Extrae Documentation

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CHAPTER

ONE

QUICK START GUIDE

1.1 The instrumentation package

1.1.1 Uncompressing the package

Extrae is a dynamic instrumentation package to trace programs compiled and run with the shared memory model (like OpenMP and pthreads), the message passing (MPI) programming model or both programming models (different MPI processes using OpenMP or pthrads within each MPI process). **Extrae** generates trace files that can be later visualized with **Paraver**.

The package is distributed in compressed tar format (*e.g.,* extrae.tar.gz). To unpack it, execute from the desired target directory the following command:

```
gunzip -c extrae.tar.gz | tar -xvf -
```

The unpacking process will create different directories on the current directory (see Table 1.1).

Table 1.1: Package contents description

Directory	Contents
bin	Contains the binary files of the **Extrae** tool.
etc	Contains some scripts to set up environment variables and the **Extrae** internal files.
lib	Contains the **Extrae** tool libraries.
share/man	Contains the **Extrae** manual entries.
share/doc	Contains the **Extrae** manuals (pdf, ps and html versions).
share/example	Contains examples to illustrate the **Extrae** instrumentation.

1.2 Quick running

Note: There are several included examples in the installation package. These examples are installed in `$EXTRAE_HOME/share/example` and cover different application types (including serial/MPI/OpenMP/CUDA/*etc.*). We suggest the user to look at them to get an idea on how to instrument their application.

Once the package has been unpacked, set the *EXTRAE_HOME* environment variable to the directory where the package was installed. Use the **export** or **setenv** commands to set it up depending on the shell you use. If you use sh-based shell (like **sh**, **bash**, **ksh**, **zsh**, . . .), issue this command:

```
export EXTRAE_HOME=<DIR>
```

however, if you use **csh**-based shell (like **csh**, **tcsh**), execute the following command:

```
setenv EXTRAE_HOME <DIR>
```

where <*DIR*> refers where **Extrae** was installed.

Note: Henceforth, all references to the usage of the environment variables will be used following the **sh** format unless specified.

Extrae is offered in two different flavors: as a DynInst-based application, or stand-alone application. DynInst is a dynamic instrumentation library that allows the injection of code in a running application without the need to recompile the target application. If the DynInst instrumentation library is not installed, **Extrae** also offers different mechanisms to trace applications.

1.2.1 Quick running Extrae - based on DynInst

Extrae needs some environment variables to be setup on each session. Issuing the command:

```
source ${EXTRAE_HOME}/etc/extrae.sh
```

on a **sh**-based shell, or

```
source ${EXTRAE_HOME}/etc/extrae.csh
```

on a **csh**-based shell will do the work. Then copy the default XML configuration file[1] into the working directory by executing:

```
cp ${EXTRAE_HOME}/share/example/MPI/extrae.xml .
```

If needed, set the application environment variables as usual (like `OMP_NUM_THREADS`, for example), and finally launch the application using the **`${EXTRAE_HOME}/bin/extrae`** instrumenter like:

```
${EXTRAE_HOME}/bin/extrae -config extrae.xml <PROGRAM>
```

where <*PROGRAM*> is the application binary.

1.2.2 Quick running Extrae - NOT based on DynInst

Extrae needs some environment variables to be setup on each session. Issuing the command:

```
source ${EXTRAE_HOME}/etc/extrae.sh
```

on a **sh**-based shell, or:

```
source ${EXTRAE_HOME}/etc/extrae.csh
```

on a **csh**-based shell will do the work. Then copy the default XML configuration file[1] into the working directory by executing:

```
cp ${EXTRAE_HOME}/share/example/MPI/extrae.xml .
```

and export `EXTRAE_CONFIG_FILE` as:

```
export EXTRAE_CONFIG_FILE=extrae.xml
```

If needed, set the application environment variables as usual (like `OMP_NUM_THREADS`, for example). Just before executing the target application, issue the following command:

[1] See section *Extrae XML configuration file* for further details regarding this file.

```
export LD_PRELOAD=${EXTRAE_HOME}/lib/<LIB>
```

where <*LIB*> is one of the libraries listed under **${EXTRAE_HOME}/lib** Table 1.2.

Table 1.2: Some of the available libraries in **Extrae**. Their availability depends upon the configure process.

Library	**Application type**								
	Serial	*MPI*	*OpenMP*	*pthread*	*SMPss*	*nanos/OMPss*	*CUDA*	*OpenCL*	*Java*
libseqtrace	Yes								
libmpitrace[2]		Yes							
libomptrace			Yes						
libpttrace				Yes					
libsmpsstrace					Yes				
libnanostrace						Yes			
libcudatrace							Yes		
libocltrace								Yes	
javaseqtrace.jar									Yes
libompitrace[2]		Yes	Yes						
libptmpitrace[2]		Yes		Yes					
libsmpssmpitrace[2]		Yes			Yes				
libnanosmpitrace[2]		Yes				Yes			
libcudampitrace[2]		Yes					Yes		
libcudaompitrace[2]		Yes	Yes				Yes		
liboclmpitrace[2]		Yes						Yes	

1.3 Quick merging the intermediate traces

Once the intermediate trace files (`*.mpit` files) have been created, they have to be merged (using the **mpi2prv** command) in order to generate the final **Paraver** trace file. Execute the following command to proceed with the merge:

```
${EXTRAE_HOME}/bin/mpi2prv -f TRACE.mpits -o output.prv
```

The result of the merge process is a **Paraver** tracefile called `output.prv`. If the `-o` option is not given, the resulting tracefile is called `EXTRAE_Paraver_Trace.prv`.

[2] If the application is Fortran append an f to the library. For example, if you want to instrument a Fortran application that is using MPI, use `libmpitracef` instead of `libmpitrace`.

CHAPTER

TWO

INTRODUCTION

Extrae is a dynamic instrumentation package to trace programs compiled and run with the shared memory model (like OpenMP and pthreads), the message passing (MPI) programming model or both programming models (different MPI processes using OpenMP or pthreads within each MPI process). **Extrae** generates trace files that can be visualized with **Paraver**.

Extrae is currently available on different platforms and operating systems: IBM PowerPC running Linux or AIX, and x86 and x86-64 running Linux. It also has been ported to OpenSolaris and FreeBSD.

The combined use of **Extrae** and **Paraver** offers an enormous analysis potential, both qualitative and quantitative. With these tools the actual performance bottlenecks of parallel applications can be identified. The microscopic view of the program behavior that the tools provide is very useful to optimize the parallel program performance.

This document tries to give the basic knowledge to use the **Extrae** tool. Chapter *Configuration, build and installation* explains how the package can be configured and installed. Chapter *Examples* explains how to monitor an application to obtain its trace file. At the end of this document there are appendices that include: *Frequently Asked Questions* and a list of *Instrumented routines* in the package.

2.1 What is the Paraver tool?

Paraver is a flexible parallel program visualization and analysis tool based on an easy-to-use wxWidgets GUI. **Paraver** was developed responding to the need of having a qualitative global perception of the application behavior by visual inspection and then to be able to focus on the detailed quantitative analysis of the problems. **Paraver** provides a large amount of information useful to decide the points on which to invest the programming effort to optimize an application.

Expressive power, flexibility and the capability of efficiently handling large traces are key features addressed in the design of **Paraver**. The clear and modular structure of **Paraver** plays a significant role towers achieving these targets.

Some **Paraver** features are the support for:

- Detailed quantitative analysis of program performance,
- concurrent comparative analysis of several traces,
- fast analysis of very large traces,
- support for mixed message passing and shared memory (network of SMPs), and,
- customizable semantics of the visualized information.

One of the main features of **Paraver** is the flexibility to represent traces coming from different environments. Traces are composed of state records, events and communications with associated timestamps. These three elements can be used to build traces that capture the behavior along time of very different kind of systems. The **Paraver** distribution includes, either in its own distribution or as additional packages, the following instrumentation modules:

1. Sequential application tracing: it is included in the **Paraver** distribution. It can be used to trace the value of certain variables, procedure invocations, ... in a sequential program.

2. Parallel application tracing: a set of modules are optionally available to capture the activity of parallel applications using shared-memory, message-passing paradigms, or a combination of them.
3. System activity tracing in a multiprogrammed environment: an application to trace processor allocations and process migrations is optionally available in the **Paraver** distribution.
4. Hardware counters tracing: an application to trace the hardware counter values is optionally available in the **Paraver** distribution.

2.2 Where can the Paraver tool be found?

The **Paraver** distribution can be found at https://tools.bsc.es/downloads

Paraver binaries are available for Linux/x86, Linux/x86-64 and Linux/ia64, Windows.

In the Documentation section of the aforementioned URL you can find the |PARAVER| *Reference Manual* and |PARAVER| *Tutorial* in addition to the documentation for other instrumentation packages.

Extrae and **Paraver** tools e-mail support is tools@bsc.es.

CHAPTER

THREE

CONFIGURATION, BUILD AND INSTALLATION

3.1 Configuration of the instrumentation package

There are many options to be applied at configuration time for the instrumentation package. We point out here some of the relevant options, sorted alphabetically. To get the whole list run `configure --help`. Options can be enabled or disabled. To enable them use `--enable-X` or `--with-X=` (depending on which option is available), to disable them use `--disable-X` or `--without-X`.

- **`--enable-instrument-dynamic-memory`**

  Allows instrumentation of dynamic memory related calls (such as malloc, free, realloc).

- **`--enable-merge-in-trace`**

  Embed the merging process in the tracing library so the final tracefile can be generated automatically from the application run.

- **`--enable-parallel-merge`**

  Build the parallel mergers (`mpimpi2prv`/`mpimpi2dim`) based on MPI.

- **`--enable-posix-clock`**

  Use POSIX clock (`clock_gettime` call) instead of low level timing routines. Use this option if the system where you install the instrumentation package modifies the frequency of its processors at runtime.

- **`--enable-single-mpi-lib`**

  Produces a single instrumentation library for MPI that contains both Fortran and C wrappers. Applications that call the MPI library from both C and Fortran languages need this flag to be enabled.

- **`--enable-sampling`**

  Enable PAPI sampling support.

- **`--enable-pmapi`**

  Enable PMAPI library to gather CPU performance counters. PMAPI is a base package installed in AIX systems since version 5.2.

- **`--enable-openmp`**

  Enable support for tracing OpenMP on IBM, GNU and Intel runtimes. The IBM runtime instrumentation is only available for Linux/PowerPC systems.

- **`--enable-openmp-gnu`**

  Enable support for tracing OpenMP on GNU runtime.

- **`--enable-openmp-intel`**

  Enable support for tracing OpenMP on Intel runtime.

- **--enable-openmp-ibm**

  Enable support for tracing OpenMP IBM runtime. The IBM runtime instrumentation is only available for Linux/PowerPC systems.

- **--enable-smpss**

  Enable support for tracing SMP-superscalar.

- **--enable-nanos**

  Enable support for tracing Nanos run-time.

- **--enable-online**

  Enables the on-line analysis module.

- **--enable-pthread**

  Enable support for tracing pthread library calls.

- **--enable-xml**

  Enable support for XML configuration (not available on BG/L, BG/P and BG/Q systems).

- **--enable-xmltest**

  Do not try to compile and run a test LIBXML program.

- **--enable-doc**

  Generates this documentation.

