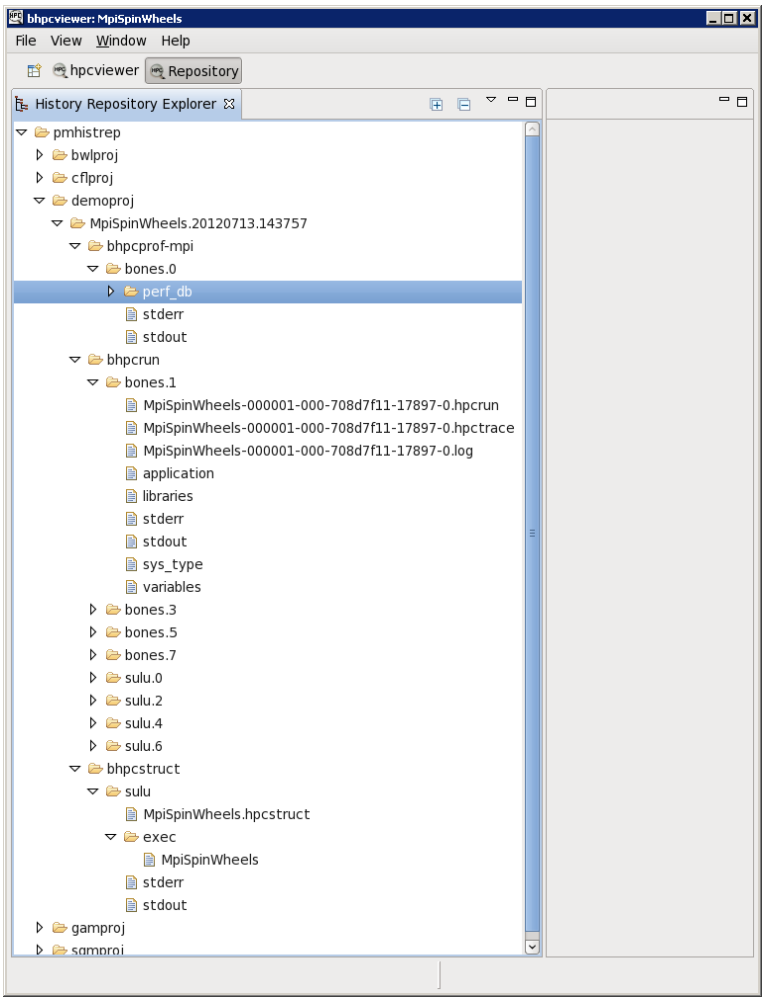


Figure 6-3. bhpcviewer Repository page

6.5.5 HPCToolkit Configuration Files

The enhanced HPCToolkit provides configuration files that are used to control the execution of each of the components in the package. Each enhanced HPCToolkit component will use a configuration file named xxx.conf (where xxx is the tool name). It will be possible for a component's configuration file to appear in one or more of the directories shown below. The enhanced HPCToolkit components will look for their configuration files in the following directories (in the order shown):

- Directory **/etc/bullhpctk** (to provide system wide default values for tools)
- Directory **$HOME/.bullhpctk** (to provide login specific values for tools)
- Directory in **$BHPCTK_CONF_DIR** environment variable (to run scripts with custom configuration files)

Bull will deliver a sample set of configuration files that can be copied into **/etc/bullhpctk** to provide system-wide default values for the components delivered with the enhanced HPCToolkit.

Configuration files contain labels to identify the argument being specified for the component. In some cases this same label, as well as a single char shortcut for the label, may be supported as a command line argument to the component.

For each label found in the configuration file, there is a value. This value specifies what the component uses for this argument. As a component processes each of its configuration files found in the search path and finds labels, it sets the component's value for this label to the value found in the configuration file. Therefore, the values found in files later in the search path normally override the earlier ones.

Configuration files also contain a special label by the name **lock**. The value for this label is a comma separated list of the other labels found in this configuration file. When a component encounters this special label it locks the values provided with each of the labels in the list. If a label's value has been locked, it prevents the component from replacing it with a value found in a later configuration file.

Most components also support command line arguments, which follow the same rules described above for configuration file labels. The values provided on a command line argument will replace a configuration file value unless it was locked in one of the configuration files.

The **lock** directive provides an environment in which administrators can set configuration values for specific arguments in the **/etc/bullhpctk/xxx.conf** files that users cannot override (assuming that users have only read access to the config files in **/etc**). If a directive is found that tries to change a locked value, the component prints a warning but continues to run using the value set prior to when it was locked.

6.5.5.1 Compilation Component Configuration File: bhpcstruct.conf

The compilation component uses a configuration file named **bhpstruct.conf**.

A hypothetical configuration file for this component could look something like this:

```
#
# User login level configuration for bhpcstruct
#
name democonf
hpcargs "-v 2"
testcase /opt/hpctk/test_cases/MpiSpinWheels
lock testcase
```

6.5.5.2 Parallel Manager Configuration File: bhpcrun.conf

The parallel manager component uses a configuration file named **bhpcrun.conf**.

A hypothetical configuration file for this component could look something like this:

```
#
# User login level configuration for bhpcrun
#
name democonf
events PAPI_TOT_CYC@1000000 PAPI_TOT_INS@1000000
hpcargs "-v 2"
testcase /opt/hpctk/test_cases/MpiSpinWheels
testargs
maxruntime 01:00:00
```

6.5.5.3 HOTPLOT Configuration File bhpcprof.conf

The hotplot application uses a configuration file named **bhpcprof.conf**.

A hypothetical configuration file for this component looks something like this:

```
#
# User login level configuration for bhpcprof
#
name democonf
include /home/hpctk/pmhistrep/<project>/<cpp>/bhpcprof/<data
origin>.perf_db
hpcargs "-v 2"
```

Chapter 7. I/O Profiling

This chapter describes I/O profiling tools.

7.1 Iotop

Iotop is a lightweight top-like tool that shows the I/O activity on disk of running processes.

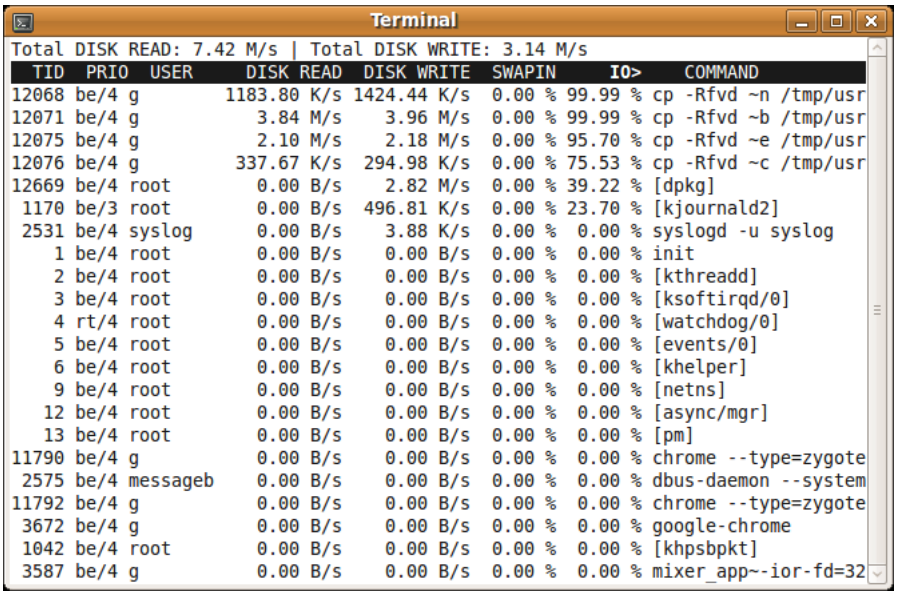


Figure 7-1. I/O activity displayed by Iotop

Please note that **Iotop** needs root privileges to run.

See

- The **Iotop** man page for usage information.
- http://guichaz.free.fr/iotop/ for more details.

7.2 Darshan

Darshan is a scalable HPC I/O characterization tool. It is designed to capture an accurate picture of application I/O behavior, including properties such as patterns of access within files, with minimum overhead. Darshan can be used to investigate and tune the I/O behavior of complex HPC applications. In addition, Darshan's lightweight design makes it suitable for full time deployment for workload characterization of large systems.

7.2.1 Darshan Usage

Using Darshan consists in loading a module file, which will set the different paths for binaries and libraries. Also the user will be reminded to set the **DARSHAN_LOGPATH** variable to the directory the Darshan's log files should be located.

Darshan instruments applications via either compile time wrappers for static executables or dynamic library preloading for dynamic executables.

The Darshan package provides several module files, described below.

- The following module files are to be loaded to use Darshan with applications compiled with bullx MPI or any OpenMPI based MPI implementation and using GNU compilers:
  - **darshan/<version>_bullxmpi_gnu_noinst**
    It is intended to be used with dynamically linked binary and prepend the Darshan library to the LD_PRELOAD environment variable.
    No recompilation is needed for the user application.
  - **darshan/<version>_bullxmpi_gnu_inst**
    It is for use with static executables and needs the application to be recompiled with provided Darshan wrappers.
- The following module files are to be loaded to use Darshan with applications compiled with bullx MPI or any OpenMPI based MPI implementation and using Intel compilers:
  - **darshan/<version>_bullxmpi_intel_noinst**
    It is intended to be used with dynamically linked binary and prepend the Darshan library to the LD_PRELOAD environment variable.
    No recompilation is needed for the user application. The Intel compilers environment, followed by the **bullxmpi** environment must be loaded before loading this module file. Please use the **compilervars.sh** script provided by Intel to load the Intel compilers environment.
  - **darshan/<version>_bullxmpi_intel_inst**
    It is for use with static executables and needs the application to be recompiled with provided Darshan wrappers.

- The following module files are to be loaded to use Darshan with applications compiled with Intel MPI:
  - **darshan/<version>_intelmpi_noinst**
    It is intended to be used with dynamically linked binary and prepend the Darshan library to the LD_PRELOAD environment variable.
    No recompilation is needed for the user application. The Intel compilers environment, followed by the Intel MPI environment must be loaded before loading this module file. Please use the **compilervars.[c]sh** script provided by Intel to load the Intel compilers environment and **mpivars.[c]sh** to load the Intel MPI environment.
  - **darshan/<version>_intelmpi_inst**
    It is for use with static executables and needs the application to be recompiled with provided Darshan wrappers.

7.2.2 Darshan log files

Before using Darshan, the location of the tool generated traces has to be set. This can be done by setting the DARSHAN_LOGPATH environment variable to an existing location.

```
export DARSHAN_LOGPATH=/path/to/logs/
```

7.2.3 Compiling with Darshan

To allow trace generation with Darshan, the MPI application has to be compiled by replacing the regular MPI compilers with the wrappers provided by the tool. That is, depending on the module file loaded:

With **darshan/<version>_bullxmpi_gnu_inst** or **darshan/<version>_bullxmpi_intel_inst**:

- **mpicc.darshan** for C source files.
- **mpiCC.darshan** or **mpicxx** for C++ source files.
- **mpif77.darshan** for Fortran 77 source files.
- **mpif90.darshan** for the Fortran 90 source files.

With **darshan/<version>_intelmpi_inst**:

- **mpiicc.darshan** for C source files.
- **mpiicpc.darshan** for C++ source files.

Note The MPI environment must be setup prior to use the Darshan wrappers.

7.2.4 Analyzing log files with Darshan utilities

Each time a Darshan instrumented application is executed, it will generate a single binary and portable log file summarizing the I/O activity from that application. This log file is generated and placed into the directory pointed by the DARSHAN_LOGPATH environment variable. The log is generated with a name in the following format:

<username>_<binary_name>_<job_ID>_<date>_<unique_ID>_<timing>.darshan.gz

The Darshan package provides a set of tools to help processing and analyzing the log files.

- **darshan-job-summary.pl**
  One can generate a graphical summary of the I/O activity for a job by using the darshan-job-summary.pl graphical summary tool as in the following example.

```
darshan-job-summary.pl carns_my-app_id114525_7-27-58921_19.darshan.gz
```

  It will generate a multi-page PDF file based on the name of the input file.

- **darshan-parser**
  This tool generates a full, human readable dump of all information contained in a log file. The following example essentially converts the contents of the log file into a fully expanded text file.

```
darshan-parser <logfile> > ~/job-characterization.txt
```

See http://www.mcs.anl.gov/research/projects/darshan/docs/darshan-util.html#_darshan_parser for a complete description of darshan-parser results.

- **darshan-convert**
  Converts an existing log file to the newest log format. If the output file has a **.bz2** extension, then it will be re-compressed in bz2 format rather than gz format. It also has command line options for anonymizing personal data and adding metadata annotation to the log header.

- **darshan-diff**
  Compares two darshan log files and shows counters that differ.

- **darshan-analyzer**
  Walks an entire directory tree of Darshan log files and produces a summary of the types of access methods used in those log files.

- **darshan-logutils***
  This is a library rather than an executable, but it provides a C interface for opening and parsing Darshan log files. This is the recommended method for writing custom utilities, as darshan-logutils provides a relatively stable interface across different versions of Darshan and different log formats.

7.2.5 Darshan Limitations

darshan/<version>_intelmpi_noinst and **darshan/<version>_intelmpi_inst** will not produce instrumentation for Fortran executables. They only work with C and C++ executables.

Chapter 8. Libraries and Other Tools

This chapter describes Boost libraries and other tools.