- **--prefix**=<PATH>

  Location where the installation will be placed. After issuing `make install` you will find under DIR the entries `lib/`, `include/`, `share` and `bin` containing everything needed to run the instrumentation package.

- **--with-bfd**=<PATH>

  Specify where to find the Binary File Descriptor package. In conjunction with libiberty, it is used to translate addresses into source code locations.

- **--with-binary-type**=<32|64|default>

  Specifies the type of memory address model when compiling (32bit or 64bit).

- **--with-boost**=<PATH>

  Specify the location of the BOOST package. This package is required when using the DynInst instrumentation with versions newer than 7.0.1.

- **--with-elfutils**=<PATH>

  Specify the location for the elfutils package to translate addresses into source code references.

- **--with-binutils**=<PATH>

  Specify the location for the binutils package to translate addresses into source code references. Note that elfutils is preferred.

- **--with-clustering**=<PATH>

  If the on-line analysis module is enabled (see *--enable-online*), specify where to find ClusteringSuite libraries and includes. This package enables support for on-line clustering analysis.

- **--with-cuda**=<PATH>

  Enable support for tracing CUDA calls on nVidia hardware and needs to point to the CUDA SDK installation path. This instrumentation is only valid in binaries that use the shared version of the CUDA library. Interposition has to be done through the `LD_PRELOAD` mechanism. It is superseded by *--with-cupti* which also supports instrmentation for static binaries.

- **--with-cupti**=<PATH>

  Specify the location of the CUPTI libraries. CUPTI is used to instrument CUDA calls, and supersedes the *--with-cuda*, although it still requires it.

- **--with-dyninst**=<PATH>

  Specify the installation location for the DynInst package. **Extrae** also requires the DWARF package --with-dwarf when using DynInst. Also, newer versions of DynInst (versions after 7.0.1) require the BOOST package *--with-boost*. This flag is mandatory. Requires a working installation of a C++ compiler.

- **--with-fft**=<PATH>

  If the spectral analysis module is enabled (see *--with-spectral*), specify where to find FFT libraries and includes. This library is a dependency of the Spectral libraries.

- **--with-java-jdk**=<PATH>

  Specify the location of JAVA development kit (JDK). This is necessary to create the connectors between **Extrae** and Java applications.

- **--with-java-aspectj**=<PATH>

  Specify the location of the AspectJ infrastructure. AspectJ is used to give support to dynamically instrumented Java applications.

- **--with-java-aspectj-weaver**=<path/to/aspectjweaver.jar>

  AspectJ includes the aspectweaver.jar file that is responsible for the execution of dynamically instrumented Java applications. If *--with-java-aspectj* cannot locate this file, use this option to tell **Extrae** where to find it.

- **--with-liberty**=<PATH>

  Specify where to find the libiberty package. In conjunction with Binary File Descriptor, it is used to translate addresses into source code locations.

- **--with-mpi**=<PATH>

  Specify the location of an MPI installation to be used for the instrumentation package. This flag is mandatory.

- **--with-mpi-name-mangling**=<0u|1u|2u|upcase|auto>

  Choose the Fortran name decoration (0, 1 or 2 underscores) for MPI symbols, or auto to automatically detect the name mangling.

- **--with-synapse**=<PATH>

  If the on-line analysis module is enabled (see *--enable-online*), specify where to find Synapse libraries and includes. This library is a front-end of the MRNet library.

- **--with-openacc**=<PATH>

  Specifies the location of OpenACC includes and libraries. It usually is the base installation folder of the compiler with support to OpenACC. Enables host activity instrumentation, to capture device activity support for CUDA must be also enabled.

- **--with-opencl**=<PATH>

  Specify the location for the OpenCL package, including library and include directories.

- **--with-openshmem**=<PATH>

  Specify the location of the OpenSHMEM installation to be used for the instrumentation package.

- **--with-papi**=<PATH>

  Specify where to find PAPI libraries and includes. PAPI is used to gather performance counters. This flag is mandatory.

- **--with-spectral**=<PATH>

  If the on-line analysis module is enabled (see *--enable-online*), specify where to find Spectral libraries and includes. This package enables support for on-line spectral analysis.

- **--with-unwind**=<PATH>

  Specify where to find Unwind libraries and includes. This library is used to get callstack information on several architectures (including IA64 and Intel x86-64). This flag is mandatory.

3.2 Build

To build the instrumentation package, just issue `make` after the configuration.

3.3 Check

The **Extrae** package contains some consistency checks. The aim of such checks is to determine whether a functionality is operative in the target environment and/or check whether the development of **Extrae** has introduced any misbehavior. To run the checks, just issue `make check` after the compilation. Please, notice that checks are meant to be run in the machine that the configure script was run, thus the results of the checks on machines with back-end nodes different to front-end nodes (like BG/* systems) are not representative at all.

3.4 Installation

To install the instrumentation package in the directory chosen at configure step (through *--prefix* option), issue `make install`.

3.5 Examples of configuration on different machines

All commands given here are given as an example to configure and install the package, you may need to tune them properly (i.e., choose the appropriate directories for packages and so). These examples assume that you are using a sh/bash shell, you must adequate them if you use other shells (like csh/tcsh).

3.5.1 Cray XC 40 - Extrae 5.1.5

Before issuing the configure command, the following modules were loaded:

- PrgEnv-gnu/5.2.40
- cray-mpich/7.2.2
- cudatoolkit6.5/6.5.14-1.0502.9613.6.1
- libunwind/1.1-CrayGNU-5.2.4

Configuration command:

```
./configure --prefix=${PREFIX}/extrae/5.1.5
            --with-papi=/opt/cray/papi/5.4.1.1
            --with-mpi=/opt/cray/mpt/7.2.2/gni/mpich2-gnu/48
            --with-unwind=/apps/daint/5.2.UP02/easybuild/software/
↪libunwind/1.1-CrayGNU-5.2.40
            --with-cuda=/opt/nvidia/cudatoolkit6.5/6.5.14-1.0502.9613.6.1
            --enable-sampling
            --without-dyninst
```

```
            --with-binary-type=64
            CC=gcc CXX=g++ MPICC=cc
```

Build and installation commands:

```
make
make install
```

3.5.2 Bluegene (L and P variants)

Configuration command:

```
./configure --prefix=/homec/jzam11/jzam1128/aplic/extrae/5.1.5
            --with-papi=/homec/jzam11/jzam1128/aplic/papi/4.1.2.1
            --with-bfd=/bgsys/local/gcc/gnu-linux_4.3.2/powerpc-linux-gnu/
↪powerpc-bgp-linux
            --with-liberty=/bgsys/local/gcc/gnu-linux_4.3.2/powerpc-bgp-
↪linux
            --with-mpi=/bgsys/drivers/ppcfloor/comm
            --without-unwind
            --without-dyninst
```

Build and installation commands:

```
make
make install
```

3.5.3 BlueGene/Q

To enable parsing the XML configuration file, the libxml2 must be installed. As of the time of writing this user guide, we have been only able to install the static version of the library in a BG/Q machine, so take this into consideration if you install the libxml2 in the system. Similarly, the elfutils package (responsible for translating application addresses into source code locations) that is available in the system may not be properly installed and we suggest installing the elfutils from the source code using the BG/Q cross-compiler. Regarding the cross-compilers, we have found that using the IBM XL compilers may require using the XL libraries when generating the final application binary with **Extrae**, so we would suggest using the GNU cross-compilers (`/bgsys/drivers/ppcfloor/gnu-linux/bin/powerpc64-bgq-linux-*`).

If you want to add libxml2 and elfutils support into **Extrae**, your configuration command may resemble to:

```
./configure --prefix=/homec/jzam11/jzam1128/aplic/juqueen/extrae/5.1.5
            --with-mpi=/bgsys/drivers/ppcfloor/comm/gcc
            --without-unwind
            --without-dyninst
            --disable-openmp
            --disable-pthread
            --with-libz=/bgsys/local/zlib/v1.2.5
            --with-papi=/usr/local/UNITE/packages/papi/5.0.1
            --with-xml-prefix=/homec/jzam11/jzam1128/aplic/juqueen/libxml2-
↪gcc
            --with-elfutils=/homec/jzam11/jzam1128/aplic/juqueen/elfutils-
↪gcc
            --enable-merge-in-trace
```

Otherwise, if you do not want to add support for the libxml2 library, your configuration may look like this:

```
./configure --prefix=/homec/jzam11/jzam1128/aplic/juqueen/extrae/5.1.5
            --with-mpi=/bgsys/drivers/ppcfloor/comm/gcc
            --without-unwind
            --without-dyninst
            --disable-openmp
```

```
            --disable-pthread
            --with-libz=/bgsys/local/zlib/v1.2.5
            --with-papi=/usr/local/UNITE/packages/papi/5.0.1
            --disable-xml
```

In any situation, the build and installation commands are:

```
make
make install
```

3.5.4 AIX

Some extensions of **Extrae** do not work properly (nanos, SMPss and OpenMP) on AIX. In addition, if using IBM MPI (aka POE) the make will complain when generating the parallel merge if the main compiler is not xlc/xlC. So, you can either change the compiler or disable the parallel merge at compile step. Also, command `ar` can complain if 64bit binaries are generated. It's a good idea to run make with `OBJECT_MODE=64` set to avoid this.

Compiling the 32bit package using the IBM compilers

Configuration command:

```
CC=xlc
CXX=xlC
./configure --prefix=${PREFIX}/extrae/5.1.5
            --disable-nanos
            --disable-smpss
            --disable-openmp
            --with-binary-type=32
            --without-unwind
            --enable-pmapi
            --without-dyninst
            --with-mpi=/usr/lpp/ppe.poe
```

Build and installation commands:

```
make
make install
```

Compiling the 64bit package without the parallel merge

Configuration command:

```
./configure --prefix=${PREFIX}/extrae/5.1.5
            --disable-nanos
            --disable-smpss
            --disable-openmp
            --disable-parallel-merge
            --with-binary-type=64
            --without-unwind
            --enable-pmapi
            --without-dyninst
            --with-mpi=/usr/lpp/ppe.poe
```

Build and installation commands:

```
OBJECT_MODE=64 make
make install
```

3.5.5 Linux

Compiling using default binary type using MPICH, OpenMP and PAPI

Configuration command:

```
./configure --prefix=${PREFIX}/extrae/5.1.5
            --with-mpi=/home/harald/aplic/mpich/1.2.7
            --with-papi=/usr/local/papi
            --enable-openmp
            --without-dyninst
            --without-unwind
```

Build and installation commands:

```
make
make install
```

Compiling 32bit package in a 32/64bit mixed environment

Configuration command:

```
./configure --prefix=${PREFIX}/extrae/5.1.5
            --with-mpi=/opt/osshpc/mpich-mx
            --with-papi=/gpfs/apps/PAPI/3.6.2-970mp
            --with-binary-type=32
            --with-unwind=${HOME}/aplic/unwind/1.0.1/32
            --with-elf=/usr
            --with-dwarf=/usr
            --with-dyninst=${HOME}/aplic/dyninst/7.0.1/32
```

Build and installation commands:

```
make
make install
```

Compiling 64bit package in a 32/64bit mixed environment

Configuration command:

```
./configure --prefix=${PREFIX}/extrae/5.1.5
            --with-mpi=/opt/osshpc/mpich-mx
            --with-papi=/gpfs/apps/PAPI/3.6.2-970mp
            --with-binary-type=64
            --with-unwind=${HOME}/aplic/unwind/1.0.1/64
            --with-elf=/usr
            --with-dwarf=/usr
            --with-dyninst=${HOME}/aplic/dyninst/7.0.1/64
```

Build and installation commands:

```
make
make install
```

Compiling using default binary type, using OpenMPI, DynInst and libunwind

Configuration command:

```
./configure --prefix=${PREFIX}/extrae/5.1.5
            --with-mpi=/home/harald/aplic/openmpi/1.3.1
            --with-dyninst=/home/harald/dyninst/7.0.1
```

```
            --with-dwarf=/usr
            --with-elf=/usr
            --with-unwind=/home/harald/aplic/unwind/1.0.1
            --without-papi
```

Build and installation commands:

```
make
make install
```

Compiling on CRAY XT5 for 64bit package and adding sampling

Notice the `--disable-xmltest`. As backends programs cannot be run in the frontend, we skip running the XML test. Also using a local installation of libunwind.

Configuration command:

```
CC=cc
CFLAGS='-O3 -g'
LDFLAGS='-O3 -g'
CXX=CC CXXFLAGS='-O3 -g'
./configure --prefix=${PREFIX}/extrae/5.1.5
            --with-mpi=/opt/cray/mpt/4.0.0/xt/seastar/mpich2-gnu
            --with-binary-type=64
            --with-xml-prefix=/sw/xt5/libxml2/2.7.6/sles10.1_gnu4.1.2
            --disable-xmltest
            --with-elfutils=/opt/cray/cce/7.1.5/cray-elfutils
            --enable-sampling
            --enable-shared=no
            --with-papi=/opt/xt-tools/papi/3.7.2/v23
            --with-unwind=/ccs/home/user/lib
            --without-dyninst
```

Build and installation commands:

```
make
make install
```

Compiling for the Intel MIC accelerator / Xeon Phi

The Intel MIC accelerators (also codenamed KnightsFerry - KNF and KnightsCorner - KNC) or Xeon Phi processors are not binary compatible with the host (even if it is an Intel x86 or x86/64 chip), thus the **Extrae** package must be compiled specially for the accelerator (twice if you want **Extrae** for the host). While the host configuration and installation has been shown before, in order to compile **Extrae** for the accelerator you must configure **Extrae** like:

Configuration command:

```
./configure --prefix=/home/Computational/harald/extrae-mic
            --with-mpi=/opt/intel/impi/4.1.0.024/mic
            --without-dyninst
            --without-papi
            --without-unwind
            --disable-xml
            --disable-posix-clock
            --with-libz=/opt/extrae/zlib-mic
            --host=x86_64-suse-linux-gnu
            --enable-mic
            CFLAGS="-O -mmic -I/usr/include"
            CC=icc
            CXX=icpc
```

```
            MPICC=/opt/intel/impi/4.1.0.024/mic/bin/mpiicc
```

To compile it, just issue:

```
make
make install
```

Compiling on a ARM based processor machine using Linux

If using the GNU toolchain to compile the library, we suggest at least using version 4.6.2 because of its enhaced in this architecture.

Configuration command:

```
CC=/gpfs/APPS/BIN/GCC-4.6.2/bin/gcc-4.6.2
./configure --prefix=/gpfs/BSCTOOLS/extrae/5.1.5
            --with-unwind=/gpfs/BSCTOOLS/libunwind/1.0.1-git
            --with-papi=/gpfs/BSCTOOLS/papi/4.2.0
            --with-mpi=/usr
            --enable-posix-clock
            --without-dyninst
```

Build and installation commands:

```
make
make install
```

Compiling in a Slurm/MOAB environment with support for MPICH2

Configuration command:

```
export MP_IMPL=anl2
./configure --prefix=${PREFIX}/extrae/5.1.5
            --with-mpi=/gpfs/apps/MPICH2/mx/1.0.8p1..3/32
            --with-papi=/gpfs/apps/PAPI/3.6.2-970mp
            --with-binary-type=64
            --without-dyninst
            --without-unwind
```

Build and installation commands:

```
make
make install
```

Compiling in a environment with IBM compilers and POE

Configuration command:

```
CC=xlc
CXX=xlC
./configure --prefix=${PREFIX}/extrae/5.1.5
            --with-mpi=/opt/ibmhpc/ppe.poe
            --without-dyninst
            --without-unwind
            --without-papi
```

Build and installation commands:

```
make
make install
```

Compiling in a environment with GNU compilers and POE

Configuration command:

```
./configure --prefix=${PREFIX}/extrae/5.1.5
            --with-mpi=/opt/ibmhpc/ppe.poe
            --without-dyninst
            --without--unwind
            --without-papi
```

Build and installation commands:

```
MP_COMPILER=gcc make
make install
```

Compiling Extrae 5.1.5 in Hornet / Cray XC40 system

Configuration command, enabling MPI, PAPI and online analysis over MRNet.

```
./configure --prefix=/zhome/academic/HLRS/xhp/xhpgl/tools/extrae/5.1.5/
↪intel
            --with-mpi=/opt/cray/mpt/7.1.2/gni/mpich2-intel/140
            --with-unwind=/zhome/academic/HLRS/xhp/xhpgl/tools/libunwind
            --without-dyninst
            --with-papi=/opt/cray/papi/5.3.2.1
            --enable-online
            --with-mrnet=/zhome/academic/HLRS/xhp/xhpgl/tools/mrnet/4.1.0
            --with-spectral=/zhome/academic/HLRS/xhp/xhpgl/tools/spectral/
↪3.1
            --with-synapse=/zhome/academic/HLRS/xhp/xhpgl/tools/synapse/2.0
```

Build and installation commands:

```
make
make install
```

Compiling Extrae 5.1.5 in Shaheen II / Cray XC40 system

With the following modules loaded:

```
module swap PrgEnv-XXX/YYY PrgEnv-cray/5.2.40
module load cray-mpich
```

Configuration command, enabling MPI, PAPI:

```
./configure --prefix=${PREFIX}/extrae/5.1.5
            --with-mpi=/opt/cray/mpt/7.1.1/gni/mpich2-cray/83
            --with-binary-type=64
            --with-unwind=/home/markomg/lib
            --without-dyninst
            --disable-xmltest
            --with-elfutils=/opt/cray/cce/default/cray-elfutils
            --enable-sampling
            --enable-shared=no
            --with-papi=/opt/cray/papi/5.3.2.1
```

Build and installation commands:

```
make
make install
```

3.5.6 Knowing how a package was configured

If you are interested on knowing how an **Extrae** package was configured execute the following command after setting `EXTRAE_HOME` to the base location of an installation.

```
${EXTRAE_HOME}/etc/configured.sh
```

this command will show the configure command itself and the location of some dependencies of the instrumentation package.

CHAPTER

FOUR

EXTRAE XML CONFIGURATION FILE

Extrae is configured through a XML file that is set through the `EXTRAE_CONFIG_FILE` environment variable. The included examples provide several XML files to serve as a basis for the end user. For instance, the MPI examples provide four XML configuration files:

- `extrae.xml` Exemplifies all the options available to set up in the configuration file. We will discuss below all the sections and options available. It is also available on this document on appendix *An example of Extrae XML configuration file*.
- `extrae_explained.xml` The same as the above with some comments on each section.
- `summarized_trace_basic.xml` A small example for gathering information of MPI and OpenMP information with some performace counters and calling information at each MPI call.
- `detailed_trace_basic.xml` A small example for gathering a summarized information of MPI and OpenMP parallel paradigms.
- `extrae_bursts_1ms.xml` An XML configuration example to setup the bursts tracing mode. This XML file will only capture the regions in between MPI calls that last more than the given threshold (1ms in this example).

Please note that most of the nodes present in the XML file have an `enabled` attribute that allows turning on and off some parts of the instrumentation mechanism. For example, `<mpi enabled="yes">` means MPI instrumentation is enabled and process all the contained XML subnodes, if any; whether `<mpi enabled="no">` means to skip gathering MPI information and do not process XML subnodes.

Each section points which environment variables could be used if the tracing package lacks XML support. See appendix *Environment variables* for the entire list.

Sometimes the XML tags are used for time selection (duration, for instance). In such tags, the following postfixes can be used: `n` or `ns` for nanoseconds, `u` or `us` for microseconds, `m` or `ms` for milliseconds, `s` for seconds, `M` for minutes, `H` for hours and `D` for days.

4.1 XML Section: Trace configuration

The basic trace behavior is determined in the first part of the XML and *contains* all of the remaining options. It looks like:

```
<?xml version='1.0'?>

<trace enabled="yes"
  home="@sed_MYPREFIXDIR@"
  initial-mode="detail"
  type="paraver"
>

< ... other XML nodes ... >

</trace>
```

The `<?xml version='1.0'?>` is mandatory for all XML files. Don't touch this. The available tunable options are under the `<trace>` node:

- `enabled` Set to `yes` if you want to generate tracefiles.
- `home` Set to where the instrumentation package is installed. Usually it points to the same location that *EXTRAE_HOME* environment variable.
- `initial-mode` Available options
  - `detail` Provides detailed information of the tracing.
  - `bursts` Provides summarized information of the tracing. This mode removes most of the information present in the detailed traces (like OpenMP and MPI calls among others) and only produces information for computation bursts.
- `type` Available options
  - `paraver` The intermediate files are meant to generate **Paraver** tracefiles.
  - `dimemas` The intermediate files are meant to generate **Dimemas** tracefiles.

See also:

EXTRAE_ON, *EXTRAE_HOME*, *EXTRAE_INITIAL_MODE* and *EXTRAE_TRACE_TYPE* environment variables in appendix *Environment variables*.

4.2 XML Section: MPI

The MPI configuration part is nested in the config file (see section *XML Section: Trace configuration*) and its nodes are the following:

```
<mpi enabled="yes">
  <counters enabled="yes" />
  <comm-calls enabled="yes" />
</mpi>
```

MPI calls can gather performance information at the begin and end of MPI calls. To activate this behavior, just set to `yes` the attribute of the nested `<counters>` node. When `<comm-calls>` is set to `no`, the calls to certain MPI_Comm_* calls (_rank, _size) are excluded from instrumentation to reduce tracing overhead.

See also:

EXTRAE_DISABLE_MPI and *EXTRAE_MPI_COUNTERS_ON* environment variables in appendix *Environment variables*.

4.3 XML Section: pthread

The pthread configuration part is nested in the config file (see section *XML Section: Trace configuration*) and its nodes are the following:

```
<pthread enabled="yes">
  <locks enabled="no" />
  <counters enabled="yes" />
</pthread>
```

The tracing package allows to gather information of some pthread routines. In addition to that, the user can also enable gathering information of locks and also gathering performance counters in all of these routines. This is achieved by modifying the enabled attribute of the `<locks>` and `<counters>`, respectively.

See also:

EXTRAE_DISABLE_PTHREAD, *EXTRAE_PTHREAD_LOCKS* and :envvar:‘ EXTRAE_PTHREAD_COUNTERS_ON‘ environment variables in appendix `cha:EnvVars`.