8.1 Boost

Boost is a collection of high quality C++ libraries intended to be widely useful and usable across a broad spectrum of application. Boost libraries are fully compliant with the C++ standard library and offer means to manipulate efficiently:

- threads
- regular expressions
- filesystem operations
- smart pointers
- strings
- mathematical graphs
- any many others

Boost contains two types of libraries:

- **header-only libraries**
  These libraries are fully defined and implemented within C++ header files (hpp files). Compiling an application with these libraries consists in indicating the compiler where to find Boost header files with the -I compilation option. In the context of bullx DE, loading the Boost module will automatically make the Boost header files visible to the compiler through the CPATH environment variable.
- **shared or static libraries**
  To compile with these libraries, one has to indicate the compiler where to find the libraries. In the context of bullx DE, the BOOST_LIB environment variable can be used to indicate the Boost libraries as shown in the following example.

Compiling with Boost shared or static libraries

```
g++ source.cpp -L$BOOST_LIB -lboost_xxxx -o executable
```

See http://www.boost.org/ for more details.

8.2 OTF (Open Trace Format)

OTF is a library used by the tools like Scalasca to generated traces in the OTF format. The OTF package also contains additional tools to help processing OTF trace files:

- **otfmerge** – converter program of OTF library
- **otfmerge-mpi** - MPI version of **otfmerge**
- **otfaux** - append snapshots and statistics to existing OTF traces at given 'break' time stamps
- **vtf2ot f** - convert VTF3 trace files to OTF format.
- **otf2vtf** - convert OTF trace files to VTF format.
- **otfdump** - convert OTF traces or parts of it into a human readable, long version .
- **otf(de)compress** - compression program for single OTF files.
- **otf-config** - shows parameters of the OTF configuration .
- **otfprofile** - generates a profile of a trace in Latex or CSV format.
- **otfshrink** - creates a new OTF file that only includes specified processes .
- **otfinfo** - program to get basic information of a trace.

See
- **/opt/bullxde/utils/OTF/share/doc/OTF/otftools.pdf** documentation on OTF tool usage.
- www.tu-dresden.de/zih/otf for more details.

8.3 Ptools

Ptools is a collection of tools that help create and manage CPUSETS.

8.3.1 CPUSETs

CPUSETs are lightweight objects in the **Linux** kernel that enable users to partition their multiprocessor machine by creating execution areas. A virtualization layer has been added so it becomes possible to split a machine in terms of CPUs.

The main motivation of this patch is to give the **Linux** kernel full administration capabilities concerning CPUs. CPUSETs are rigidly defined, and a process running inside this predefined area will not be able to run on other parts of the system.

This is useful for:

- Creating sets of CPUs on a system, and binding applications to them.
- Providing a way of creating sets of CPUs inside a set of CPUs so that a system administrator can partition a system among users, and users can further partition their partition among their applications.

Typical Usage of CPUSETS

- CPU-bound applications: Many applications (as it is often the case for cluster apps) used to have a "one process on one processor" policy using **sched_setaffinity()** to define this, but what if we have to run several such apps at the same time? One can do this by creating a CPUSET for each app.
- Critical applications: processors inside strict areas may not be used by other areas. Thus, a critical application may be run inside an area with the knowledge that other processes will not use its CPUs. This means that other applications will not be able to lower its reactivity. This can be done by creating a CPUSET for the critical application, and another for all the other tasks.

Bull CPUSETS

CPUSETS are integrated in the standard **Linux** kernel. However, the **Bull** kernel includes the following additional CPUSET features:

Migration

Change on the fly the execution area for a whole set of processes (for example, to give more resources to a critical application). When you change the CPU list of a CPUSET all the processes that belong to the CPUSET will be migrated to stay inside the CPU list, if and as necessary.

Virtualization

Translate the masks of CPUs given to **sched_setaffinity()** so they stay inside the set of CPUs. With this mechanism processors are virtualized for the use of **sched_setaffinity()** and **/proc** information. Thus, any former application using this **system call** to bind processes to processors will work with virtual CPUs without any change. A new file is added to each CPUSET, in the CPUSET file system, to allow a CPUSET to be virtualized, or not.

8.3.2 CPUSETs management tools

The **ptools** package provides a set of tools to help create, manage end delete CPUSETs:

- **pcreate** and **pexec** to create a CPUSET.
- **pdestroy** to destroy a CPUSET.
- **pls** to list the existing CPUSETs.
- **pshell** to launch a shell within an environment created with **pcreate** or **pexec**.
- **pplace** and **passign** to control the placement of processes on CPUs.

See The tools man pages for more details on their usage.

Appendix A. Performance Monitoring with BCS Counters

The performance monitoring implemented in the BCS chip provides a means for measuring system performance and detecting bottlenecks caused by hardware or software. This Appendix describes some of the ways that the Performance Monitoring (PM) resources can be programmed to obtain some basic measurements.

A.1 Bull Coherent Switch Architecture

To be able to create monitoring experiments the user must have some understanding of the BCS architecture. The BCS units are:

- Remote Space Manager (REM) and Local Space Manager (LOM), collectively referred to as the Protocol Engine (PE).
- Link Layer QPI/IOH/XQPI (LLCH, LLIH, and LLXH), collectively referred to as LL; Output Buffering blocks to QPI/IOH/XQPI (OBC, OBI, and OBX) are considered to be part of the appropriate LL unit for the purposes of Performance Monitoring, collectively referred to as OB.
- Non-coherent Manager Unit (NCMH)
- Route Through IOH-to-QPI/QPI-to-IOH (ROIC and ROCI), collectively referred to as RO.

Figure A-1 shows a schematic representation of the BCS units with their performance monitoring blocks and connections.

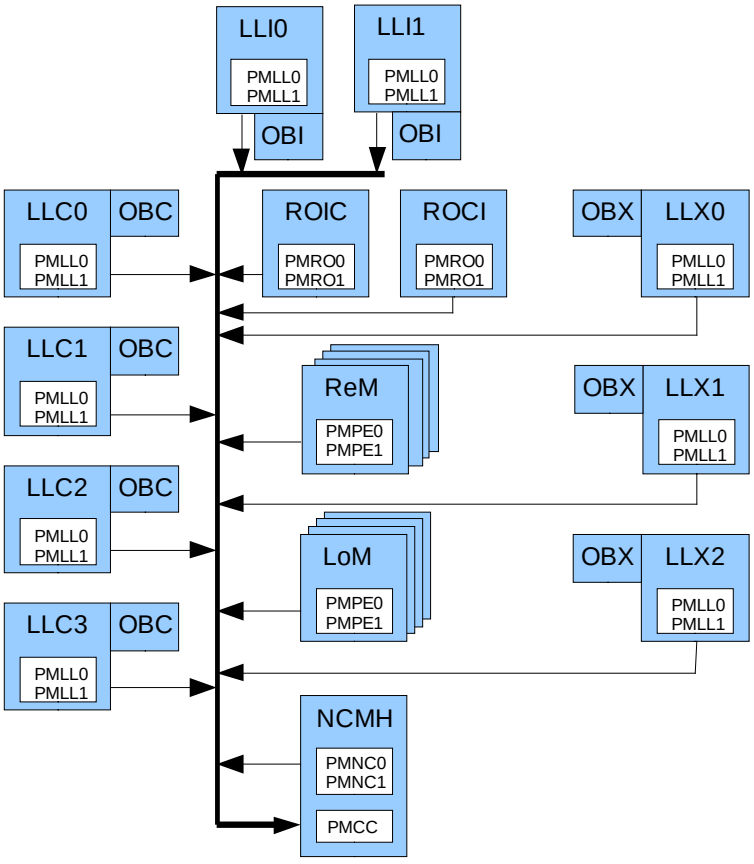


Figure A-1. BCS Architecture for performance monitoring blocks and connections

A.2 Performance Monitoring Architecture

Performance Monitoring as supported by BPMON and Bull's PAPI enhancement is composed of two parts:

- event detection
- event counting

Event detection logic is placed in all major units. Two events can be decoded per cycle in each block. All events are then centralized in the Performance Monitoring Central Counter block (PMCC) implemented in the Non Coherent Manager Unit (NCMH). The PMCC consists of four counters.

Event Detection

Each unit has two blocks containing the Performance Monitoring Event register (PME) which can be independently programmed to detect and forward different events. These blocks are named PMxx0 and PMxx1 (where xx is the unit identifier), whose events are referred to as event0 and event1, respectively. This two block construct allows two similar events in the same unit to be selected and sent to the counter blocks, for example a target event such as a directory access with a specific state as one event and a reference event of all directory read accesses as a second event.

Event Counting

All unit event outputs are collected in the central counter block located in the NCMH unit. Here the events are selected as inputs to the four counters. Each counter is controlled by a Performance Monitoring Resource Control and Status register (PMR). Events from PMxx0 are hardwired to the event selection for counter0 of each counter pair; events from PMxx1 are hardwired to the event selection for counter1 of each counter pair. This is important to keep in mind if one is trying to combine events from different units into one counter.

A.3 Event Types

This is a general description of event types. Any differences or additions in the units are addressed in later sections.

1. **Interface** – measure BCS internal traffic from the selected unit to a destination unit. Details about message type are not available at this level of measurement.
2. **Buffer Occupation** – measurement of buffer occupation at or greater than a specified threshold. Used in association with the timer and multiple runs at different thresholds to make a histogram of occupation.
3. **Errors** – measure double and single ECC errors.
4. **Traffic Identification** – measure various events in the life of a transaction based on the traffic direction and the transaction type (message class and opcode) dependent upon a mask. **Incoming** and **Outgoing** directions are with respect to the unit being monitored.
5. **Latency** – measure latency for selected message sequences, often dependent upon a mask.

PE Event Types

LoM (Local space Manager) is responsible for ensuring coherency for local addresses. It behaves as a Home Agent on XQPI representing the Home Agents of all the other modules and as a Caching Agent on QPI representing the Caching Agents of the local module.

ReM (Remote space Manager) is responsible for ensuring coherency on remote addresses. It behaves as a Home Agent on QPI representing the Home Agents of all the other modules and as a Caching Agent on XQPI representing the Caching Agents of the local module.

Protocol Engine (PE) event types are monitored in the PE units, ReM and LoM, by setting fields in the PMPE0 or PMPE1 PME registers in the selected unit. Each unit consists of four instances which must have identical settings for their PME registers. For example, if you have chosen to monitor an event using the PMPE0_PME register in ReM, all four PMPE0_PME registers in ReM must have the same value. In the cases where only one instance event is to be used, such as measuring average latency, the event registers should still be set up the same for all instances, with the counter control registers selecting only one instance.

The following event types can be monitored in the PE. Descriptive information is in addition to the general description above.

1. **Interface** – measure traffic from a PE block to OB. Can choose either West (Caching Agent or CA) side or East (Home Agent or HA) side.
2. **Buffer Occupation** – the size of the buffer is in parentheses.
3. **Errors** – measure directory, Tracker, and Virtual Output FIFO ECC errors.

4. **Traffic Identification** – four choices for traffic direction:
    a. Incoming Traffic – incoming traffic can be identified by a mask-enabled Request or Home Node ID (RHNID) in addition to Transaction Type.
    b. Outgoing Traffic – outgoing traffic can be identified by a mask-enabled Destination Node ID in addition to Transaction Type.
    c. Tracker Output Traffic – measure responses during Tracker phases **Snoop Snoopy Nodes**, **Snoop Directory Nodes**, and **Read Memory** for cache-to-cache transfers.
    d. Lookup Response Traffic – directory status during Read Access of IPT (In Process Table) or SRAM directories. Shared and Exclusive State events can act as indicators of program affinity.
5. **Transaction Latency** – measure latency for Read, Write, or Snoop transactions based on the opcode dependent upon an opcode mask.
6. **Starvation** – measure starvation starts, duration, or number of starved transactions versus a threshold.
7. **Retry** – measure initial retries, all retries, and all transactions that enter the Retry Detection stage; select between Short (early detection) or Long (detection at end of pipeline) and one/some/all Retry types.
8. **Directory Access** – measure Read and Update accesses to the SRAM directory, or to both IPT and SRAM. In ReM, the directories comprise the ILD; in LoM, the directories comprise the ELD.
9. **Directory Levels** – measurement of level occupation at or greater than a specific threshold. Used in association with the timer and multiple runs at different thresholds to make a histogram of occupation.
10. **Twin Lines** – measure different types of SRAM Directory Look-ups related to entries that contain a Twin Line address, defined as a pair of addresses that differ by one specific address bit (allows for sharing of the directory entry).

A depiction of the 119 bit PMPE_PME register follows. It is shown in 32-bit packets as that is how it is read and written in Configuration Access mode using the BCS CSR. Field description details can be found in the PMPE Event Configuration Register Description.

Bits	31 30	29 … 20	19 … 17	16 … 12	11 10	9 … 7	6 … 0
Group	Traffic Identification Tracker Output	Traffic Identification Tracker Output	Directory Access	Directory Active Levels	Directory Active Levels	Twin Lines	Error Monitoring
Field	State	Response Type Received	Event	Threshold	Event	Event	Event
Default	0 0	0 0 0 0 0 0 0 0 0 0	0 0 0	0 0 0 0 0	0 0	0 0 0	0 0 0 0 0 0 0

Error Monitoring Event (bits 6–0)

6	5	4	3	2	1	0	
0	0	0	0	0	0	0	**No Event**
x	x	x	x	x	x	1	Directory SRAM single ECC error
x	x	x	x	x	1	x	Directory SRAM double ECC error
x	x	x	x	1	x	x	Directory LOT single ECC error
x	x	x	1	x	x	x	Directory DCT single ECC error
x	x	1	x	x	x	x	Directory DLIT single ECC error
x	1	x	x	x	x	x	Tracker single ECC error
1	x	x	x	x	x	x	Virtual Output FIFO single ECC error

Twin Lines Event (bits 9–7)

9	8	7	
0	0	0	**No Event**
0	0	1	Lookup to Directory SRAM
0	1	0	Lookup miss
0	1	1	Lookup hit with one of the twin lines in non-I state
1	0	0	Lookup hit with both of the twin lines in non-I state

Directory Active Levels Event (bits 11–10)

11	10	
0	0	**No Event**
0	1	The number of active levels is greater than threshold
1	0	The number of active levels is equal to the threshold

Directory Access Event (bits 19–17)

19	18	17	
0	0	0	**No Event**
0	0	1	Directory SRAM update access
0	1	0	Directory SRAM read access
0	1	1	Directory IPT or SRAM update access
1	0	0	Directory IPT or SRAM read access
1	0	1	Transaction elected to access the pipeline

Response Type Received (bits 29–20)

29	28	27	26	25	24	23	22	21	20	snSnp or dnSnp	homeReq
0	0	0	0	0	0	0	0	0	0	**No Event**	
x	x	x	x	x	x	x	x	x	1	Undef	Undef
x	x	x	x	x	x	x	x	1	x	RspI	DataC_I
x	x	x	x	x	x	x	1	x	x	RspS	DataC_S/F
x	x	x	x	x	x	1	x	x	x	RspCnflt	DataC_E/M
x	x	x	x	x	1	x	x	x	x	RspIWb	
x	x	x	x	1	x	x	x	x	x	RspSWb	
x	x	x	1	x	x	x	x	x	x	RspFwdI	
x	x	1	x	x	x	x	x	x	x	RspFwdS	
x	1	x	x	x	x	x	x	x	x	RspFwdIWb	
1	x	x	x	x	x	x	x	x	x	RspFwdSWb	

State (bits 31–30)

31	30	
0	0	snSnp: snoop Snoopy nodes
0	1	dnSnp: snoop Directory nodes
1	0	homeReq: access memory

Bits	64 63	62 … 55	54 … 47	46 … 42	41 … 37	36 … 32
Group	Traffic Identification	Traffic Identification	Traffic Identification	Traffic Identification – Incoming/Outgoing	Traffic Identification – Incoming/Outgoing	Traffic Identification – Lookup Response
Field	Direction	Transaction Type: (msgclass+opcode) required for all Traffic ID Events	Transaction Type Mask: (msgclass+opcode) required for all Traffic ID Events	Node ID: DNID outgoing; RHNID incoming	NID Mask	Lookup Directory Status
Default	0	1 1 1 1 1 1 1 1	0 0 0 0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0

Lookup Directory Status (bits 36–32)

36	35	34	33	32	
0	0	0	0	0	**No Event**
x	x	x	x	1	Exclusive State
x	x	x	1	x	Shared State and 3 sharers
x	x	1	x	x	Shared State and 2 sharers
x	1	x	x	x	Shared State and 1 sharers
1	x	x	x	x	Invalid State

Node ID (bits 46–42) and NID Mask (bits 41–37)

Node ID 46–42	NID Mask 41–37	
	1 1 1 1 1	Specific NID
	0 0 0 0 0	All NID's
x x x x 1	0 0 0 0 1	CA (for default configuration)
x x x 0 0	0 0 0 1 1	IOH (for default configuration)
x x x 1 0	0 0 0 1 1	Ubox (for default configuration)

Transaction Type Mask (bits 54–47)

54–51	50–47	
1 1 1 1	1 1 1 1	Specific type
0 0 0 0	0 0 0 0	All types

Transaction Type (bits 62–55)

62–59	58–55	
1 1 1 1	1 1 1 1	**No Event**
0 0 0 0		HOM: Home - Request
0 0 0 1		HOM: Home - Response & Writes (commands only)
0 0 1 0		NDR: Non Data Response
0 0 1 1		SNP: Snoop
0 1 0 0		NCS: Non Coherent Standard
1 1 0 0		NCB: Non Coherent Bypass
1 1 1 0		DRS: Data Response
1 1 1 1		SPC: Special Control

Direction (bits 64–63)

64	63	
0	0	Incoming
0	1	Outgoing
1	0	Tracker Output
1	1	Lookup Response

Buffer Occupation						Starvation														Retry													
Threshold				Event		Type			Threshold								Event			Type								Event						
95			92	91	90	89		87	86							78	77		75	74	73						67	66	65	64				
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
																												0	0	**No Event**				
																												0	1	Retry has occurred				
																												1	0	New retry has occurred				
																												1	1	Valid transaction seen in retry detection				
																												Short Retry						
																				0	x	x	x	x	x	x	1	Impossible lookup						
																				0	x	x	x	x	x	1	x	Atomicity: same/twin address already in pipeline						
																												Long Retry						
																				1	x	x	x	x	x	x	1	back invalidate refused						
																				1	x	x	x	x	x	1	x	single ECC errors						
																				1	x	x	x	x	1	x	x	full conflict						
																				1	x	x	x	1	x	x	x	partial conflict						
																				1	x	x	1	x	x	x	x	W-TID pool unavailable						
						0	0	0	ReadReq											1	x	1	x	x	x	x	x	E-TID pool unavailable						
						0	0	1	Snoop											1	1	x	x	x	x	x	x	Output channel not available						
						0	1	0	WSB									0	0	0	**No Event**													
						0	1	1	WrReq									0	0	1	Start of new Starvation mechanism													
						1	0	0	CmpFwd									0	1	0	Starvation mechanism is active													
						1	0	1	PtlCnfList									0	1	1	Number of starved transactions at start of mechanism is greater than threshold													
				0	0	**No Event**												1	0	0	Number of starved transactions at start of mechanism is equal to threshold													
				0	1	Number of occupied entries is greater than threshold																													
				1	0	Number of occupied entries is equal to threshold																													

Transaction Latency										Interface		Buffer Occupation													
Event		Type		Opcode				Opcode Mask				Event		Buffer Select (max size)				Threshold							
118	117	116	115	114			111	110			107	106	105	104			101	100			96	95	94	93	92
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
														0	0	0	0	Write Buffer (8)							
														0	0	0	1	DCT (256)							
														0	0	1	0	LOT (256)							
														0	0	1	1	West TID pool 0 (64)							
														0	1	0	0	West TID pool 1 (64)							
														0	1	0	1	West TID pool 2 (64)							
														0	1	1	0	West TID pool 3 (64)							
														0	1	1	1	Sum of West TID pools (96)							
														1	0	0	0	East TID pool (64)							
														1	0	0	1	East NDR Virtual fifo (276)							
														1	0	1	0	East SNP Virtual fifo (276)							
														1	0	1	1	West HOM Virtual fifo (276)							
														1	1	0	0	West SNP Virtual fifo (276)							
														1	1	0	1	WSB (16)							
												0	0	**No Event**													
		0	0	Read Request								0	1	A packet (=1 flit) has been emitted RT-East to OB													
		0	1	Write Request								1	0	A packet (=1 flit) has been emitted RT-West to OB													
		1	0	Snoop				1	1	1	1	Specific opcode															
0	0	**No Event**						0	0	0	0	All opcodes															
0	1	The message selected in the "Type" field has been captured																									
1	0	The response to the "Type" field message has been received (DataC for Read, Cmp for Write, and last Snp for Snoop)																									

NCMH Event Types

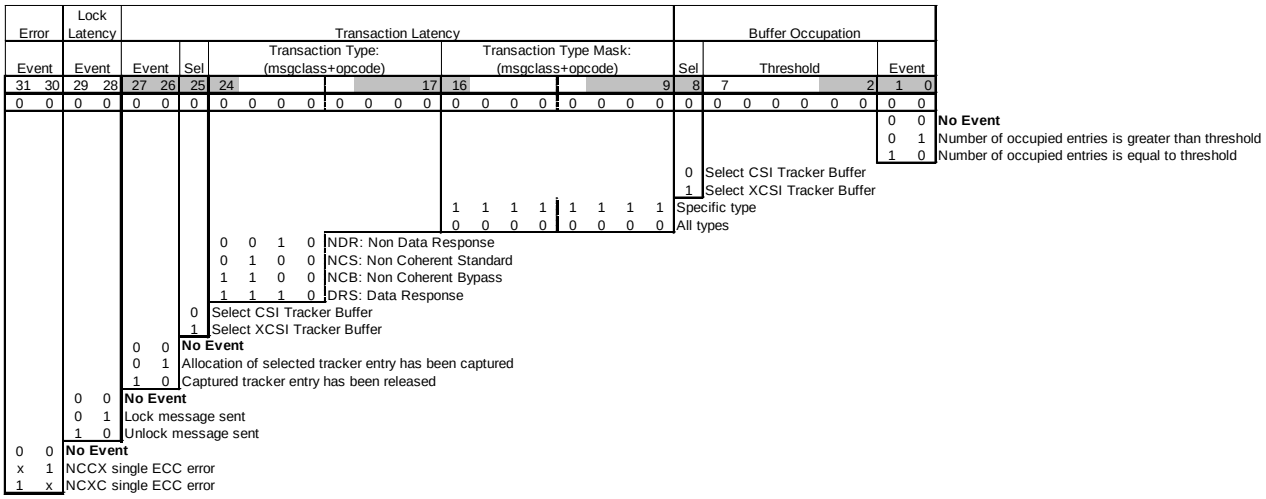
Non Coherent Manager Unit (NCMH) manages non-coherent transactions through QPI and XQPI interfaces.

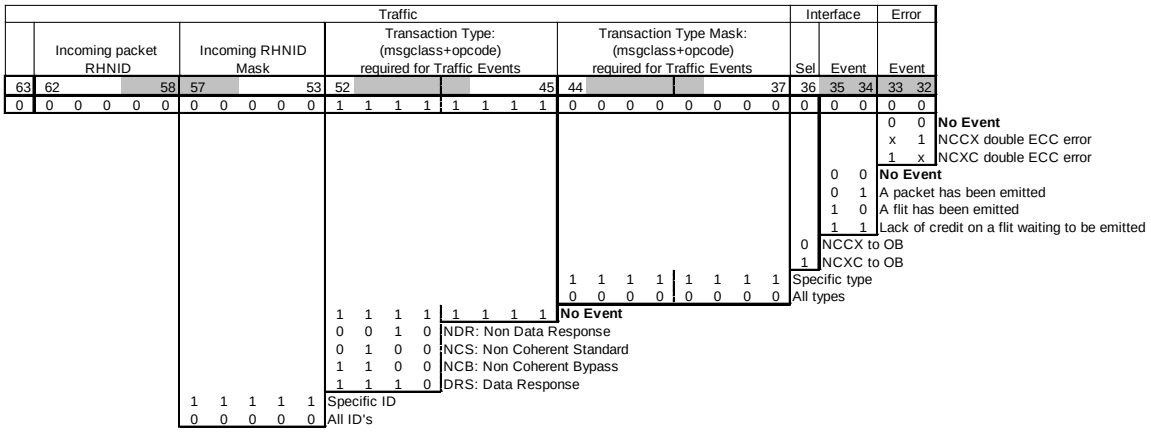
NCMH event types are monitored by setting fields in the PMNC0 or PMNC1 PME registers.

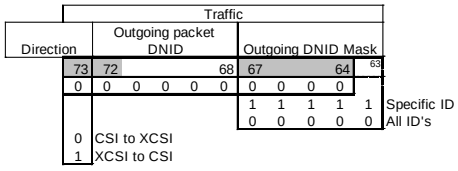
The following event types can be monitored in NCMH. Descriptive information is in addition to the general description at the beginning of this section.

1. **Interface** – measure non-coherent traffic from NC to QPI or XQPI.
2. **Buffer Occupation** – measure occupation of QPI or XQPI Tracker buffers.
3. **Error** – measure ECC errors in NC register files.
4. **Traffic Identification** – two choices for traffic direction, QPI to XQPI and XQPI to QPI. Traffic identification can be made using the outgoing mask-enabled updated DNID and the incoming mask-enabled RHNID in addition to Transaction Type.
5. **Transaction Latency** – measure latency of selected transactions from the QPI or XQPI tracker.
6. **Lock Latency** – measure latency of Lock transactions.

A depiction of the 74 bit PMNC_PME register follows. It is shown in 32-bit packets as that is how it is read and written in Configuration Access mode using the BCS CSR. Field description details can be found in the PMNC Event Configuration Register Description.







LL and OB Event Types

Link Layer (LL) is the interface between QPI/IOH/XQPI and the Protocol Engines and Routing Layer of the BCS. Output Buffers (OB) store and route messages from the Protocol Engines to the Link Layer.

LL event types are monitored in the LL units, LLCH, LLIH and LLXH, by setting fields in the PMLL0 or PMLL1 PME registers in the selected unit. Each unit consists of multiple instances; four in LLCH, two in LLIH, three in LLXH. Unlike the PE units, the LL unit instance need not have identical settings for their PME registers as each instance is connected to a specific agent. OB Event types are monitored in the appropriate LL unit.

The following event type can be monitored in LL. Descriptive information is in addition to the general description at the beginning of this section.

Interface – measure OB to LL traffic.