4.4 XML Section: OpenMP

The OpenMP configuration part is nested in the config file (see section *XML Section: Trace configuration*) and its nodes are the following:

```
<openmp enabled="yes">
  <locks enabled="no" />
  <task dependencies="yes" />
  <taskloop enabled="yes" dependencies="yes"/>
  <counters enabled="yes" />
</openmp>
```

The tracing package allows to gather information of some OpenMP runtimes and outlined routines. In addition to that, the user can also enable gathering information of locks and also gathering performance counters in all of these routines. This is achieved by modifying the enabled attribute of the `<locks>` and `<counters>`, respectively.

See also:

EXTRAE_DISABLE_OMP, *EXTRAE_OMP_LOCKS* and *EXTRAE_OMP_COUNTERS_ON* environment variables in appendix *Environment variables*.

4.5 XML Section: Callers

```
<callers enabled="yes">
  <mpi enabled="yes">1-3</mpi>
  <sampling enabled="no">1-5</sampling>
  <dynamic-memory enabled="no">1-5</dynamic-memory>
</callers>
```

Callers are the routine addresses present in the process stack at any given moment during the application run. Callers can be used to link the tracefile with the source code of the application.

The instrumentation library can collect a partial view of those addresses during the instrumentation. Such collected addresses are translated by the merging process if the correspondent parameter is given and the application has been compiled and linked with debug information.

There are three points where the instrumentation can gather this information:

- Entry of MPI calls
- Sampling points *(if sampling is available in the tracing package)*
- Dynamic memory calls (malloc, free, realloc)

The user can choose which addresses to save in the trace (starting from 1, which is the closest point to the MPI call or sampling point) specifying several stack levels by separating them by commas or using the hyphen symbol.

See also:

EXTRAE_MPI_CALLER environment variable in appendix *Environment variables*.

4.6 XML Section: User functions

```
<user-functions enabled="no"
  list="/home/bsc41/bsc41273/user-functions.dat"
  exclude-automatic-functions="no">
  <counters enabled="yes" />
</user-functions>
```

The file contains a list of functions to be instrumented by **Extrae**. There are different alternatives to instrument application functions, and some alternatives provides additional flexibility, as a result, the format of the list varies depending of the instrumentation mechanism used:

- DynInst Supports instrumentation of user functions, outer loops, loops and basic blocks. The given list contains the desired function names to be instrumented. After each function name, optionally you can define different basic blocks or loops inside the desired function always by providing different suffixes that are provided after the + character. For instance:
  - To instrument the entry and exit points of foo function just provide the function name (`foo`).
  - To instrument the entry and exit points of foo function plus the entry and exit points of its outer loop, suffix the function name with `outerloops` (*i.e.,* `foo+outerloops`).
  - To instrument the entry and exit points of foo function plus the entry and exit points of its N-th loop function you have to suffix it as `loop_N`, for instance `foo+loop_3`.
  - To instrument the entry and exit points of foo function plus the entry and exit points of its N-th basic block inside the function you have to use the suffix `bb_N`, for instance `foo+bb_5`. In this case, it is also possible to specifically ask for the entry or exit point of the basic block by additionally suffixing `_s` or `_e`, respectively.

  Additionally, these options can be added by using comas, as in: `foo+outerloops,loop_3,bb_3_e,bb_4_s,bb_5`.

  To discover the instrumentable loops and basic blocks of a certain function you can execute the command **`${EXTRAE_HOME}/bin/extrae -config extrae.xml -decodeBB`**, where `extrae.xml` is an **Extrae** configuration file that provides a list on the user functions attribute that you want to get the information.
- GCC and ICC (through `-finstrument-functions`) GNU and Intel compilers provide a compile and link flag named `-finstrument-functions` that instruments the routines of a source code file that **Extrae** can use. To use this functionality a file containing the names of the functions to be instrumented has to be provided. Compile the executable using the flag `-rdynamic` (or link it using `-export-dynamic`) in order to make the functions visible. For instance, to instrument the functions `foo`, `bar` and `baz` the user would create a file with:

  ```
  foo
  bar
  baz
  ```

  In specific cases (e.g., functions declared inside a Fortran CONTAINS construct) the user may also need to provide the function address as given by the command **`nm`**. For instance, to instrument the routine `pi_kernel` from the `pi` executable the user would run **`nm`** as follows:

  ```
  $ nm -a pi | grep pi_kernel

  00000000004005ed T pi_kernel
  ```

  and then add `<FUNCTION_NAME> # <HEX_ADDRESS>` into the function list:

  ```
  pi_kernel # 00000000004005ed
  ```

The `exclude-automatic-functions` attribute is used only by the DynInst instrumenter. By setting this attribute to `yes` the instrumenter will avoid automatically instrumenting the routines that either call OpenMP outlined routines (*i.e.,* routines with OpenMP pragmas), call CUDA kernels or HIP Kernels.

Finally, in order to gather performance counters in these functions and also in those instrumented using the `extrae_user_function` API call, the node `counters` has to be enabled.

> **Warning:** Note that you need to compile your application binary with debugging information (typically the `-g` compiler flag) in order to translate the captured addresses into valuable information such as: function name, file name and line number.

See also:

EXTRAE_FUNCTIONS environment variable in appendix *Environment variables*.

4.7 XML Section: Performance counters

The instrumentation library can be compiled with support for collecting performance metrics of different components available on the system. These components include:

- Processor performance counters. Such access is granted by PAPI[1] or PMAPI[2].
- Network performance counters. *(Only available in systems with Myrinet GM/MX networks).*
- Operating system accounts.

Here is an example of the counters section in the XML configuration file:

```
<counters enabled="yes">
  <cpu enabled="yes" starting-set-distribution="1">
    <set enabled="yes" domain="all" changeat-time="5s">
      PAPI_TOT_INS,PAPI_TOT_CYC,PAPI_L1_DCM
      <sampling enabled="yes" period="100000000">PAPI_TOT_CYC</sampling>
    </set>
    <set enabled="yes" domain="user" changeat-globalops="5">
      PAPI_TOT_INS,PAPI_TOT_CYC,PAPI_FP_INS
    </set>
  </cpu>
  <network enabled="yes" />
  <resource-usage enabled="yes" />
</counters>
```

See also:

EXTRAE_COUNTERS, *EXTRAE_NETWORK_COUNTERS* and *EXTRAE_RUSAGE* environment variables in appendix *Environment variables*.

4.7.1 Processor performance counters

Processor performance counters are configured in the `<cpu>` nodes. The user can configure many sets in the `<cpu>` node using the `<set>` node, but just one set will be used at any given time in a specific task. The `<cpu>` node supports the `starting-set-distribution` attribute with the following accepted values:

- `number` (*in range 1..N, where N is the number of configured sets*) All tasks will start using the set specified by number.
- `block` Each task will start using the given sets distributed in blocks (*i.e.,* if two sets are defined and there are four running tasks: tasks 1 and 2 will use set 1, and tasks 3 and 4 will use set 2).
- `cyclic` Each task will start using the given sets distributed cyclically (*i.e.,* if two sets are defined and there are four running tasks: tasks 1 and 3 will use, and tasks 2 and 4 will use set 2).

[1] More information available on their website http://icl.cs.utk.edu/papi. **Extrae** requires at least PAPI 3.x.
[2] PMAPI is only available for AIX operating system, and it is on the base operating system since AIX5.3. **Extrae** requires at least AIX 5.3.

- `thread-cyclic` Sets will be distributed cyclically between tasks and threads in a task.
- `random` Each task will start using a random set, and also calls either to `Extrae_next_hwc_set` or `Extrae_previous_hwc_set` will change to a random set.

Each set contains a list of performance counters to be gathered at different instrumentation points (see sections *XML Section: MPI*, *XML Section: OpenMP* and *XML Section: User functions*). If the tracing library is compiled to support PAPI, performance counters must be given using the canonical name (like PAPI_TOT_CYC and PAPI_L1_DCM), or the PAPI code in hexadecimal format (like 8000003b and 80000000, respectively)[3] If the tracing library is compiled to support PMAPI, only one group identifier can be given per set[4] and can be either the group name (like pm_basic and pm_hpmcount1) or the group number (like 6 and 22, respectively).

In the given example (which refers to PAPI support in the tracing library) two sets are defined. First set will read PAPI_TOT_INS (total instructions), PAPI_TOT_CYC (total cycles) and PAPI_L1_DCM (1st level cache misses). Second set is configured to obtain PAPI_TOT_INS (total instructions), PAPI_TOT_CYC (total cycles) and PAPI_FP_INS (floating point instructions).

Additionally, if the underlying performance library supports sampling mechanisms, each set can be configured to gather information (see section *XML Section: Callers*) each time the specified counter reaches a specific value. The counter that is used for sampling must be present in the set. In the given example, the first set is enabled to gather sampling information every 100M cycles.

Furthermore, performance counters can be configured to report accounting on different basis depending on the `domain` attribute specified on each set. Available options are:

- `kernel` Only counts events ocurred when the application is running in kernel mode.
- `user` Only counts events ocurred when the application is running in user-space mode.
- `all` Counts events independently of the application running mode.

In the given example, first set is configured to count all the events ocurred, while the second one only counts those events ocurred when the application is running in user-space mode.

Finally, the instrumentation can change the active set in a manual and an automatic fashion. To change the active set manually see *Extrae_previous_hwc_set* and *Extrae_next_hwc_set* API calls in section *Basic API*. To change automatically the active set two options are allowed: based on time and based on application code. The former mechanism requires adding the attribute `changeat-time` and specify the minimum time to hold the set. The latter requires adding the attribute `changeat-globalops` with a value. The tracing library will automatically change the active set when the application has executed as many MPI global operations as selected in that attribute. When In any case, if either attribute is set to zero, then the set will not me changed automatically.

4.7.2 Network performance counters

Network performance counters are only available on systems with Myrinet GM/MX networks and they are fixed depending on the firmware used. Other systems, like BG/* may provide some network performance counters, but they are accessed through the PAPI interface (see section *XML Section: Performance counters* and PAPI documentation).

If `<network>` is enabled the network performance counters appear at the end of the application run, giving a summary for the whole run.

4.7.3 Operating system accounting

Operating system accounting is obtained through the *`getrusage(2)`* system call when `<resource-usage>` is enabled. As network performance counters, they appear at the end of the application run, giving a summary for the whole run.

[3] Some architectures do not allow grouping some performance counters in the same set.
[4] Each group contains several performance counters.

4.8 XML Section: Storage management

The instrumentation package can be instructed on what/where/how produce the intermediate trace files. These are the available options:

```
<storage enabled="no">
  <trace-prefix enabled="yes">TRACE</trace-prefix>
  <size enabled="no">5</size>
  <temporal-directory enabled="yes">/scratch</temporal-directory>
  <final-directory enabled="yes">/gpfs/scratch/bsc41/bsc41273</final-directory>
</storage>
```

Such options refer to:

- `trace-prefix` Sets the intermediate trace file prefix. Its default value is `TRACE`.
- `size` Let the user restrict the maximum size (in megabytes) of each resulting intermediate trace file[5].
- `temporal-directory` Where the intermediate trace files will be stored during the execution of the application. By default they are stored in the current directory. If the directory does not exist, the instrumentation will try to make it.
- `final-directory` Where the intermediate trace files will be stored once the execution has been finished. By default they are stored in the current directory. If the directory does not exist, the instrumentation will try to make it.