Below is a depiction of the 33 bit PMLL_PME register. It is shown as a 32-bit packets and a 1-bit packet as that is how it is read and written in Configuration Access mode using the BCS CSR.

	Interface		Anticipation	Buffer Occupation			Error Monitoring	Clock Correct	
	Select	Event	Event	Select	Threshold	Event	Event	Event	
32	31 28	27 25	24 23	22 20	19 10	9 8	7 2	1 0	
0	0 0 0 0	0 0 0	0 0	0 0 0	0 0 0 0 0 0 0 0 0 0	0 0	0 0 0 0 0 0	0 0	
								0 0	**No Event**
							0 0 0 0 0 0		**No Event**
			0 0						**No Event**
						0 0			**No Event**
		0 0 0							**No Event**
		0 0 1							A packet has been emitted
		0 1 0							A packet has been emitted w/ idle latency
		0 1 1							A flit has been emitted
		1 0 0							Flow control (or lack of credit) on a flit waiting to be emitted
0	1 1 0 1								OB to LL flit0
0	1 1 1 0								OB to LL flit1
0	1 1 1 1								OB to LL flit2
1	0 0 0 0								OB to LL flit3
1	0 0 0 1								OB to LL flit0 and flit1
1	0 0 1 0								OB to LL flit2 and flit3
1	0 0 1 1								OB to LL flit0,1,2,3
1	0 1 0 0								OB to LL flit0,1,2,3; VN0 traffic only

RO Event Type

Route Through (RO) units are the direct routing path for messages from the two IOH modules to QPI and between the IOH modules.

RO event type is monitored in the ROIC and ROCI units by setting fields in the PMRO0 or PMRO1 PME registers in the selected unit. The following event type can be monitored in RO. Descriptive information is in addition to the general description at the beginning of this section.

Interface - measure RO-to-OB traffic or ROIC-to-ROCI traffic.

Below is a depiction of the 4 bit PMRO_PME register. Field description details can be found in the PMRO Event Configuration Register Description.

Interface				
Select		Event		
3	2	1	0	
0	0	0	0	
		0	0	**No Event**
		0	1	A packet has been emitted
		1	0	A flit has been emitted
		1	1	Flow control (or lack of credit) on a flit waiting to be emitted
0	0			RO to OB flow0 (2 flits)
0	1			RO to OB flow1 (2 flits)
1	0			RO to OB flow0 and flow1 (4 flits)
1	1			ROIC to ROCI flow0 and flow1 (unused in ROCI)

A.4 Event Counts and Counter Threshold Comparisons

There are four Performance Monitor Counters comprised of a counter and a data storage register, the Performance Monitoring Data register (PMD). Counting is enabled by selecting a Counter Enable source, either a Local Enable/Interval Timer, or the counter's partner. It is important to note that Local Enable and Interval Timer are controlled by the global registers PERFCON and PTCTL and are mutually exclusive, meaning that all counters making this selection will receive the same enable source. For example, one cannot choose Local Enable for one counter and Interval Timer for another.

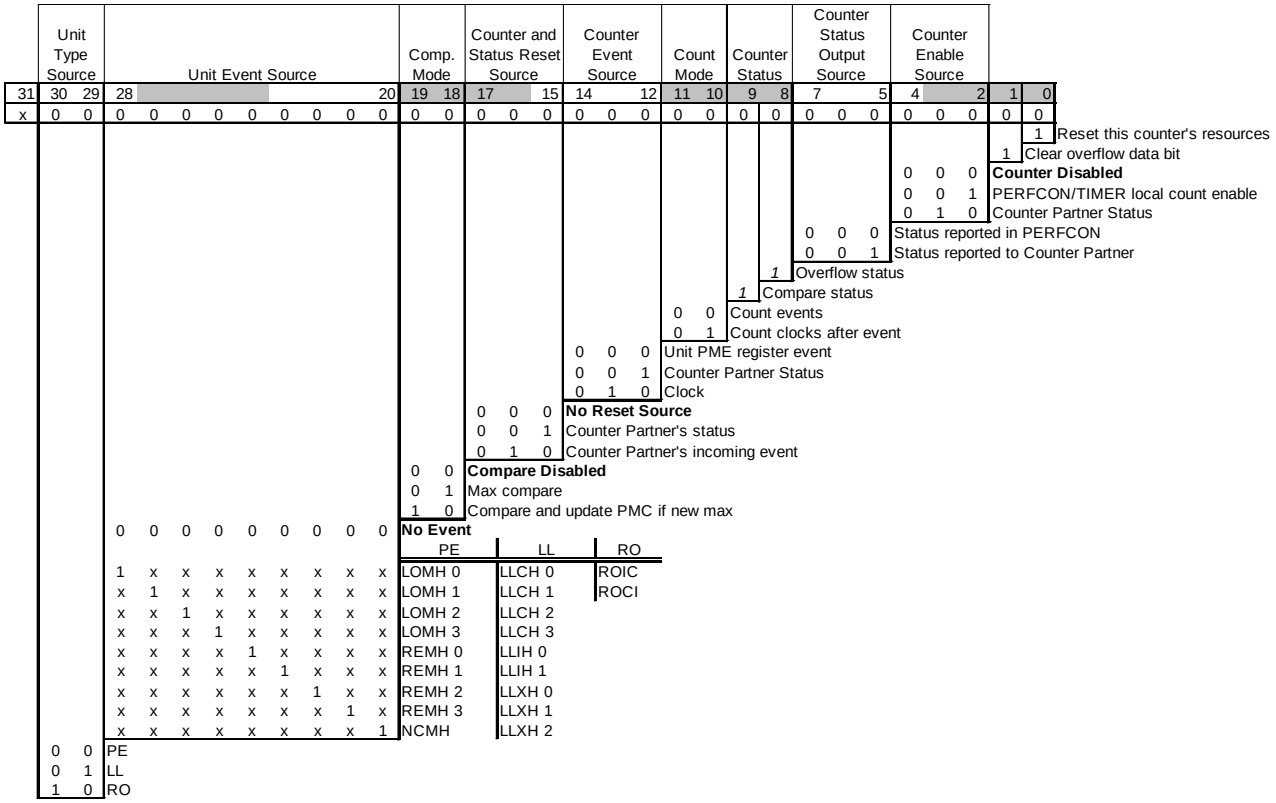
Each PMD can be compared with its own Performance Monitoring Compare register (PMC). There are two comparison modes: maximum compare, and compare then update. In maximum compare mode, the PMC is loaded with an initial value and a notification occurs when the PMD reaches this value. In the compare then update mode, the PMC is loaded each time the PMD exceeds the PMC value.

Each PM Counter is controlled by a Performance Monitoring Resource Control and Status register (PMR). The fields to carry out the actions described above are listed below.

1. **unit selection for events or no event** - select the units whose events are to be monitored, based upon the unit type (PE, LL, RO).
2. **compare mode or no comparison** - select maximum compare, compare then update, or no comparison mode.
3. **reset source for counter and status** - select partner's compare or overflow status, partner's event, or nothing as the reset.
4. **source of counter events** - select PME event, partner's status, or clock.
5. **count mode** - count events or clocks after event.
6. **destination of counter status output** - select PERFCON or partner.
7. **counter enable source** - local (by PERFCON) or timer, partner's status, or disabled.
8. **reset counter and clear status bits**.

Using Bull's tools the user has no capability to use the Interval Timer 0r Compare mechanisms.

A depiction of the 32-bit PMR register follows. Field description details can be found in the PMR Configuration Register Description.


Unit Type Source
Unit Event Source
Comp. Mode
Counter and Status Reset Source
Counter Event Source
Count Mode
Counter Status
Counter Status Output Source
Counter Enable Source
31 30 29 28 20 19 18 17 15 14 12 11 10 9 8 7 5 4 2 1 0
x 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 Reset this counter's resources
1 Clear overflow data bit
0 0 0 Counter Disabled
0 0 1 PERFCON/TIMER local count enable
0 1 0 Counter Partner Status
0 0 0 Status reported in PERFCON
0 0 1 Status reported to Counter Partner
1 Overflow status
1 Compare status
0 0 Count events
0 1 Count clocks after event
0 0 0 Unit PME register event
0 0 1 Counter Partner Status
0 1 0 Clock
0 0 0 No Reset Source
0 0 1 Counter Partner's status
0 1 0 Counter Partner's incoming event
0 0 Compare Disabled
0 1 Max compare
1 0 Compare and update PMC if new max
0 0 0 0 0 0 0 0 0 No Event
PE LL RO
1 x x x x x x x x LOMH 0 LLCH 0 ROIC
x 1 x x x x x x x LOMH 1 LLCH 1 ROCI
x x 1 x x x x x x LOMH 2 LLCH 2
x x x 1 x x x x x LOMH 3 LLCH 3
x x x x 1 x x x x REMH 0 LLIH 0
x x x x x 1 x x x REMH 1 LLIH 1
x x x x x x 1 x x REMH 2 LLXH 0
x x x x x x x 1 x REMH 3 LLXH 1
x x x x x x x x 1 NCMH LLXH 2
0 0 PE
0 1 LL
1 0 RO

A.5 Software Application Supported BCS Monitoring Events

In this section the set of BCS Performance monitoring events is described. Each performance event is named, the syntax for requesting it is defined, and the abbreviations of the many fields that must be used by name and the contents of those fields are defined. The message classes and their opcodes are used as defined in Section A.6. In making this description of the supported performance monitoring events some simplifications are made. Therefore if a user only uses this syntax to describe events then not all capability in the BCS performance monitoring is available.

A list of all performance events is presented here in the order defined in this section. As defined they collect counts from all the BCSs in the node:

BCS_PE[]
BCS_PE_Error[]
BCS_PE_LOM_Error[]
BCS_PE_REM_Error[]
BCS_PE_Twin_Lines[]
BCS_PE_LOM_Twin_Lines[]
BCS_PE_REM_Twin_Lines[]
BCS_PE_Directory_Active_Levels[]
BCS_PE_LOM_Directory_Active_Levels[]
BCS_PE_REM_Directory_Active_Levels[]
BCS_PE_Directory_Access_Event[]
BCS_PE_LOM_Directory_Access_Event[]
BCS_PE_REM_Directory_Access_Event[]
BCS_PE_Incoming_Traffic[]
BCS_PE_LOM_Incoming_Traffic[]
BCS_PE_REM_Incoming_Traffic[]
BCS_PE_Outgoing_Traffic[]
BCS_PE_LOM_Outgoing_Traffic[]
BCS_PE_REM_Outgoing_Traffic[]
BCS_PE_Tracker_Traffic[]
BCS_PE_LOM_Tracker_Traffic[]
BCS_PE_REM_Tracker_Traffic[]
BCS_PE_Lookup_Traffic[]
BCS_PE_LOM_Lookup_Traffic[]
BCS_PE_REM_Lookup_Traffic[]
BCS_PE_Short_Retry[]
BCS_PE_LOM_Short_Retry[]
BCS_PE_REM_Short_Retry[]
BCS_PE_Long_Retry[]
BCS_PE_LOM_Long_Retry[]
BCS_PE_REM_Long_Retry[]
BCS_PE_Starvation[]
BCS_PE_LOM_Starvation[]
BCS_PE_REM_Starvation[]
BCS_PE_Buffer_Occupation[]
BCS_PE_LOM_Buffer_Occupation[]
BCS_PE_REM_Buffer_Occupation[]
BCS_PE_Interface_RT_East
BCS_PE_LOM_Interface_RT_East

BCS_PE_REM_Interface_RT_East
BCS_PE_Interface_RT_West
BCS_PE_LOM_Interface_RT_West
BCS_PE_REM_Interface_RT_West
BCS_PE_Tx_Request[]
BCS_PE_LOM_Tx_Request[]
BCS_PE_REM_Tx_Request[]
BCS_PE_Tx_Response[]
BCS_PE_LOM_Tx_Response[]
BCS_PE_REM_Tx_Response[]

BCS_NCMH[]
BCS_NCMH_Buffer_Occupation[]
BCS_NCMH_Tx_QPI_Alloc[]
BCS_NCMH_Tx_XQPI_Alloc[]
BCS_NCMH_Tx_QPI_Release[]
BCS_NCMH_Tx_XQPI_Release[]
BCS_NCMH_Lock_Message
BCS_NCMH_Unlock_Message
BCS_NCMH_Lock_Message_Latency
BCS_NCMH_ECC_Error[]
BCS_NCMH_NCCX_OB[]
BCS_NCMH_NCXC_OB[]
BCS_NCMH_QPI_XQPI_Traffic[]
BCS_NCMH_XQPI_QPI_Traffic[]

BCS_LL[]
BCS_LL_Interface[]
BCS_LL_LLCH_Interface[]
BCS_LL_LLIH_Interface[]
BCS_LL_LLXH_Interface[]

BCS_RO[]
BCS_RO_Interface[]
BCS_RO_ROIC_Interface[]
BCS_RO_ROCI_Interface[]

If the counts from all the BCSs are added together then the syntax above is used as shown. However a special variant of each performance event is allowed that provides the capability to choose from which BCS the counts for an event will be collected. This is controlled in the event definition by noting which BCSs will collect counts for this event. It is noted by the following syntax for each BCS that will collect the count by putting its number (0, 1, 2, 3) in the event name (up to three of the four BCSs may be listed):

BCS#1#2#3_PE_REM_Incoming_Traffic[]

For example to get the count from BCS0:

BCS0_PE_Incoming_Traffic[MC=DRS,MCM=0xF,OC=0x0,OCM=0x0,
NID=0,NIDM=0]

For example to get the count from BCS1, BCS2 and BCS3:

BCS123_PE_Incoming_Traffic[MC=DRS,MCM=0xF,OC=0x0,OCM=0x0,
NID=0,NIDM=0]

This can be especially useful in experiments where the performance analyst is evaluating a test program that is referencing from one BCS to another and wishes to collect separate counts from the BCS where the CPU is executing the test and from the BCS where the memory being referenced is located.

PE Event Setup

For PE count events the PMR for the chosen counter for this event should have the following settings where Unit Event Source can have one of three values:

Counter Enable Source :	local count enable = 001
Counter Status Output Source :	perfcon = 000
Count Mode :	count events = 00
Counter Event Source :	unit pme event = 000
Counter and Status Reset Source :	no reset = 000
Compare Mode :	disabled = 00
Unit Event Source :	LoM0-3 & ReM0-3 = 111111110
Unit Type Source :	PE = 00

The Unit Event Source can have the above value if both LoM0-3 and ReM0-3 are configured to provide the source of the count. Here are the three choices:

Unit Event Source :	LoM0-3 & ReM0-3 = 111111110
Unit Event Source :	LoM0-3 = 111100000
Unit Event Source :	ReM0-3 = 000011110

The syntax for the expert user that does not wish any software tool help in defining an event is to provide the PMR and PMPE_PME register contents:

BCS_PE[PMR=0x1FE00004,LOMH=0.0.0x7E0420.0,REMH=0.0.0x7E0420.0]

Error Monitoring

You select the set of errors you wish to monitor. The definition will fill bits 6-0 of PMPE_PME register. The PMR for the chosen counter for this event should have values shown in the "PE Event Setup" section with Unit Event Source chosen as LoM0-3 and ReM0-3. For example:

	Bits 6-0 in binary
BCS_PE_Error[DSS]	0000001
BCS_PE_Error[DSS+DSD]	0000011

Where the set of errors and their abbreviations are:

Directory SRAM Single ECC Error DSS
Directory SRAM Double ECC Error DSD
Directory LOT Single ECC Error DLS
Directory DCT Single ECC Error DDCS
Directory DLIT Single ECC Error DDLS
Tracker Single ECC Error TRS
Virtual Output FIFO Single ECC Error VOFS

For Unit Event Source chosen as LoM0-3, here is an example:

BCS_PE_LOM_Error[VOFS]	1000000

For Unit Event Source chosen as ReM0-3, here is an example:

BCS_PE_REM_Error[DDLS]	0010000

Twin Lines Monitoring

You select the Event of this type that you want to count. The definition will fill bits 9-7 of PMPE_PME register. The PMR for the chosen counter for this event should have values shown in the "PE Event Setup" section with Unit Event Source chosen as LoM0-3 and ReM0-3. For example:

	Bits 9-7 in binary
BCS_PE_Twin_Lines[LDS]	001
BCS_PE_Twin_Lines[LM]	010
BCS_PE_Twin_Lines[LHO]	011

Where the set of events and their abbreviations are:

Lookup to Directory SRAM	LDS
Lookup Miss	LM
Lookup Hit with one of the Twin Lines in non-I State	LHO
Lookup Hit with both of the Twin Lines in non-I State	LHB
For Unit Event Source chosen as LoM0-3, here is an example:	
BCS_PE_LOM_Twin_Lines[LM]	010

For Unit Event Source chosen as ReM0-3, here is an example:

BCS_PE_REM_Twin_Lines[LHB]	100

Directory Active Levels Monitoring

You select the Directory Active Levels Threshold (0-31). You select Active Levels Event: greater than or equal.

The Directory Active Levels Monitoring field is

Threshold	THR

The definition will fill bits 16-10 of PMPE_PME register. The PMR for the chosen counter for this event should have values shown in the "PE Event Setup" section with Unit Event Source chosen as LoM0-3 and ReM0-3. For example:

	Bits 16-10 in binary
BCS_PE_Directory_Active_Levels[THR>12]	0110001
BCS_PE_Directory_Active_Levels[THR=12]	0110010

For Unit Event Source chosen as LoM0-3, here is an example:

BCS_PE_LOM_Directory_Active_Levels[THR>12	0110001

For Unit Event Source chosen as ReM0-3, here is an example:

BCS_PE_REM_Directory_Active_Levels[THR=12]	0110010

Directory Access Monitoring

You select the directory access type to count. The definition will fill bits 19-17 of PMPE_PME register. The PMR for the chosen counter for this event should have values shown in the "PE Event Setup" section with Unit Event Source chosen as LoM0-3 and ReM0-3. For example:

	Bits 19-17 in binary
BCS_PE_Directory_Access_Event[DSU]	001
BCS_PE_Directory_Access_Event[DIR]	100

Where the set of exclusive events and their abbreviations are:

Directory SRAM Update Access	DSU

Directory SRAM Read Access	DSR
Directory IPT or SRAM Update Access	DIU
Directory IPT or SRAM Read Access	DIR
Transaction Elected to Access the Pipeline	TEA

For Unit Event Source chosen as LoM0-3, here is an example:

BCS_PE_LOM_Directory_Access_Event[TEA] 101

For Unit Event Source chosen as ReM0-3, here is an example:

BCS_PE_REM_Directory_Access_Event[DSR] 010

Incoming Traffic Identification Monitoring

There are four cases of Traffic Identification Events. This is the first. The Traffic Identification Direction is selected by setting bits (64-63):

Incoming=	00
Outgoing=	01
Tracker Output=	10
Lookup Response=	11

For this case Incoming (00) is chosen. The defaulted fields are:

Lookup Directory Status=	00000	LST
Tracker Output State=	00	TOS
Tracker Output Response Type Received=	0000000000	TOR

The filled fields are:

Direction= 00
Transaction Type MsgClass MC
Transaction Type OpCode OC
Transaction Type MsgClass Mask MCM
Transaction Type OpCode Mask OCM
Node ID (NID) NID
NID Mask NIDM

The definition will fill bits 64-20 of PMPE_PME register. The PMR for the chosen counter for this event should have values shown in the "PE Event Setup" section with Unit Event Source chosen as LoM0-3 and ReM0-3. For example:

Bits 64-20 in binary
BCS_PE_Incoming_Traffic[MC=DRS,MCM=0xF,OC=0x0,OCM=0x0, NID=0,NIDM=0]
00111000001111000000000000000000000000000000

This counts DRS transaction types for all opcodes for all RHNIDs

For Unit Event Source chosen as LoM0-3, here is an example:

BCS_PE_LOM_Incoming_Traffic[MC=DRS,MCM=0xF,OC=0x0,OCM=0x0,
NID=0,NIDM=0]
00111000001111000000000000000000000000000000

For Unit Event Source chosen as ReM0-3, here is an example:

BCS_PE_REM_Incoming_Traffic[MC=DRS,MCM=0xF,OC=0x0,OCM=0x0,
NID=0,NIDM=0]
00111000001111000000000000000000000000000000

Outgoing Traffic Identification Monitoring

There are four cases of Traffic Identification Events. For this case Outgoing (01) is chosen. The defaulted fields are:

Lookup Directory Status=	00000	LST
Tracker Output State=	00	TOS
Tracker Output Response Type Received=	0000000000	TOR

The filled fields are

Direction=	01	
Transaction Type MsgClass		MC
Transaction Type OpCode		OC
Transaction Type MsgClass Mask		MCM
Transaction Type OpCode Mask		OCM
Node ID (NID)		NID
NID Mask		NIDM

The definition will fill bits 64-20 of PMPE_PME register. The PMR for the chosen counter for this event should have values shown in the "PE Event Setup" section with Unit Event Source chosen as LoM0-3 and ReM0-3. For example:

Bits 64-20 in binary

BCS_PE_Outgoing_Traffic[MC=DRS,MCM=0xF,OC=0x0,OCM=0x0, NID=0,NIDM=0]

01111000001111000000000000000000000000000000000

This counts DRS transaction types for all opcodes for all DNIDs

For Unit Event Source chosen as LoM0-3, here is an example:

BCS_PE_LOM_Outgoing_Traffic[MC=DRS,MCM=0xF,OC=0x0,OCM=0x0, NID=0,NIDM=0]

00111000001111000000000000000000000000000000000

For Unit Event Source chosen as ReM0-3, here is an example:

BCS_PE_REM_Outgoing_Traffic[MC=DRS,MCM=0xF,OC=0x0,OCM=0x0, NID=0,NIDM=0]

00111000001111000000000000000000000000000000000

Tracker Output Traffic Identification Monitoring

There are four cases of Traffic Identification Events. For this case Tracker Output (10) is chosen. The defaulted fields are:

Node ID (NID)	00000	NID
NID Mask	00000	NIDM
Lookup Directory Status=	00000	LST

The filled fields are:

Direction=	10	
Transaction Type MsgClass		MC
Transaction Type OpCode		OC
Transaction Type MsgClass Mask		MCM
Transaction Type OpCode Mask		OCM
Tracker Output State=		TOS
Tracker Output Response Type Received=		TOR

The definition will fill bits 64-20 of PMPE_PME register. The PMR for the chosen counter for this event should have values shown in the "PE Event Setup" section with Unit Event Source chosen as LoM0-3 and ReM0-3. For example:

Bits 64-20 in binary

BCS_PE_Tracker_Traffic[MC=DRS,MCM=0xF,OC=0x0,OCM=0x0,
TOS=dnSnp,TOR=RsplWb+RspSWb]

10111000001111000000000000000000000000000000

This counts DRS transaction types for all opcodes for the selected Tracker Output state.

For Unit Event Source chosen as LoM0-3, here is an example:

BCS_PE_LOM_Tracker_Traffic[MC=DRS,MCM=0xF,OC=0x0,OCM=0x0,
TOS=dnSnp,TOR=RsplWb+RspSWb]

10111000001111000000000000000000000000000000

For Unit Event Source chosen as ReM0-3, here is an example:

BCS_PE_REM_Tracker_Traffic[MC=DRS,MCM=0xF,OC=0x0,OCM=0x0,
TOS=dnSnp,TOR=RsplWb+RspSWb]

10111000001111000000000000000000000000000000

Lookup Response Traffic Identification Monitoring

There are four cases of Traffic Identification Events. For this case Lookup Response (11) is chosen. The defaulted fields are:

Node ID (NID)	00000	NID
NID Mask	00000	NIDM
Tracker Output State=	00	TOS
Tracker Output Response Type Received=	0000000000	TOR

The filled fields are:

Direction=	11	
Transaction Type MsgClass		MC
Transaction Type OpCode		OC
Transaction Type MsgClass Mask		MCM
Transaction Type OpCode Mask		OCM
Lookup Directory Status		LST

The definition will fill bits 64-20 of PMPE_PME register. The PMR for the chosen counter for this event should have values shown in the "PE Event Setup" section with Unit Event Source chosen as LoM0-3 and ReM0-3. For example:

Bits 64-20 in binary

BCS_PE_Lookup_Traffic[MC=DRS,MCM=0xF,OC=0x0,OCM=0x0, LST=EXC+1S]

10111000001111000000000000000000000000000000000

This counts DRS transaction types for all opcodes for the selected Lookup Directory Statuses.

Where the set of exclusive Lookup Directory Statuses and their abbreviations are::

Exclusive State	EXC
Shared State and 3 Sharers	3S
Shared State and 2 Sharers	2S
Shared State and 1 Sharer	1S
Invalid State	INV

For Unit Event Source chosen as LoM0-3, here is an example:

BCS_PE_LOM_Lookup_Traffic[MC=DRS,MCM=0xF,OC=0x0,OCM=0x0, LST=EXC+1S]
10111000001111000000000000000000000000000000000

For Unit Event Source chosen as ReM0-3, here is an example:

BCS_PE_REM_Lookup_Traffic[MC=DRS,MCM=0xF,OC=0x0,OCM=0x0, LST=EX+1S]
10111000001111000000000000000000000000000000000

Retry Monitoring

You select the Retry Event Type. You select Short or Long Retry type. You select the set of retries that you wish to monitor.

The Retry Monitoring fields are:

Retry Type	TY
Retry Event	EV

The definition will fill bits 74-65 of PMPE_PME register. The PMR for the chosen counter for this event should have values shown in the "PE Event Setup" section with Unit Event Source chosen as LoM0-3 and ReM0-3. For example:

	Bits 74-65 in binary
BCS_PE_Short_Retry[EV=NEW,TY=ATOM]	0000001010
BCS_PE_Long_Retry[EV=RET,TY=FC+PC]	1000110001

Where the set of exclusive Retry Events and their abbreviations are:

Retry has Occurred	RET
New Retry has Occurred	NEW
Valid Transaction Seen in Retry Detection	VAL

Where the set of inclusive Short Retry Types and their abbreviations are:

Impossible Lookup	IMP
Atomicity: Same/Twin Address already in Pipeline	ATOM

Where the set of inclusive Long Retry Types and their abbreviations are:

Back Invalidate Refused	BIR
Single ECC Errors	SEE
Full Conflict	FC
Partial Conflict	PC
W-TID Pool Unavailable	WTID
E-TID Pool Unavailable	ETID
Output Channel not Available	OCNA

For Unit Event Source chosen as LoM0-3, here is an example:

BCS_PE_LOM_Short_Retry[EV=NEW,TY=ATOM]	0000001010
BCS_PE_LOM_Long_Retry[EV=RET,TY=FC+PC]	1000110001

For Unit Event Source chosen as ReM0-3, here is an example:

BCS_PE_REM_Short_Retry[EV=NEW,TY=ATOM]	0000001010
BCS_PE_REM_Long_Retry[EV=RET,TY=FC+PC]	1000110001

Starvation Monitoring

You select the Starvation Type. You select Starvation Event. You select Starvation Threshold; if you choose Event 011 or 100 otherwise it is set to 0.