See also:

EXTRAE_PROGRAM_NAME, *EXTRAE_FILE_SIZE*, *EXTRAE_DIR*, *EXTRAE_FINAL_DIR* and *EXTRAE_GATHER_MPITS* environment variables in appendix *Environment variables*.

4.9 XML Section: Buffer management

Modify the buffer management entry to tune the tracing buffer behavior.

```
<buffer enabled="yes">
  <size enabled="yes">150000</size>
  <circular enabled="no" />
</buffer>
```

By, default (even if the enabled attribute is `no`) the tracing buffer is set to 500k events. If `<size>` is enabled the tracing buffer will be set to the number of events indicated by this node. If the circular option is enabled, the buffer will be created as a circular buffer and the buffer will be dumped only once with the last events generated by the tracing package.

See also:

EXTRAE_BUFFER_SIZE environment variable in appendix *Environment variables*.

4.10 XML Section: Trace control

```
<trace-control enabled="yes">
  <file enabled="no" frequency="5M">/gpfs/scratch/bsc41/bsc41273/control</file>
  <global-ops enabled="no">10</global-ops>
  <remote-control enabled="yes">
    <mrnet enabled="yes" target="150" analysis="spectral" start-after="30">
      <clustering max_tasks="26" max_points="8000"/>
```

[5] This check is done each time the buffer is flushed, so the resulting size of the intermediate trace file depends also on the number of elements contained in the tracing buffer (see *XML Section: Buffer management*).

```
      <spectral min_seen="1" max_periods="0" num_iters="3" signals="DurBurst,InMPI
↪"/>
    </mrnet>
  </remote-control>
</trace-control>
```

This section groups together a set of options to limit/reduce the final trace size. There are three mechanisms which are based on file existence, global operations executed and external remote control procedures.

Regarding the `file`, the application starts with the tracing disabled, and it is turned on when a control file is created. Use the property `frequency` to choose at which frequency this check must be done. If not supplied, it will be checked every 100 global operations on MPI_COMM_WORLD.

If the `global-ops` tag is enabled, the instrumentation package begins disabled and starts the tracing when the given number of global operations on MPI_COMM_WORLD has been executed. The user can also specify multiple intervals in the form `start-stop` separated by commas.

The `remote-control` tag section allows to configure some external mechanisms to automatically control the tracing. Currently, there is only one option which is built on top of MRNet and it is based on clustering and spectral analysis to generate a small yet representative trace.

These are the options in the `mrnet` tag:

- `target` the approximate requested size for the final trace (in Mb).
- `analysis` one between `clustering` and `spectral`.
- `start-after` number of seconds before the first analysis starts.

The `clustering` tag configures the clustering analysis parameters:

- `max_tasks` maximum number of tasks to get samples from.
- `max_points` maximum number of points to cluster.

The `spectral` tag section configures the spectral analysis parameters:

- `min_seen` minimum times a given type of period has to be seen to trace a sample.
- `max_periods` maximum number of representative periods to trace. 0 equals to unlimited.
- `num_iters` number of iterations to trace for every representative period found.
- `signals` performance signals used to analyze the application. If not specified, `DurBurst` is used by default.

See also:

EXTRAE_CONTROL_FILE, *EXTRAE_CONTROL_GLOPS*, *EXTRAE_CONTROL_TIME* environment variables in appendix *Environment variables*.

4.11 XML Section: Bursts

```
<burst enabled="no" threshold="500u" mpi-statistics="yes" omp-statistics="yes" omp-
↪summarization="no" />
```

If the user enables this option, the instrumentation library will just emit information of computation bursts (*i.e.,* not does not trace MPI calls, OpenMP runtime, and so on) when the current mode (through initial-mode in section *XML Section: Trace configuration*) is set to `bursts`. The library will discard all those computation bursts that last less than the selected threshold.

In addition to that, when the tracing library is running in burst mode, it computes some statistics of MPI activity. Such statistics can be dumped in the tracefile by enabling `mpi-statistics`.

See also:

EXTRAE_INITIAL_MODE, *EXTRAE_BURST_THRESHOLD* and *EXTRAE_MPI_STATISTICS* environment variables in appendix *Environment variables*.

4.12 XML Section: Others

```
<others enabled="yes">
  <minimum-time enabled="no">10M</minimum-time>
  <finalize-on-signal enabled="yes"
    SIGUSR1="no" SIGUSR2="no" SIGINT="yes"
    SIGQUIT="yes" SIGTERM="yes" SIGXCPU="yes"
    SIGFPE="yes" SIGSEGV="yes" SIGABRT="yes"
  />
  <flush-sampling-buffer-at-instrumentation-point enabled="yes" />
</others>
```

This section contains other configuration details that do not fit in the previous sections. At the moment, there are three options to be configured.

- The `minimum-time` option indicates the instrumentation package the minimum instrumentation time. To enable it, set `enabled` to `yes` and set the minimum time within the `minimum-time` tag.
- The option labeled as `finalize-on-signal` instructs the instrumentation package to listen for different types of signals[6] and dump and finalize the execution whenever they occur. If a signal occurs but it is not configured, then the execution may finish without generating the trace-file. *Caveat:* Some MPI implementations use `SIGUSR1` and/or `SIGUSR2`, so if you want to capture those signals check first that enabling them do not alter with the application execution.
- The `flush-sampling-buffer-at-instrumentation-point` lets the user decide whether the sampling buffer should be checked for flushing at instrumentation points. If this option is not enabled, then the buffer will only be dumped once at the end of the application execution.

4.13 XML Section: Sampling

```
<sampling enabled="no" type="default" period="50m" variability="10m"/>
```

This section configures the time-based sampling capabilities. Every sample contains processor performance counters (if enabled in section *Processor performance counters* and either PAPI or PMAPI are referred at configure time) and callstack information (if enabled in section *XML Section: Callers* and proper dependencies are set at configure time).

This section contains two attributes besides `enabled`. These are:

- `type` determines which timer domain is used (see *setitimer(2)* or *setitimer(3p)* for further information on time domains). Available options are: `real` (which is also the `default` value, `virtual` and `prof` (which use the SIGALRM, SIGVTALRM and SIGPROF respectively). The default timing accumulates real time, but only issues samples at master thread. To let all the threads to collect samples, the type must be `virtual` or `prof`.
- `period` specifies the sampling periodicity. In the example above, samples are gathered every 50ms.
- `variability` specifies the variability to the sampling periodicity. Such variability is calculated through the `random()` system call and then is added to the periodicity. In the given example, the variability is set to 10ms, thus the final sampling period ranges from 45 to 55ms.

See also:

EXTRAE_SAMPLING_PERIOD, *EXTRAE_SAMPLING_VARIABILITY*, *EXTRAE_SAMPLING_CLOCKTYPE* and *EXTRAE_SAMPLING_CALLER* environment variables in appendix *Environment variables*.

[6] See *man signal(2)* and *man signal(7)* for more details.

4.14 XML Section: CUDA

```
<cuda enabled="yes" />
```

This section indicates whether the CUDA calls should be instrumented or not. If `enabled` is set to yes, CUDA calls will be instrumented, otherwise they will not be instrumented.

4.15 XML Section: HIP

```
<hip enabled="yes" />
```

This section indicates whether the HIP calls should be instrumented or not. If `enabled` is set to yes, HIP calls will be instrumented, otherwise they will not be instrumented.

4.16 XML Section: OpenACC

```
<openacc enabled="yes" />
```

This section indicates wheter OpenACC host activity should be instrumented. If `enabled` is set to yes, OpenACC activity made by the host will be instrumented, otherwise it will be not. If the user wants to capture device activity, they must also enable CUDA instrumentation.

4.17 XML Section: OpenCL

```
<opencl enabled="yes" />
```

This section indicates whether the OpenCL calls should be instrumented or not. If `enabled` is set to yes, Opencl calls will be instrumented, otherwise they will not be instrumented.

4.18 XML Section: Input/Output

```
<input-output enabled="no" internals="no"/>
```

This section indicates whether I/O calls (`read` and `write`) are meant to be instrumented. If `enabled` is set to yes, the aforementioned calls will be instrumented, otherwise they will not be instrumented. If `internals` is set to yes, I/O calls that occur inside other traced calls will also be captured.

4.19 XML Section: Dynamic memory

```
<dynamic-memory enabled="no">
  <alloc enabled="yes" threshold="32768" />
  <free  enabled="yes" />
</dynamic-memory>
```

This section indicates whether dynamic memory calls (`malloc`, `free`, `realloc`) are meant to be instrumented. If `enabled` is set to yes, the aforementioned calls will be instrumented, otherwise they will not be instrumented.

This section allows deciding whether allocation and free-related memory calls shall be instrumented.

Additionally, the configuration can also indicate whether allocation calls should be instrumented if the requested memory size surpasses a given threshold (32768 bytes, in the example).

4.20 XML Section: Memory references through Intel PEBS sampling

```
<pebs-sampling enabled="yes">
  <loads  enabled="yes" frequency="100" minimum-latency="10" />
  <stores enabled="no" frequency="50">
    <offcore-l3-misses enabled="no" /> <!-- Read together with stores samples. -->
  </stores>
  <load-l3-misses enabled="no" frequency="25" />
</pebs-sampling>
```

This section tells **Extrae** to use the PEBS feature from recent Intel processors[7] to sample memory references. These memory references capture the linear address referenced, the component of the memory hierarchy that solved the reference and the number of cycles to solve the reference.

In the example above, PEBS monitors one load instruction every 100 Hz that requires at least 10 cycles to be solved. Alternatively, the setting 'frequency' can be replaced by 'period', then PEBS will monitor one load instruction every given number of loads. Please note that the 'period' setting is not available for Skylake and newer processors.

4.21 XML Section: Executing CPU identification

```
<cpu-events enabled="no" frequency="0" emit-always="no" poi="none|openmp" />
```

By default the core identifier where every thread is executing is emitted at initialization points. This section enables extra measurements, configurable by time ('frequency') and points of interest ('poi'). When 'frequency' is set, new measurements are emitted at instrumentation points if enough time has passed since the previous measurement. When 'poi' is set to 'openmp', new measurements are emitted at the entry and exit points of OpenMP outlined functions, tasks, and work dispatches. This option may introduce high variable overhead, please use with caution.

4.22 XML Section: Merge

```
<merge enabled="yes"
  synchronization="default"
  binary="mpi_ping"
  tree-fan-out="16"
  max-memory="512"
  joint-states="yes"
  keep-mpits="yes"
  translate-addresses="yes"
  sort-addresses="yes"
  translate-data-addresses="yes"
  overwrite="yes"
  stop-at-percentage="50"
>
  mpi_ping.prv
</merge>
```

[7] Check for availability on your system by looking for pebs in `/proc/cpuinfo`.

If this section is enabled and the instrumentation package is configured to support this, the merge process will be automatically invoked after the application run. The merge process will use all the resources devoted to run the application.