The Starvation Monitoring fields are:

Starvation Type	TY
Starvation Event	EV

The definition will fill bits 89-75 of PMPE_PME register. The PMR for the chosen counter for this event should have values shown in the "PE Event Setup" section with Unit Event Source chosen as LoM0-3 and ReM0-3. For example:

	Bits 89-75 in binary
BCS_PE_Starvation[TY=Snoop,EV_ACT]	001000000000010
BCS_PE_Starvation[TY=WrReq,EV_THR>3]	011000000011011

Where the set of exclusive Starvation Events and their abbreviations are:

Start of New Starvation Mechanism	EV_STR
Starvation Mechanism is Active	EV_ACT
Threshold Comparison (Including the threshold amount)	EV_THR

For Unit Event Source chosen as LoM0-3, here is an example:

BCS_PE_LOM_Starvation[TY=WrReq,EV_THR>3]	011000000011011

For Unit Event Source chosen as ReM0-3, here is an example:

BCS_PE_REM_Starvation[TY=WrReq,EV_THR>3]	011000000011011

Buffer Occupation Monitoring

You select the Buffer Select (choose the buffer to monitor). You select comparison Event: greater than or equal. You select occupation Threshold.

The Buffer Occupation Monitoring fields are:

Buffer Select	BUF
Threshold	THR

The definition will fill bits 104-90 of PMPE_PME register. The PMR for the chosen counter for this event should have values shown in the "PE Event Setup" section with Unit Event Source chosen as LoM0-3 and ReM0 3. For example:

	Bits 104-90 in binary
BCS_PE_Buffer_Occupation[BUF=WT0,THR>7]	001100000011101
BCS_PE_Buffer_Occupation[BUF=WB,THR=0]	000000000000011

Where the set of exclusive Buffer Names and their abbreviations are:

Write Buffer	WB
DCT	DCT
LOT	LOT
West TID Pool 0	WT0
West TID Pool 1	WT1
West TID Pool 2	WT2
West TID Pool 3	WT3
Sum of West TID Pools	WTA
East TID Pool	ETP
East NDR Virtual FIFO	ENDR
East SNP Virtual FIFO	ESNP
West HOM Virtual FIFO	WHOM
West SNP Virtual FIFO	WSNP
WSB	WSB

For Unit Event Source chosen as LoM0-3, here is an example:

BCS_PE_LOM_Buffer_Occupation[BUF=WT0,THR>7]	001100000011101

For Unit Event Source chosen as ReM0-3, here is an example:

BCS_PE_REM_Buffer_Occupation[BUF=WT0,THR>7]	001100000011101

Interface Monitoring

You select the direction of packet (flit) flow. Then you can count the number of flits emitted. The definition will fill bits 106-105 of PMPE_PME register. The PMR for the chosen counter for this event should have values shown in the "PE Event Setup" section with Unit Event Source chosen as LoM0-3 and ReM0-3, for example:

	Bits 106-105 in binary
BCS_PE_Interface_RT_East	01
BCS_PE_Interface_RT_West	10

BCS_PE_Interface_RT_East counts the number of flits that has been emitted RT-East to OB.
BCS_PE_Interface_RT_West counts the number of flits that has been emitted RT-West to OB.

For Unit Event Source chosen as LoM0-3, here is an example:

BCS_PE_LOM_Interface_RT_East	01
BCS_PE_LOM_Interface_RT_West	10

For Unit Event Source chosen as ReM0-3, here is an example:

BCS_PE_REM_Interface_RT_East	01
BCS_PE_REM_Interface_RT_West	10

Transaction Monitoring

You select the Event: Request or Response. You select the Transaction Type. Then you select the Opcode and Opcode Mask.

The Buffer Occupation Monitoring fields are:

Transaction Type	TY
OpCode	OC
OpCode Mask	OCM

The definition will fill bits 118-107 of PMPE_PME register. The PMR for the chosen counter for this event should have values shown in the "PE Event Setup" section with Unit Event Source chosen as LoM0-3 and
ReM0-3. For example:

Bits 118-107 in binary

BCS_PE_Tx_Request[TY=Write,OC=WbMtoI,OCM=0xF] 010101001111
BCS_PE_Tx_Response[TY=Snoop,OC=SnpInvOwn,OCM=0xF] 101011001111

For Unit Event Source chosen as LoM0-3, here is an example:

BCS_PE_LOM_Tx_Request[TY=Write,OC=WbMtoI,OCM=0xF] 10101001111

BCS_PE_LOM_Tx_Response[TY=Snoop,OC=SnpInvOwn,OCM=0xF] 101011001111

For Unit Event Source chosen as ReM0-3, here is an example:

BCS_PE_REM_Tx_Request[TY=Write,OC=WbMtoI,OCM=0xF] 010101001111

BCS_PE_REM_Tx_Response[TY=Snoop,OC=SnpInvOwn,OCM=0xF] 101011001111

This is setup to count PE Transactions.

NCMH Event Setup

For the NCMH count events the PMR for the chosen counter for this event should have the following settings:

Counter Enable Source :	local count enable = 001
Counter Status Output Source :	perfcon = 000
Count Mode :	count events = 00
Counter Event Source :	unit pme event = 000
Counter and Status Reset Source :	no reset = 000
Compare Mode :	disabled = 00
Unit Event Source :	ncmh = 000000001
Unit Type Source :	PE = 00

The syntax for the expert user that does not wish any software tool help in defining an event is to provide the PMR and PMNC_PME register contents:

BCS_NCMH[PMR=0x00100004,NCMH=0.0x7E0420.0]

Buffer Occupation Monitoring

You select the QPI Tracker Buffer or the XQPI Tracker Buffer. You select the Threshold (0 to 63). You select comparison Event: greater than or equal.

The Buffer Occupation Monitoring fields are:

QPI Tracker Buffer QPI_Tracker
XQPI Tracker Buffer XQPI_Tracker

To the field name is appended the comparison event type > or = and the Threshold amount as shown in the example below.

The definition will fill bits 8-0 of PMNC_PME register. For example:

	Bits 8-0 in binary
BCS_NCMH_Buffer_Occupation[QPI_Tracker>31]	001111101
BCS_NCMH_Buffer_Occupation[XQPI_Tracker=3]	100001101
BCS_NCMH_Buffer_Occupation[QPI_Tracker>0]	000000001

The PMR for the chosen counter for this event should have values shown above.

Transaction Monitoring

You select the Event: Allocate or Release. You Select the Buffer: QPI Tracker or XQPI Tracker. Then you select the Transaction Type Msgclass, Msgclass Mask, Opcode, and Opcode Mask.

The Buffer Occupation Monitoring fields are

Transaction Type MsgClass MC
Transaction Type OpCode OC
Transaction Type MsgClass Mask MCM
Transaction Type OpCode Mask OCM

The definition will fill bits 27-9 of PMNC_PME register. For example

Bits 27-9 in binary

BCS_NCMH_Tx_QPI_Alloc[MC=DRS,MCM=0xF,OC=0,OCM=0]
0101110111100000000

BCS_NCMH_Tx_XQPI_Alloc[MC=DRS,MCM=0xF,OC=0,OCM=0]
0111110111100000000

BCS_NCMH_Tx_QPI_Release[MC=DRS,MCM=0xF,OC=0,OCM=0]
1001110111100000000
BCS_NCMH_Tx_XQPI_Release[MC=DRS,MCM=0xF,OC=0,OCM=0]
1011110111100000000

The PMR for the chosen counter for this event should have values shown in the "NCMH Event Setup" section.

This is setup to count NCMH Transactions.

Lock Monitoring

Two ways are available to use the Lock Latency event:
1. As a counter to count lock messages and / or
2. As a timer to accumulate the time that Locks are closed.

To setup the counter capability you select one of the two counters listed below (the count results are expected to be the same). The definition will fill bits 29-28 of PMNC_PME register. For example:

	Bits 29-28 in binary
BCS_NCMH_Lock_Message	01
BCS_NCMH_Unlock_Message	10

The PMR for the chosen counter for this event should have values shown in the "NCMH Event Setup" section.

There are a number of different latency measurements that can be taken in the PE and NCMH units. A single measurement is taken by counting the number of cycles from a Start Event to a Stop Event. As a single measurement isn't useful, the average latency is measured by counting the latencies of all target transactions and dividing that by the number of target transactions. [The counter definition above is the definition of **target transactions** for this example.]

A pair of counters is required to accumulate the total latency time. PAIR0_CNT0 is set up to create a signal that lasts for the duration of the transaction. The start event of the transaction (for example Lock sent to NCMH) is the Event Source; the stop event (Unlock sent to NCMH) is programmed as the Event Source input to the Partner counter and is used by PAIR0_CNT0 as the reset source. The compare register for this counter is initialized with one and the compare output is sent to the partner as the Status Output.

Set up the NCMH event registers for a Lock Latency transaction: Event 0 is the Lock, Event1 is the Unlock. The monitoring event is requested by
BCS_NCMH_Lock_Message_Latency

Pair0_PMNC_PME0

	Bits 29-28 in binary
BCS_NCMH_Lock_Message	01

Lock Latency Event : Lock message sent = 01

Pair0_PMNC_PME1

	Bits 29-28 in binary
BCS_NCMH_Unlock_Message	10

Set up PMCC for the Interval Timer or Local Count Enable method of running the monitor. Collect the results by reading the counter PMD registers. Note that PAIR0_CNT0 is not read as it is not interesting.

The **PAIR0_CNT0_PMR** for this event should have the following settings:
Counter Enable Source : local count enable/timer = 001

Counter Status Output Source : partner = 001
Count Mode : count events = 00
Counter Event Source : unit pme event = 000
Counter and Status Reset Source : partner's incoming event = 010
Compare Mode : max compare = 01
Unit Event Source : ncmh = 000000001
Unit Type Source : PE = 00

The **PAIR0_CNT1_PMR** for this event should have the following settings:
Counter Enable Source : local count enable/timer = 001
Counter Status Output Source : perfcon = 000
Count Mode : count events = 00
Counter Event Source : partner status = 001
Counter and Status Reset Source : no reset = 000
Compare Mode : disabled = 00
Unit Event Source : same as PAIR0_CNT0_PMR
Unit Type Source : PE = 00

The **PAIR0_CNT0_PMC** for this event should have the Compare value set to 1.

PAIR0_CNT1 is setup to count cycles for the duration of the transaction, the sum of the latencies of all target transactions. The partner status, the comparison of the PAIR0_CNT0_PMD with the value in PMC (=1), is the Event Source. Note that the Unit Event Source is set up for one of the PE units, but it is not being used as the Counter Event Source for this counter; it is being used by the partner as a reset source (remember the hard link between event0/counter0 and event1/counter1).

ECC Error Monitoring

You select the ECC errors you want to count.
The definition will fill bits 33-30 of the PMNC_PME register. For example:

	Bits 33-30 in binary
BCS_NCMH_ECC_Error[CXS]	0001
BCS_NCMH_ECC_Error[CXS+XCS]	0011

Where the set of inclusive ECC Error Types and their abbreviations are

QPI to XQPI (NCCX) Single ECC error	CXS
XQPI to QPI (NCXC) Single ECC error	XCS
QPI to XQPI Double ECC error	CXD
XQPI to QPI Double ECC error	XCD

The PMR for the chosen counter for this event should have values shown in the "NCMH Event Setup" section.

Interface Monitoring

You select QPI or XQPI to Output Buffer (NCCX to OB or NCXC to OB). You select the Event that you want to count.
The definition will fill bits 36-34 of PMNC_PME register. For example

	Bits 36-34 in binary
BCS_NCMH_NCCX_OB[PKT]	001
BCS_NCMH_NCXC_OB[FLT]	110

Where the set of exclusive Interface Events and their abbreviations are

A Packet has been emitted	PKT
A Flit has been emitted	FLT
Lack of credit on a Flit waiting to be emitted	LOC

The PMR for the chosen counter for this event should have values shown in the "NCMH Event Setup" section.

Traffic Monitoring

You select direction: QPI to XQPI or XQPI to QPI. You select the destination node ID (DNID) and its DNID Mask. You select the requestor node ID (RHNID) and its RHNID Mask. You select Transaction Type and Mask (msgclass + opcode).

The Traffic Monitoring fields are:

Destination Node ID (NID)	DNID
Destination NID Mask	DNIDM
Request NID	RNID
Request NID Mask	RNIDM
Transaction Type MsgClass	MC
Transaction Type OpCode	OC
Transaction Type MsgClass Mask	MCM
Transaction Type OpCode Mask	OCM

The definition will fill bits 73-37 of PMNC_PME register. For example:

Bits 73-37 in binary

BCS_NCMH_QPI_XQPI_Traffic[DNID=0,DNIDM=0,
RNID=0,RNIDM=0,MC=DRS,MCM=0xF,OC=0x0,OCM=0x0]
00000000000000000000011101111100000000

BCS_NCMH_XQPI_QPI_Traffic[DNID=0,DNIDM=0,
RNID=0,RNIDM=0,MC=DRS,MCM=0xF,OC=0x0,OCM=0x0]
10000000000000000000011101111100000000

The PMR for the chosen counter for this event should have values shown in the "NCMH Event Setup" section.