In the given example, the leaf of this node will be used as the tracefile name (`mpi_ping.prv`). Current available options for the merge process are given as attribute of the `<merge>` node and they are:

- `synchronization`: which can be set to `default`, `node`, `task`, `no`. This determines how task clocks will be synchronized (*default* is node).
- `binary`: points to the binary that is being executed. It will be used to translate gathered addresses (MPI callers, sampling points and user functions) into source code references.
- `tree-fan-out`: *only for MPI executions* sets the tree-based topology to run the merger in a parallel fashion.
- `max-memory`: limits the intermediate merging process to run up to the specified limit (in MBytes).
- `joint-states`: which can be set to `yes`, `no`. Determines if the resulting Paraver tracefile will split or join equal consecutive states (*default is ''yes''*).
- `keep-mpits`: whether to keep the intermediate tracefiles after performing the merge.
- `translate-addresses` : whether to identify the calling site of instrumented calls and samples by the specified levels of the callstack (enabled by default); or just by their instruction addresses.
- `sort-addresses`: whether to sort all addresses that refer to the source code (enabled by default).
- `translate-data-addresses`: whether to identify allocated objects by their full callpath (enabled by default); or just by the tuple <library_base_address, symbol_offset_within_library>.
- `overwrite`: set to `yes` if the new tracefile can overwrite an existing tracefile with the same name. If set to `no`, then the tracefile will be given a new name using a consecutive id.
- `stop-at-percentage`: stops the generation of the tracefile at a given percentage. Accepts integer values from `1` to `99`. All other values disable this option.

In Linux systems, the tracing package can take advantage of certain functionalities from the system and can guess the binary name, and from it the tracefile name. In such systems, you can use the following reduced XML section replacing the earlier section.

```
<merge enabled="yes"
  synchronization="default"
  tree-fan-out="16"
  max-memory="512"
  joint-states="yes"
  keep-mpits="yes"
  translate-addresses="yes"
  sort-addresses="yes"
  translate-data-addresses="yes"
  overwrite="yes"
  stop-at-percentage="50"
/>
```

See also:

For further references, see chapter *Merging process*.

4.23 Using environment variables within the XML file

XML tags and attributes can refer to environment variables that are defined in the environment during the application run. If you want to refer to an environment variable within the XML file, just enclose the name of the variable using the dollar symbol (`$`), for example: `{$FOO$}`.

Note that the user has to put an specific value or a reference to an environment variable which means that expanding environment variables in text is not allowed as in a regular shell (i.e., the instrumentation package will not convert the follwing text {`bar$FOO$bar`).

CHAPTER

FIVE

EXTRAE API

There are two levels of the API in the **Extrae** instrumentation package. Basic API refers to the basic functionality provided and includes emitting events, source code tracking, changing instrumentation mode and so. Extended API is an *experimental* addition to provide several of the basic API within single and powerful calls using specific data structures.

5.1 Basic API

The following routines are defined in `$EXTRAE_HOME/include/extrae.h` These routines are intended to be called by C/C++ programs. The instrumentation package also provides bindings for Fortran applications. The Fortran API bindings have the same name as the C API but honoring the Fortran compiler function name mangling scheme. To use the API in Fortran applications use the module provided in `$EXTRAE_HOME/include/extrae_module.f90` by using the Fortran `use` clause. This module has to be compiled beforehand with the same compiler as the program being instrumented, with the following command:

```
make -f ${EXTRAE_HOME}/include/Makefile.extrae_module
```

- **`void Extrae_get_version (unsigned *major, unsigned *minor, unsigned *revision)`**

  Returns the version of the underlying **Extrae** package. Although an application may be compiled to a specific **Extrae** library, by using the appropriate shared library commands, the application may use a different **Extrae** library.

- **`void Extrae_init (void)`**

  Initializes the tracing library.

  This routine is called automatically in different circumstances, which include:

  - Call to MPI_Init when the appropriate instrumentation library is linked or preload with the application.
  - Usage of the DynInst launcher.
  - If either the `libseqtrace.so`, `libomptrace.so` or `libpttrace.so` are linked dynamically or preloaded with the application.

  No major problems should occur if the library is initialized twice, only a warning appears in the terminal output noticing the intent of double initialization.

- **`extrae_init_type_t Extrae_is_initialized (void)`**

  This routine tells whether the instrumentation has been initialized, and if so, also which mechanism was the first to initialize it (regular API or MPI initialization).

- **`void Extrae_fini (void)`**

  Finalizes the tracing library and dumps the intermediate tracing buffers onto disk.

- **`void Extrae_event (extrae_type_t type, extrae_value_t value)`**

  Adds a single timestamped event into the tracefile.

Some common uses of events are:

- Identify loop iterations (or any code block):

  Given a loop, the user can set a unique type for the loop and a value related to the iterator value of the loop. For example:

```
for (i = 1; i <= MAX_ITERS; i++)
{
  Extrae_event (1000, i);
  [original loop code]
  Extrae_event (1000, 0);
}
```

  The last added call to `Extrae_event` marks the end of the loop setting the event value to 0, which facilitates the analysis with Paraver.

- Identify user routines:

  Choosing a constant type (6000019 in this example) and different values for different routines (set to 0 to mark a "leave" event).

```
void routine1 (void)
{
  Extrae_event (6000019, 1);
  [routine 1 code]
  Extrae_event (6000019, 0);
}

void routine2 (void)
{
  Extrae_event (6000019, 2);
  [routine 2 code]
  Extrae_event (6000019, 0);
}
```

- Identify any point in the application using a unique combination of type and value.

- **void Extrae_nevent (unsigned count, extrae_type_t *types, extrae_value_t *values)**

  Allows the user to place *count* events with the same timestamp at the given position.

- **void Extrae_counters (void)**

  Emits the value of the active hardware counters set. See chapter *Extrae XML configuration file* for further information.

- **void Extrae_eventandcounters (extrae_type_t event, extrae_value_t value)**

  This routine lets the user add an event and obtain the performance counters with one call and a single timestamp.

- **void Extrae_neventandcounters (unsigned count, extrae_type_t *types, extrae_value_t**

  This routine lets the user add several events and obtain the performance counters with one call and a single timestamp.

- **void Extrae_define_event_type (extrae_type_t *type, char *description, unsigned *nva**

  This routine adds to the Paraver Configuration File human readable information regarding type `type` and its values `values`. If no values need to be decribed set `nvalues` to 0 and also set `values` and `description_values` to NULL.

- **void Extrae_shutdown (void)**

  Turns off the instrumentation.

- **void Extrae_restart (void)**

  Turns on the instrumentation.

- **void Extrae_previous_hwc_set (void)**

  Makes the previous hardware counter set defined in the XML file to be the active set (see section *XML Section: MPI* for further information).

- **void Extrae_next_hwc_set (void)**

  Makes the following hardware counter set defined in the XML file to be the active set (see section *XML Section: MPI* for further information).

- **void Extrae_set_tracing_tasks (int from, int to)**

  Allows the user to choose from which tasks (not *threads*!) store information in the tracefile.

- **void Extrae_set_options (int options)**

  Permits configuring several tracing options at runtime. The `options` parameter has to be a bitwise or combination of the following options, depending on the user's needs:

  - EXTRAE_CALLER_OPTION

    Dumps caller information at each entry or exit point of the MPI routines. Caller levels need to be configured at XML (see chapter *Extrae XML configuration file*).

  - EXTRAE_HWC_OPTION

    Activates hardware counter gathering.

  - EXTRAE_MPI_OPTION

    Activates tracing of MPI calls.

  - EXTRAE_MPI_HWC_OPTION

    Activates hardware counter gathering in MPI routines.

  - EXTRAE_OMP_OPTION

    Activates tracing of OpenMP runtime or outlined routines.

  - EXTRAE_OMP_HWC_OPTION

    Activates hardware counter gathering in OpenMP runtime or outlined routines.

  - EXTRAE_UF_HWC_OPTION

    Activates hardware counter gathering in the user functions.

  - EXTRAE_PTHREAD_OPTION

    Activates pthreads instrumentation

  - EXTRAE_PTHREAD_HWC_OPTION

    Activates hardware counters gathering in pthread routines

  - EXTRAE_SAMPLING_OPTION

    Activates instrumentation using time-based sampling

- **void Extrae_network_counters (void)**

  Emits the value of the network counters if the system has this capability. *(Only available for systems with Myrinet GM/MX networks).*

- **void Extrae_network_routes (int task)**

  Emits the network routes for an specific `task`. *(Only available for systems with Myrinet GM/MX networks.*

- **unsigned long long Extrae_user_function (unsigned enter)**

  Emits an event into the tracefile which references the source code (data includes: source line number, file name and function name). If `enter` is 0 it marks an end (*i.e.,* leaving the function), otherwise it marks the beginning of the routine. The user must be careful to place the call of this routine in places where the code is always executed, being careful not to place them inside `if` and `return` statements. The function returns the address of the reference.

```
void routine1 (void)
{
  Extrae_user_function (1);
  [routine 1 code]
  Extrae_user_function (0);
}

void routine2 (void)
{
  Extrae_user_function (1);
  [routine 2 code]
  Extrae_user_function (0);
}
```

  In order to gather performance counters during the execution of these calls, the `user-functions` tag and its `counters` have to be both enabled int section *XML Section: User functions*.

> **Warning:** Note that you need to compile your application binary with debugging information (typically the `-g` compiler flag) in order to translate the captured addresses into valuable information such as function name, file name and line number.

- **unsigned long long Extrae_user_function_at_level (unsigned enter, unsigned lvl)**
  Same as `Extrae_user_function` but allows the specification of callstack levels to skip.
- **void Extrae_flush (void)**
  Forces the calling thread to write the events stored in the tracing buffers to disk.

5.2 Extended API

> **Warning:** This API is in experimental stage and it is only available in C. Use it at your own risk!

The extended API makes use of two special structures located in `$PREFIX/include/extrae_types.h`. The structures are `extrae_UserCommunication` and `extrae_CombinedEvents`. The former is intended to encode an event that will be converted into a **Paraver** communication when its partner equivalent event has found. The latter is used to generate events containing multiple kinds of information at the same time.

```
struct extrae_UserCommunication
{
  extrae_user_communication_types_t type;
  extrae_comm_tag_t tag;
  unsigned size; /* size_t? */
  extrae_comm_partner_t partner;
  extrae_comm_id_t id;
};
```

The structure `extrae_UserCommunication` contains the following fields:

- `type` Available options are:
  - `EXTRAE_USER_SEND`, if this event represents a send point.

  - EXTRAE_USER_RECV, if this event represents a receive point.
- tag The tag information in the communication record.
- size The size information in the communication record.
- partner The partner of this communication (receive if this is a send or send if this is a receive). Partners (ranging from 0 to N-1) are considered across tasks whereas all threads share a single communication queue. Special value '-1' means the partner is the same process (i.e. communication between threads).
- id An identifier that is used to match communications between partners.

```
struct extrae_CombinedEvents
{
  /* These are used as boolean values */
  int HardwareCounters;
  int Callers;
  int UserFunction;
  /* These are intended for N events */
  unsigned nEvents;
  extrae_type_t *Types;
  extrae_value_t *Values;
  /* These are intended for user communication records */
  unsigned nCommunications;
  extrae_user_communication_t *Communications;
};
```

The structure extrae_CombinedEvents contains the following fields:

- HardwareCounters Set to non-zero if this event has to gather hardware performance counters.
- Callers Set to non-zero if this event has to emit callstack information.
- UserFunction Available options are:
  - EXTRAE_USER_FUNCTION_NONE, if this event should not provide information about user routines.
  - EXTRAE_USER_FUNCTION_ENTER, if this event represents the starting point of a user routine.
  - EXTRAE_USER_FUNCTION_LEAVE, if this event represents the ending point of a user routine.
- nEvents Set the number of events given in the Types and Values fields.
- Types A pointer containing nEvents type that will be stored in the trace.
- Values A pointer containing nEvents values that will be stored in the trace.
- nCommunications Set the number of communications given in the Communications field.
- Communications A pointer to extrae_UserCommunication structures containing nCommunications elements that represent the involved communications.

The extended API contains the following routines:

- **void Extrae_init_UserCommunication (struct extrae_UserCommunication *)**

  Use this routine to initialize an extrae_UserCommunication structure.

- **void Extrae_init_CombinedEvents (struct extrae_CombinedEvents *)**

  Use this routine to initialize an extrae_CombinedEvents structure.

- **void Extrae_emit_CombinedEvents (struct extrae_CombinedEvents *)**

  Use this routine to emit to the tracefile the events set in the extrae_CombinedEvents given.

- **void Extrae_resume_virtual_thread (unsigned vthread)**

  This routine changes the thread identifier so as to be vthread in the final tracefile. *Improper use of this routine may result in corrupt tracefiles.*

- **void Extrae_suspend_virtual_thread (void)**

  This routine recovers the original thread identifier (given by routines like `pthread_self` or `omp_get_thread_num`, for instance).

- **void Extrae_register_codelocation_type (extrae_type_t t1, extrae_type_t t2, const ch**

  Registers type `t2` to reference user source code location by using its address. During the merge phase the `mpi2prv` command will assign type `t1` to the event type that references the user function and to the event `t2` to the event that references the file name and line location. The strings `s1` and `s2` refers, respectively, to the description of `t1` and `t2`

- **void Extrae_register_function_address (void *ptr, const char *funcname, const char**

  By default, the `mpi2prv` process uses the binary debugging information to translate program addresses into information that contains function name, the module name and line. The `Extrae_register_function_address` allows providing such information by hand during the execution of the instrumented application. This function must provide the function name (`funcname`), module name (`modname`) and line number for a given address.

- **void Extrae_register_stacked_type (extrae_type_t type)**

  Registers which event types are required to be managed in a stack way whenever `void Extrae_resume_virtual_thread` or `void Extrae_suspend_virtual_thread` are called.

- **void Extrae_set_threadid_function (unsigned (*threadid_function)(void))**

  Defines the routine that will be used as a thread identifier inside the tracing facility.

- **void Extrae_set_numthreads_function (unsigned (*numthreads_function)(void))**

  Defines the routine that will count all the executing threads inside the tracing facility.

- **void Extrae_set_taskid_function (unsigned (*taskid_function)(void))**

  Defines the routine that will be used as a task identifier inside the tracing facility.

- **void Extrae_set_numtasks_function (unsigned (*numtasks_function)(void))**

  Defines the routine that will count all the executing tasks inside the tracing facility.

- **void Extrae_set_barrier_tasks_function (void (*barriertasks_function)(void))**

  Establishes the barrier routine among tasks. It is needed for synchronization purposes.

5.3 Java bindings

If Java is enabled at configure time, a basic instrumentation library for serial application based on JNI bindings to **Extrae** will be installed. The current bindings are within the package `es.bsc.cepbatools.extrae` and the following bindings are provided:

- **void Init ();**

  Initializes the instrumentation package.

- **void Fini ();**

  Finalizes the instrumentation package.

- **void Event (int type, long value);**

  Emits one event into the trace-file with the given pair type-value.

- **void Eventandcounters (int type, long value);**

  Emits one event into the trace-file with the given pair type-value as well as read the performance counters.

- **void nEvent (int types[], long values[]);**

  Emits a set of pair type-value at the same timestamp. Note that both arrays must be the same length to proceed correctly, otherwise the call ignores the call.

- **void nEventandcounters (int types[], long values[]);**

  Emits a set of pair type-value at the same timestamp as well as read the performance counters. Note that both arrays must be the same length to proceed correctly, otherwise the call ignores the call.

- **void defineEventType (int type, String description, long[] values, String[] descript**

  Adds a description for a given event type (through `type` and `description` parameters). If the array `values` is non-null, then the array `descriptionValues` should be the an array of the same length and each entry should be a string describing each of the values given in `values`.

- **void SetOptions (int options);**

  This API call changes the behavior of the instrumentation package but none of the options currently apply to the Java instrumentation.

- **void Shutdown();**

  Disables the instrumentation until the next call to `Restart()`.

- **void Restart();**

  Resumes the instrumentation from the previous `Shutdown()` call.

5.3.1 Advanced Java Bindings

Since **Extrae** does not have features to automatically discover the thread identifier of the threads that run within the virtual machine, there are some calls that allows to do this manually.

These calls are, however, intended for expert users and should be avoided whenever possible because their behavior may be highly modified, or even removed, in future releases.

- **SetTaskID (int id);**

  Tells **Extrae** that this process should be considered as task with identifier `id`. Use this call before invoking `Init()`.

- **SetNumTasks (int num);**

  Instructs **Extrae** to allocate the structures for `num` processes. Use this call before invoking `Init()`.

- **SetThreadID (int id);**

  Instructs **Extrae** that this thread should be considered as thread with identifier `id`.

- **SetNumThreads (int num);**

  Tells **Extrae** that there are `num` threads active within this process. Use this call before invoking `Init()`.

- **Comm (boolean send, int tag, int size, int partner, long id);**

  Allows generating communications between two processes. The call emits one of the two-point communication part, so it is necessary to invoke it from both the sender and the receiver part. The `send` parameter determines whether this call will act as send or receive message. The `tag` and `size` parameters are used to match the communication and their parameters can be displayed in **Extrae**. The `partner` refers to the communication partner and it is identified by its TaskID. The `id` is meant for matching purposes but cannot be recovered during the analysis with **Paraver**.

5.4 Command-line version

Extrae incorporates a mechanism to generate trace-files from the command-line in a very naïve way in order to instrument executions driven by shell-scripted applications.

The command-line binary is installed in `${EXTRAE_HOME}/bin/extrae-cmd` and supports the following commands:

- `init` <TASKID> <THREADS>

  This command initializes the tracing on the node that executed the command. The initialization command receives two parameters (TASKID, THREADS). The TASKID parameter gives an task identifier to the following forthcoming events. The THREADS parameter indicates how many threads should the task contain.

- `emit` <THREAD-SLOT> <TYPE> <VALUE>

  This command emits an event with the pair TYPE, VALUE into the the thread THREAD at the timestamp when the command is invoked.

- `fini`

  This command finalizes the instrumentation using the command-line version. Note that this finalization does not automatically call the merge process (`mpi2prv`).

Warning: To use these commands, **do not** export neither *EXTRAE_ON* nor `EXTRAE_CONFIG_FILE`, otherwise the behavior of these commands is undefined.

The initialization can be executed only once per node, so if you want to represent multiple tasks you need different tasks.

CHAPTER

SIX

MERGING PROCESS

Once the application has finished, and if the automatic merge process is not setup, the merge must be executed manually. Here we detail how to run the merge process manually.

The inserted probes in the instrumented binary are responsible for gathering performance metrics of each task/thread and for each of them several files are created where the XML configuration file specified (see section *XML Section: Storage management*). Such files are:

- As many `.mpit` files as tasks and threads were running the target application. Each file contains information gathered by the specified task/thread in raw binary format.
- A single `.mpits` file that contain a list of related `.mpit` files.
- If the DynInst based instrumentation package was used, an addition `.sym` file that contains some symbolic information gathered by the DynInst library.

In order to use **Paraver**, those intermediate files (*i.e.*, `.mpit` files) must be merged and translated into **Paraver** trace file format. The same applies if the user wants to use the **Dimemas** simulator. To proceed with any of these translations, all the intermediate trace files must be merged into a single trace file using one of the available mergers in the `bin` directory (see Table 6.1).

The target trace type is defined in the XML configuration file used at the instrumentation step (see section *XML Section: Trace configuration*), and it has to match with the used merger (`mpi2prv` and `mpimpi2prv` for **Paraver** and `mpi2dim` and `mpimpi2dim` for **Dimemas**). However, it is possible to force the format nevertheless the selection done in the XML file using the parameters `-paraver` or `-dimemas`[1].

Table 6.1: Description of the available mergers in the **Extrae** package

mpi2prv	Sequential version of the **Paraver** merger.
mpi2dim	Sequential version of the **Dimemas** merger.
mpimpi2prv	Parallel version of the **Paraver** merger.
mpimpi2dim	Parallel version of the **Dimemas** merger.

6.1 Paraver Merger

As stated before, there are two **Paraver** mergers: `mpi2prv` and `mpimpi2prv`. The former is for use in a single processor mode, while the latter is meant to be used with multiple processors using MPI (and cannot be run using one MPI task).

Paraver merger receives a set of intermediate trace files and generates three files with the same name (which is set with the `-o` option) but differ in the extension. The **Paraver** trace itself (.prv file) that contains timestamped records that represent the information gathered during the execution of the instrumented application. It also generates the **Paraver** Configuration File (.pcf file), which is responsible for translating values contained in the **Paraver** trace into a more human readable values. Finally, it also generates a file containing the distribution of the application across the cluster computation resources (.row file).

[1] The timing mechanism differ in **Paraver/Dimemas** at the instrumentation level. If the output trace format does not correspond with that selected in the XML some timing inaccuracies may be present in the final tracefile. Such inaccuracies are known to be higher due to clock granularity if the XML is set to obtain **Dimemas** tracefiles but the resulting tracefile is forced to be in **Paraver** format.

6.1.1 Sequential Paraver Merger

These are the available options for the sequential **Paraver** merger:

-d, -dump
Dumps the information stored in the intermediate trace files.

-dump-time, -no-dump-time
Choose whether the information dumped with *-d* or *-dump* includes (default) or not the event timestamp.

-dump-symtab, -no-dump-symtab
Include or omit (default) the main's task symbol table in the PCF.

-e <BINARY>
Uses the specified <BINARY> to translate addresses stored in the intermediate trace files into human-readable information (including function names, source files and line numbers). The application must be compiled with the `-g` flag to include the necessary debug information.

Note: Since **Extrae** version 2.4.0, this flag has been superseded on Linux systems where `/proc/self/maps` is readable. The instrumentation component will save a copy of the process's memory mappings (binaries and shared libraries) and attempt to use them for the translations.

This flag remains available for all other systems, as well as on Linux as a fallback, in case `/proc/self/maps` cannot be retrieved, or the mappings referenced in it are not accessible.

-emit-library-events
Emit additional events for the source code references that belong to a separate shared library that cannot be translated. Only add information with respect to the shared library name. This option is disabled by default.

-evtnum <N>
Partially processes (up to <N> events) the intermediate trace files to generate the **Dimemas** tracefile.

-f <FILE.mpits>
(where <FILE.mpits> file is generated by the instrumentation)

The merger uses the given file (which contains a list of intermediate trace files of a single executions) instead of giving set of intermediate trace files.

This option looks first for each file listed in the parameter file. Each contained file is searched in the absolute given path, if it does not exist, then it's searched in the current directory.

-f-relative <FILE.mpits>
(where <FILE.mpits> file is generated by the instrumentation)

This options behaves like the *-f* options but looks for the intermediate files in the current directory.