LL Event Setup

The event interface from most LL blocks in the BCS chip was connected incorrectly making many of the event selections non-functional. In fact only one remains usable.

For the LL count events the PMR for the chosen counter for this event should have the following settings where Unit Event Source can have one of four values:

Counter Enable Source :	local count enable = 001
Counter Status Output Source :	perfcon = 000
Count Mode :	count events = 00
Counter Event Source :	unit pme event = 000
Counter and Status Reset Source :	no reset = 000
Compare Mode :	disabled = 00
Unit Event Source :	LLch0-3 & LLih0-1 & LLxh0-2 = 111111111
Unit Type Source :	LL = 01

The Unit Event Source can have the above value if LLch0-3, LLih0-1 and LLxh0-3 are configured to provide the source of the count. Here are the four choices:

Unit Event Source :	LLch0-3 & LLih0-1 & LLxh0-2 = 111111111
Unit Event Source :	LLch0-3 = 111100000
Unit Event Source :	LLih0-1 = 000011000
Unit Event Source :	LLxh0-2 = 000000111

The syntax for the expert user that does not wish any software tool help in defining an event is to provide the PMR and PMLL_PME register contents:

BCS_LL[PMR=0x3FF00004,LLCH=0.0x7E0420,LLIH=0.0x7E0420, LLXH=0.0x7E0420]

Interface Monitoring

You select the Select the type of OB to LL traffic needed. You select the Event.

The Interface Monitoring fields are

Interface Select	IS
Interface Event	IE

The definition will fill bits 32-25 of PMLL_PME register. The PMR for the chosen counter for this event should have values shown in the "LL Event Setup" section with Unit Event Source chosen as LLch0-3, LLih0-1 and LLxh0-3. For example

	Bits 32-25 in binary
BCS_LL_Interface[IS=OL01,IE=FLT]	10001011

Where the set of exclusive Interface Select Types and their abbreviations are:

(X)QPI to LL Flit 0 and 1	CL01
(X)QPI to LL Flit 2 and 3	CL23
(X)QPI to LL Flit 0, 1, 2 and 3	CL0123
(X)QPI to LL Flit 0, 1, 2 and 3 and VNO Traffic Only	CLV
LL to HD*R	LHR
LL to HD*L	LHL
LL to HD*L; Snoop Traffic Only	LSNP
LL to NC Flit 0 and 1	LN01
LL to RO Flit 0 and 1	LR01
LL to RO Flit 2 and 3	LR23
LL to RO Flit 0, 1 ,2 and 3	LR0123
LLC/I to OBX or LLX to OBC/I_REM Flit 0 and 1	LOBX
LLC to OBC_LOM	LOBC
OB to LL Flit 0	OL0
OB to LL Flit 1	OL1
OB to LL Flit 2	OL2
OB to LL Flit 3	OL3
OB to LL Flit 0 and 1	OL01
OB to LL Flit 2 and 3	OL23
OB to LL Flit 0, 1 ,2 and 3	OL0123
OB to LL Flit 0, 1 ,2 and 3 and VNO Traffic Only	OLV

Where the set of exclusive Interface Event Types and their abbreviations are

A Packet has been Emitted	PKT
A Packet has been Emitted with Idle Latency	PIL
A Flit has been Emitted	FLT
Lack or Credit on a Flit Waiting to be Emitted	LOC

For Unit Event Source chosen as LLch0-3, here is an example:

BCS_LL_LLCH_Interface[IS=OL01,IE=FLT]	10001011

For Unit Event Source chosen as LLih0-1, here is an example:

BCS_LL_LLIH_Interface[IS=OL01,IE=FLT]	10001011

For Unit Event Source chosen as LLxh0-2, here is an example:

BCS_LL_LLXH_Interface[IS=OL01,IE=FLT]	10001011

RO Event Setup

Only internal Interface Traffic is measured.

For the RO count events the PMR for the chosen counter for this event should have the following settings where Unit Event Source can have one of three values:

Counter Enable Source :	local count enable = 001
Counter Status Output Source :	perfcon = 000
Count Mode :	count events = 00
Counter Event Source :	unit pme event = 000
Counter and Status Reset Source :	no reset = 000
Compare Mode :	disabled = 00
Unit Event Source :	ROIC & ROCI = 110000000
Unit Type Source :	RO = 10

The Unit Event Source can have the above value if both ROIC and ROCI are configured to provide the source of the count. Here are the three choices:

Unit Event Source :	ROIC & ROCI = 110000000
Unit Event Source :	ROIC = 100000000
Unit Event Source :	ROCI = 010000000

The syntax for the expert user that does not wish any software tool help in defining an event is to provide the PMR and PMRO_PME register contents:

BCS_RO[PMR=0x58000004,ROIC=2,ROCI=2]

Interface Monitoring

You select the Select of the type of traffic needed. You select the Event.

The Interface Monitoring fields are:

Interface Select	IS
Interface Event	IE

The definition will fill bits 3-0 of PMRO_PME register. The PMR for the chosen counter for this event should have values shown in the "RO Event Setup" section with Unit Event Source chosen as ROIC and ROCI. For example:

	Bits 3-0 in binary
BCS_RO_Interface[IS=ROB01,IE=LOC]	1011

Where the set of exclusive Interface Select Types and their abbreviations are:

RO to OB Flow 0	ROB0
RO to OB Flow 1	ROB1
RO to OB Flow 0 and 1	ROB01
ROIC to ROCI Flow 0 and 1	ICCI

Where the set of exclusive Interface Event Types and their abbreviations are:

A Packet has been Emitted	PKT
A Flit has been Emitted	FLT
Lack or Credit on a Flit Waiting to be Emitted	LOC

For Unit Event Source chosen as ROIC, here is an example:

BCS_RO_ROIC_Interface[IS=ROB01,IE=LOC]	1011

For Unit Event Source chosen as ROCI, here is an example:

BCS_RO_ROCI_Interface[IS=ROB01,IE=LOC]	1011

A.6 BCS Key Architectural Values

Message Class and Opcode Mapping

Any Opcodes not explicitly defined are reserved for future use. Opcodes listed as **unsupported** have been found to be unsupported in the current version of the BCS. Other Opcodes may also be unsupported; anyone wishing to discover them is directed to the Intel QPI Protocol Specification. Likewise, a NHM or TWK designation means that the Opcode is only valid for that platform. Once again, the designation is not exhaustive, the assumption being that a user who is counting events based upon Opcodes has the knowledge to be doing so, or access to documentation that would interpret it. Also, NcMsgB and NcMsgS contain six and ten message types respectively which cannot be differentiated for performance monitoring.

Message Class	Name	Message Class Encoding	Opcode
Snoop (SNP /3)	SnpCur	0011	0000
	SnpCode	0011	0001
	SnpData	0011	0010
	SnpInvOwn	0011	0100
	SnpInvWbMtoI or SnpInvXtoI	0011	0101
	SnpInvItoE	0011	1000
	PrefetchHint (unsupported)	0011	1111
Home Request (HM / 0)	RdCur	0000	0000
	RdCode	0000	0001
	RdData	0000	0010
	NonSnpRd (unsupported)	0000	0011
	RdInvOwn	0000	0100
	InvWbMtoI or InvXtoI	0000	0101
	EvctCln (NHM)	0000	0110
	NonSnpWr (unsupported)	0000	0111
	InvItoE	0000	1000
	AckCnfltWbI	0000	1001
	WbMtoI	0000	1100
	WbMtoE	0000	1101
	WbMtoS	0000	1110
	AckCnflt	0000	1111
Home Response (HOM / 1)	RspI	0001	0000
	RspS	0001	0001

Message Class	Name	Message Class Encoding	Opcode
	RspCnflt	0001	0100
	RspCnfltOwn	0001	0110
	RspFwd	0001	1000
	RspFwdI	0001	1001
	RspFwdS	0001	1010
	RspFwdIWb	0001	1011
	RspFwdSWb	0001	1100
	RspIWb	0001	1101
	RspSWb	0001	1110
Response Channel - Data (DRS / 14)	DataC_(FEIMS)	1110	0000
	DataNc	1110	0011
	DataC_(FEIS)_FrcAckCnflt	1110	0001
	DataC_(FEIS)_Cmp	1110	0010
	WbiData	1110	0100
	WbSData	1110	0101
	WbEData	1110	0110
	NonSnpWrData (unsupported)	1110	0111
	WbIDataPtl	1110	1000
	WbEDataPtl	1110	1010
	NonSnpWrDataPtl (unsupported)	1110	1011
Response Channel - Non Data (NDR / 2)	Gnt_Cmp	0010	0000
	Gnt_FrcAckCnflt	0010	0001
	Cmp	0010	1000
	FrcAckCnflt	0010	1001
	Cmp_FwdCode	0010	1010
	Cmp_FwdInvOwn	0010	1011
	Cmp_FwdInvItoE	0010	1100
	CmpD	0010	0100
	AbortTO (unsupported)	0010	0101

Message Class	Name	Message Class Encoding	Opcode
Non Coherent Bypass (NCB /12)	NcWr	1100	0000
	WcWr	1100	0001
	NcMsgB	1100	1000
	PurgeTC (TKW)	1100	1001
	IntLogical (NHM)	1100	1001
	IntPhysical	1100	1010
	IntPrioUpd	1100	1011
	NcWrPtl	1100	1100
	WcWrPtl	1100	1101
	NCP2PB	1100	1110
	DebugData	1100	1111
Non Coherent Standard (NCS / 4)	NcRd	0100	0000
	IntAck	0100	0001
	FERR	0100	0011
	NcRdPtl	0100	0100
	NcCfgRd	0100	0101
	NcLTRd (unsupported)	0100	0110
	NcIORd	0100	0111
	NcCfgWr	0100	1001
	NcLTWr (unsupported)	0100	1010
	NcIOWr	0100	1011
	NcMsgS	0100	1100
	NcP2PS	0100	1101

Table A-1. Message Class and Opcode Mapping

QPI and XQPI NodeID Maps

The following are the NodeID maps that represent the QPI NodeIDs used by the protocol internal to the mainboard and the XQPI NodeIDs used by the protocol between mainboards.

QPI NodeID Map

Component	Agent	NID
NHM 0	CA0/ HA0	00001
	Ubox	00010
	CA1/HA1	00011
NHM 1	CA0/ HA0	00101
	Ubox	00110
	CA1/HA1	00111
NHM 2	CA0/ HA0	01001
	Ubox	01010
	CA1/HA1	01011
NHM 3	CA0/ HA0	01101
	Ubox	01110
	CA1/HA1	01111
IOH 0		00000
IOH 1		00100
BCS	CA0/HA0	10001
	NCM	10010
	CA1/HA1	10011
	HA2	10101
	HA3	10111

Table A-2. QPI NodeID Map

XQPI NodeID Map

Component	Agent	NID
BCS 0	CA0/HA0	00000
	CA1/HA1	00001
	NCM	00010
	CA2/HA2	00011
	CA3/HA3	00100
BCS 1	CA0/HA0	01000
	CA1/HA1	01001
	NCM	01010
	CA2/HA2	01011
	CA3/HA3	01100
BCS 2	CA0/HA0	10000
	CA1/HA1	10001
	NCM	10010
	CA2/HA2	10011
	CA3/HA3	10100
BCS 3	CA0/HA0	11000
	CA1/HA1	11001
	NCM	11010
	CA2/HA2	11011
	CA3/HA3	11100

Table A-3. XQPI NodeID Map

A.7 Configuration Management Description

Performance Monitor Configuration Registers

Register Symbolic Name	Real Address	CSR Address	Attribute	Function	Description
	for BCS=0/1/2/3, n=0/2/4/6				
					Registers that should be initialized
PERFCON	0000_FDnC_5000	3_1400	RW	Control and status	Counter control and Status
PTCTL	0000_FDnC_5004	3_1401	RW	Control and status	Interval timer control and Status
PAIR0_CNT0_PMR [31:0]	0000_FDnC_5018	3_1406	RW	Control and status	Pair0 Counter0 resource control and status
PAIR0_CNT1_PMR [31:0]	0000_FDnC_502C	3_140B	RW	Control and status	Pair0 Counter1 resource control and status
PAIR1_CNT0_PMR [31:0]	0000_FDnC_5040	3_1410	RW	Control and status	Pair1 Counter0 resource control and status
PAIR1_CNT1_PMR [31:0]	0000_FDnC_5054	3_1415	RW	Control and status	Pair1 Counter1 resource control and status
PMINIT [31:0]	0000_FDnC_5008	3_1402	RW	Initial value	Initial value of timer, low order bits
PMINIT [44:32]	0000_FDnC_500C	3_1403	RW	Initial value	Initial value of timer, high order bits
					Registers that can be initialized, depending on usage
PAIR0_CNT0_PMC [31:0]	0000_FDnC_501C	3_1407	RW	Initial or current value	Pair0 Counter0 compare value or max count, low order bits
PAIR0_CNT0_PMC [44:32]	0000_FDnC_5020	3_1408	RW	Initial or current value	Pair0 Counter0 compare value or max count, high order bits
PAIR0_CNT1_PMC [31:0]	0000_FDnC_5030	3_140C	RW	Initial or current value	Pair0 Counter1 compare value or max count, low order bits
PAIR0_CNT1_PMC [44:32]	0000_FDnC_5034	3_140D	RW	Initial or current value	Pair0 Counter1 compare value or max count, high order bits
PAIR1_CNT0_PMC [31:0]	0000_FDnC_5044	3_1411	RW	Initial or current value	Pair1 Counter0 compare value or max count, low order bits
PAIR1_CNT0_PMC [44:32]	0000_FDnC_5048	3_1412	RW	Initial or current value	Pair1 Counter0 compare value or max count, high order bits
PAIR1_CNT1_PMC [31:0]	0000_FDnC_5058	3_1416	RW	Initial or current value	Pair1 Counter1 compare value or max count, low order bits
PAIR1_CNT1_PMC [44:32]	0000_FDnC_505C	3_1417	RW	Initial or current value	Pair1 Counter1 compare value or max count, high order bits
					Registers that are read and can be cleared
PAIR0_CNT0_PMD [31:0]	0000_FDnC_5024	3_1409	RW	Current value	Pair0 Counter0 current count, low order bits
PAIR0_CNT0_PMD [44:32]	0000_FDnC_5028	3_140A	RW	Current value	Pair0 Counter0 current count, high order bits
PAIR0_CNT1_PMD	0000_FDnC_5038	3_140E	RW	Current value	Pair0 Counter1 current count, low order

Register Symbolic Name	Real Address	CSR Address	Attribute	Function	Description
[31:0]					bits
PAIR0_CNT1_PMD [44:32]	0000_FDnC_503C	3_140F	RW	Current value	Pair0 Counter1 current count, high order bits
PAIR1_CNT0_PMD [31:0]	0000_FDnC_504C	3_1413	RW	Current value	Pair1 Counter0 current count, low order bits
PAIR1_CNT0_PMD [44:32]	0000_FDnC_5050	3_1414	RW	Current value	Pair1 Counter0 current count, high order bits
PAIR1_CNT1_PMD [31:0]	0000_FDnC_5060	3_1418	RW	Current value	Pair1 Counter1 current count, low order bits
PAIR1_CNT1_PMD [44:32]	0000_FDnC_5064	3_1419	RW	Current value	Pair1 Counter1 current count, high order bits
					Registers that are only read
PMTIM [31:0]	0000_FDnC_5010	3_1404	RO		
PMTIM [44:32]	0000_FDnC_5014	3_1405	RO		

Table A-4. Performance Monitor Configuration Registers

Event Configuration Registers

Register Symbolic Name	Real Address	CSR Address	Attribute	Function	Description
	for BCS=0/1/2/3, n=0/2/4/6				
	for Inst=0/1/2/3, i=0/1/2/3, k=0/4/8/C				
u_LLCH.PMLL0	0000_FDni_0000	0_k000	RW	LLCH events	Event0 bits [31:0]
u_LLCH.PMLL0	0000_FDni_0004	0_k001	RW	LLCH events	Event0 bit [32]
u_LLCH.PMLL1	0000_FDni_2000	0_k800	RW	LLCH events	Event1 bits [31:0]
u_LLCH.PMLL1	0000_FDni_2004	0_k801	RW	LLCH events	Event1 bit [32]
	for Inst=0/1, i=4/5, k=0/4				
u_LLIH.PMLL0	0000_FDni_0000	1_k000	RW	LLIH events	Event0 bits [31:0]
u_LLIH.PMLL0	0000_FDni_0004	1_k001	RW	LLIH events	Event0 bit [32]
u_LLIH.PMLL1	0000_FDni_2000	1_k800	RW	LLIH events	Event1 bits [31:0]
u_LLIH.PMLL1	0000_FDni_2004	1_k801	RW	LLIH events	Event1 bit [32]
	for Inst=0/1/2, i=8/9/A, k=0/4/8				
u_LLXH.PMLL0	0000_FDni_0000	2_k000	RW	LLXH events	Event0 bits [31:0]
u_LLXH.PMLL0	0000_FDni_0004	2_k001	RW	LLXH events	Event0 bit [32]
u_LLXH.PMLL1	0000_FDni_1000	2_k400	RW	LLXH events	Event1 bits [31:0]
u_LLXH.PMLL1	0000_FDni_1004	2_k401	RW	LLXH events	Event1 bit [32]
u_ROIC.PMRO0	0000_FDn6_CC20	1_B308	RW	ROIC events	Event0 bits [3:0]
u_ROIC.PMRO1	0000_FDn6_CC24	1_B309	RW	ROIC events	Event1 bits [3:0]
u_ROCI.PMRO0	0000_FDn7_CC20	1_F308	RW	ROCI events	Event0 bits [3:0]

Register Symbolic Name	Real Address	CSR Address	Attribute	Function	Description
u_ROCI.PMRO1	0000_FDn7_CC24	1_F309	RW	ROCI events	Event1 bits [3:0]
u_NCMH.PMNC0	0000_FDnC_6000	3_1800	RW	NCMH events	Event0 bits [31:0]
u_NCMH.PMNC0	0000_FDnC_6004	3_1801	RW	NCMH events	Event0 bits [63:32]
u_NCMH.PMNC0	0000_FDnC_6008	3_1802	RW	NCMH events	Event0 bits [73:64]
u_NCMH.PMNC1	0000_FDnC_7000	3_1C00	RW	NCMH events	Event1 bits [31:0]
u_NCMH.PMNC1	0000_FDnC_7004	3_1C01	RW	NCMH events	Event1 bits [63:32]
u_NCMH.PMNC1	0000_FDnC_7008	3_1C02	RW	NCMH events	Event1 bits [73:64]
	for BCS=0/1/2/3, n=1/3/5/7				
	for Inst=0/1/2/3, i=0/1/2/3, k=0/4/8/C				
u_REMH.u_REM.PMPE0	0000_FDni_3000	4_kC00	RW	REMH events	Event0 bits [31:0]
u_REMH.u_REM.PMPE0	0000_FDni_3004	4_kC01	RW	REMH events	Event0 bits [63:32]
u_REMH.u_REM.PMPE0	0000_FDni_3008	4_kC02	RW	REMH events	Event0 bits [95:64]
u_REMH.u_REM.PMPE0	0000_FDni_300C	4_kC03	RW	REMH events	Event0 bits [118:96]
u_REMH.u_REM.PMPE1	0000_FDni_3800	4_kE00	RW	REMH events	Event1 bits [31:0]
u_REMH.u_REM.PMPE1	0000_FDni_3804	4_kE01	RW	REMH events	Event1 bits [63:32]
u_REMH.u_REM.PMPE1	0000_FDni_3808	4_kE02	RW	REMH events	Event1 bits [95:64]
u_REMH.u_REM.PMPE1	0000_FDni_380C	4_kE03	RW	REMH events	Event1 bits [118:96]
	for Inst=0/1/2/3, i=4/5/6/7, k=0/4/8/C				
u_LOMH.u_LOM.PMPE0	0000_FDni_3000	5_kC00	RW	LOMH events	Event0 bits [31:0]
u_LOMH.u_LOM.PMPE0	0000_FDni_3004	5_kC01	RW	LOMH events	Event0 bits [63:32]
u_LOMH.u_LOM.PMPE0	0000_FDni_3008	5_kC02	RW	LOMH events	Event0 bits [95:64]
u_LOMH.u_LOM.PMPE0	0000_FDni_300C	5_kC03	RW	LOMH events	Event0 bits [118:96]
u_LOMH.u_LOM.PMPE1	0000_FDni_3800	5_kE00	RW	LOMH events	Event1 bits [31:0]
u_LOMH.u_LOM.PMPE1	0000_FDni_3804	5_kE01	RW	LOMH events	Event1 bits [63:32]
u_LOMH.u_LOM.PMPE1	0000_FDni_3808	5_kE02	RW	LOMH events	Event1 bits [95:64]
u_LOMH.u_LOM.PMPE1	0000_FDni_380C	5_kE03	RW	LOMH events	Event1 bits [118:96]

Table A-5. Event Configuration Registers

A.8 BCS BPMON Usage Examples

Total Memory Traffic For All BCSs Using Incoming Traffic

This BPMON monitor setup collects all the reads and writes from the requesting nodes (using REM events) and the local nodes fulfilling the requests (using LOM events) using Incoming Traffic. As the example shows the REM event counts closely match the LOM events counts. Read opcodes are counted by using a mask to get the RdCur, RdCode, RdData from the HOM0 Message Class in an event. The Write opcode, RdInvOwn, is specifically counted in a different event.

The test used generates reads for one test pass and writes for another test pass. The test program generates about 500,000,000 remote memory requests per program instance and four instances are executed. Here are the read results from BPMON that also shows the BCS performance events measured.

```
+-------------------------------------------------------------------+
|     BPMON Single Thread Event Results                             |
+-------------------------------------------------------------------+
Event Description                                        Event Count
BCS_PE_REM_Incoming_Traffic                                1978856781
[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=0x01,NIDM=0x01]
BCS_PE_REM_Incoming_Traffic                                1066138
[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=0x01,NIDM=0x01]
BCS_PE_LOM_Incoming_Traffic                               1976723675
[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=0,NIDM=0x00]
BCS_PE_LOM_Incoming_Traffic                                1063453
[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=0,NIDM=0x00]
```

Here are the write results from BPMON that also shows the BCS performance events measured.

```
+-------------------------------------------------------------------+
|     BPMON Single Thread Event Results                             |
+-------------------------------------------------------------------+
Event Description                                        Event Count
BCS_PE_REM_Incoming_Traffic                                11792759
[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=0x01,NIDM=0x01]
BCS_PE_REM_Incoming_Traffic                                1940487514
[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=0x01,NIDM=0x01]
BCS_PE_LOM_Incoming_Traffic                                9609143
[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=0,NIDM=0x00]
BCS_PE_LOM_Incoming_Traffic                                1940484848
[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=0,NIDM=0x00]
```

Total Memory Traffic for All BCSs Using Outgoing Traffic

This BPMON monitor setup collects all the reads and writes from the requesting nodes (using LOM events) and the local nodes fulfilling the requests (using REM events) using Outgoing Traffic. As the example shows the LOM event counts closely match the REM events counts. Read opcodes are counted by using a mask to get the RdCur, RdCode, RdData from the HOM0 Message Class in an event. The Write opcode, RdInvOwn, is specifically counted in a different event.

The test used generates reads for one test pass and writes for another test pass. The test program generates about 500,000,000 remote memory requests per program instance and four instances are executed. Here are the read results from BPMON that also shows the BCS performance events measured.

```
+-------------------------------------------------------------------+
|     BPMON Single Thread Event Results                             |
+-------------------------------------------------------------------+
Event Description                                              Event Count
BCS_PE_REM_Outgoing_Traffic                                     1976316475
[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=0x00,NIDM=0x00]
BCS_PE_REM_Outgoing_Traffic                          10              23535
[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=0x00,NIDM=0x00]
BCS_PE_LOM_Outgoing_Traffic                                     1975865466
[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=0x01,NIDM=0x01]
BCS_PE_LOM_Outgoing_Traffic                                        1021035
[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=0x01,NIDM=0x01]
```

Here are the write results from BPMON that also shows the BCS performance events measured.

```
+-------------------------------------------------------------------+
|     BPMON Single Thread Event Results                             |
+-------------------------------------------------------------------+
Event Description                                              Event Count
BCS_PE_REM_Outgoing_Traffic                                        9663484
[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=0x00,NIDM=0x00]
BCS_PE_REM_Outgoing_Traffic                                     1941802417
[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=0x00,NIDM=0x00]
BCS_PE_LOM_Outgoing_Traffic                                        9217576
[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=0x01,NIDM=0x01]
BCS_PE_LOM_Outgoing_Traffic                                     1941799879
[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=0x01,NIDM=0x01]
```

Memory Traffic For a Source and a Destination BCS Using Incoming Traffic

This BPMON monitor setup collects all the reads and writes from the requesting node on BCS0 (using REM events) and the local node fulfilling the requests on BCS3 (using LOM events) using Incoming Traffic. As the example shows the REM event counts closely match the LOM events counts.

The test used generates reads for one test pass and writes for another test pass. The test program generates about 500,000,000 remote memory requests per program instance and one instance is executed. Here are the read results from BPMON that also shows the BCS performance events measured.

```
+-------------------------------------------------------------------+
|     BPMON Single Thread Event Results                             |
+-------------------------------------------------------------------+
Event Description                                          Event Count
BCS0_PE_REM_Incoming_Traffic                                 496006785
[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=0x01,NIDM=0x01]
BCS0_PE_REM_Incoming_Traffic                                    246838
[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=0x01,NIDM=0x01]
BCS3_PE_LOM_Incoming_Traffic                                 494996140
[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=0,NIDM=0x00]
BCS3_PE_LOM_Incoming_Traffic                                    221481
[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=0,NIDM=0x00]
```

Here are the write results from BPMON that also shows the BCS performance events measured.

```
+-------------------------------------------------------------------+
|     BPMON Single Thread Event Results                             |
+-------------------------------------------------------------------+
Event Description                                          Event Count
BCS0_PE_REM_Incoming_Traffic                                   3485584
[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=0x01,NIDM=0x01]
BCS0_PE_REM_Incoming_Traffic                                 489939668
[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=0x01,NIDM=0x01]
BCS3_PE_LOM_Incoming_Traffic                                   2502476
[MC=HOM0,MCM=0xF,OC=0,OCM=0xC,NID=0,NIDM=0x00]
BCS3_PE_LOM_Incoming_Traffic                                 489917358
[MC=HOM0,MCM=0xF,OC=RdInvOwn,OCM=0xF,NID=0,NIDM=0x00]
```

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