-f-absolute <FILE.mpits>
(where <FILE.mpits> file is generated by the instrumentation)

This options behaves like the *-f* options but uses the full path of every intermediate file so as to locate them.

-h
Provides minimal help about merger options.

-keep-mpits, -no-keep-mpits
Tells the merger to keep (or remove) the intermediate files after the trace generation.

-maxmem <M>
The last step of the merging process will be limited to use <M> megabytes of memory. By default, <M> is 512.

-s <FILE.sym>
(where <FILE.sym> file is generated with the Dyninst instrumentator)

Passes information regarding instrumented symbols into the merger to aid the **Paraver** analysis. If *-f*, *-f-relative* or *-f-absolute* paramters are given, the merge process will try to automatically load the symbol file associated to that <FILE.mpits> file.

-o <FILE.prv[.gz]>
Choose the name of the target **Paraver** tracefile, can be compressed with the libz library. If *-o* is not given, the merging process will automatically name the tracefile using the application binary name, if possible.

-remove-files
The merging process removes the intermediate tracefiles when succesfully generating the **Paraver** tracefile.

-skip-sendrecv
Do not match point to point communications issued by MPI_Sendrecv or MPI_Sendrecv_replace.

-sort-addresses
Sort event values that reference source code locations so as the values are sorted by file name first and then line number (enabled by default).

-split-states
Do not join consecutive states that are the same into a single one.

-stop-at-percentage
Stops the generation of the tracefile at a given percentage. Accepts integer values from 1 to 99. All other values disable this option.

-no-syn
If set, the merger will not attempt to synchronize the different tasks. This is useful when merging intermediate files obtained from a single node (and thus, share a single clock).

-syn-by-task
If different nodes are used in the execution of a tracing run, there can exist some clock differences on all the nodes. This option makes mpi2prv to recalculate all the timings based on the end of the MPI_Init call. This will usually lead to "synchronized" tasks, but it will depend on how the clocks advance in time.

-syn-by-node
If different nodes are used in the execution of a tracing run, there can exist some clock differences on all the nodes. This option makes mpi2prv to recalculate all the timings based on the end of the MPI_Init call and the node where they ran. This will usually lead to better synchronized tasks than using *-syn-by-task*, but, again, it will depend on how the clocks advance in time.

-syn-apps
If synchronization is enabled, also align all applications at their synchronization points.

-trace-overwrite, -no-trace-overwrite
Tells the merger to overwrite (or not) the final tracefile if it already exists. If the tracefile exists and *-no-trace-overwrite* is given, the tracefile name will have an increasing numbering in addition to the name given by the user.

-translate-addresses, -no-translate-addresses
Identify the calling site of instrumented calls and samples by the specified levels of the callstack (enabled by default); or just by their instruction addresses.

-translate-data-addresses, -no-translate-data-addresses
Identify allocated objects by their full callpath (enabled by default); or just by the tuple <library_base_address, symbol_offset_within_library>.

-unique-caller-id
Choose whether use a unique value identifier for different callers locations (MPI calling routines, user routines, OpenMP outlined routines and pthread routines).

6.1.2 Parallel Paraver Merger

These options are specific to the parallel version of the **Paraver** merger:

-block
Intermediate trace files will be distributed in a block fashion instead of a cyclic fashion to the merger.

-cyclic
Intermediate trace files will be distributed in a cyclic fashion instead of a block fashion to the merger.

-size
The intermediate trace files will be sorted by size and then assigned to processors in a such manner that each processor receives approximately the same size.

-consecutive-size
Intermediate trace files will be distributed consecutively to processors but trying to distribute the overall size equally among processors.

-use-disk-for-comms
Use this option if your memory resources are limited. This option uses an alternative matching communication algorithm that saves memory but uses intensively the disk.

-tree-fan-out <N>
Use this option to instruct the merger to generate the tracefile using a tree-based topology. This should improve the performance when using a large number of processes at the merge step. Depending on the combination of processes and the width of the tree, the merger will need to run several stages to generate the final tracefile.

The number of processes used in the merge process must be equal or greater than the <N> parameter. If it is not, the merger itself will automatically set the width of the tree to the number of processes used.

6.2 Dimemas merger

As stated before, there are two **Dimemas** mergers: **mpi2dim** and **mpimpi2dim**. The former is for use in a single processor mode while the latter is meant to be used with multiple processors using MPI.

In contrast with **Paraver** merger, **Dimemas** mergers generate a single output file with the `.dim` extension that is suitable for the **Dimemas** simulator from the given intermediate trace files.

These are the available options for both **Dimemas** mergers:

-evtnum <N>
Partially processes (up to <N> events) the intermediate trace files to generate the **Dimemas** tracefile.

-f <FILE.mpits>
(where <FILE.mpits> file is generated by the instrumentation)

The merger uses the given file (which contains a list of intermediate trace files of a single executions) instead of giving set of intermediate trace files.

This option takes only the file name of every intermediate file so as to locate them.

-f-relative <FILE.mpits>
(where <FILE.mpits> file is generated by the instrumentation)

This options works exactly as the *-f* option.

-f-absolute <FILE.mpits>
(where <FILE.mpits> file is generated by the instrumentation)

This options behaves like the *-f* option but uses the full path of every intermediate file so as to locate them.

-h
Provides minimal help about merger options.

-maxmem <M>
The last step of the merging process will be limited to use <M> megabytes of memory. By default, M is 512.

-o <FILE.dim>
Choose the name of the target **Dimemas** tracefile.

6.3 Environment variables

There are some environment variables that are related to the mergers:

6.3.1 Environment variables suitable to the Paraver merger

EXTRAE_LABELS

Lets the user add custom information to the generated **Paraver** Configuration File (`.pcf`). Just set this variable to point to a file containing labels for the unknown (user) events.

The format for the file is:

```
EVENT_TYPE
0 [type1] [label1]
0 [type2] [label2]
...
0 [typeK] [labelK]
```

Where `[typeN]` is the event value and `[labelN]` is the description for the event with value `[typeN]`.

It is also possible to link both type and value of an event:

```
EVENT_TYPE
0 [type] [label]
VALUES
[value1] [label1]
[value2] [label2]
...
[valueN] [labelN]
```

With this information, **Paraver** can deal with both type and value when giving textual information to the end user. If **Paraver** does not find any information for an event/type it will shown it in numerical form.

MPI2PRV_TMP_DIR

Points to a directory where all intermediate temporary files will be stored.

These files will be removed as soon the application ends.

6.3.2 Environment variables suitable to the Dimemas merger

MPI2DIM_TMP_DIR

Points to a directory where all intermediate temporary files will be stored.

These files will be removed as soon the application ends.

CHAPTER

SEVEN

EXTRAE ON-LINE USER GUIDE

7.1 Introduction

Extrae On-line is a new module developed for the **Extrae** tracing toolkit, available from version 3.0, that incorporates intelligent monitoring, analysis and selection of the traced data. This tracing setup is tailored towards long executions that are producing large traces. Applying automatic analysis techniques based on clustering, signal processing and active monitoring, **Extrae** gains the ability to inspect and filter the data while it is being collected to minimize the amount of data emitted into the trace, while maximizing the amount of relevant information presented.

Extrae On-line has been developed on top of Synapse[1], a framework that facilitates the deployment of applications that follow the master/slave architecture based on the MRNet[2] software overlay network. Thanks to its modular design, new types of automatic analysis can be added very easily as new plug-ins into the on-line tracing system, just by defining new Synapse protocols.

This document briefly describes the main features of the **Extrae** On-line module, and shows how it has to be configured and the different options available.

7.2 Automatic analysis

Extrae On-line currently supports three types of automatic analysis:

1. fine-grain structure detection based on clustering techniques,
2. periodicity detection based on signal processing techniques,
3. and multi-experiment analysis based on active monitoring techniques.

Extrae On-line has to be configured to apply one of these types of analysis, and then the analysis will be performed periodically as new data is being traced.

7.3 Structure detection

This mechanism aims at identifying the fine-grain structure of the computing regions of the program. Applying density-based clustering, this method is able to expose the main performance trends in the computations, and this information is useful to focus the analysis on the zones of real interest. To perform the cluster analysis, **Extrae** On-line relies on the ClusteringSuite tool[3].

At each phase of analysis, several outputs are produced:

- A scatter-plot representation that illustrates the behavior of the main computing regions of the program, that enables a quick evaluation of potential imbalances.

[1] https://github.com/gllort/synapse
[2] http://www.paradyn.org/mrnet/
[3] You can download it from https://tools.bsc.es/downloads.

- A summary of several performance metrics per cluster.
- On supported machines, a CPI stack model that attributes stall cycles to specific hardware components.
- And a trace that is augmented with the clusters information, that allows to identify patterns of performance and variabilites.

Subsequent clustering results can be used to study the evolution of the application over time. In order to study how the clusters are evolving, the xtrack tool[4] can be used.

7.4 Periodicity detection

This mechanism allows to detect iterative patterns over a wide region of time, and precisely delimit where the iterations start. Once a period has been found, those iterations presenting less perturbations are selected to produce a representative trace, and the rest of the data is basically discarded. The result of applying this mechanism is a compact trace where only the representative iterations are traced in full detail, and for the rest of the execution we can optionally keep summarized information in the form of phase profiles or a "low resolution" trace.

Please note that applying this technique to a very short execution, or if no periodicity can be detected in the application, may result in an empty trace depending on the configuration options selected (see section *Configuration*).

7.5 Multi-experiment analysis

This mechanism employs active measurement techniques in order to simulate different execution scenarios under the same execution. **Extrae** On-line is able to add controlled interference into the program to simulate different computation loads, network bandwidth, memory congestion and even tuning some configurations of the parallel runtime (currently supports MPI Dynamic Load Balance (DLB) runtime). Then, the application behavior can be studied under different circumstances, and tracking can be used to analyze the impact of these configurations on the program performance. This technique aims at reducing the number of executions necessary to evaluate different parameters and characteristics of your program.

7.6 Configuration

In order to activate the On-line tracing mode, the user has to enable the corresponding configuration section in the **Extrae** XML configuration file. This section is found under *trace-control* > *remote-control* > *online*. The default configuration is already ready to use:

```
<online enabled="yes"
        analysis="clustering"
        frequency="auto"
        topology="auto">
```

The available options for the `<online>` section are the following:

- `enabled` Set to `yes` to activate the On-line tracing mode.
- `analysis` Choose from `clustering`, `spectral` and `gremlins`.
- `frequency` Set the time in seconds after which a new phase of analysis will be triggered, or `auto` to let **Extrae** decide this automatically.
- `topology` Set the desired tree process tree topology, or `auto` to let **Extrae** decide this automatically.

Depending on the analysis selected, the following specific options become available.

[4] You can download it from https://tools.bsc.es/downloads.

7.6.1 Clustering analysis options

```
<clustering config="cl.I.IPC.xml"/>
```

- `config` Specify the path to the ClusteringSuite XML configuration file.

7.6.2 Spectral analysis options

```
<spectral max_periods="0"
          num_iters="3"
          min_seen="0"
          min_likeness="85">
  <spectral_advanced enabled="no"
                     burst_threshold="80">
    <periodic_zone detail_level="profile" />
    <non_periodic_zone detail_level="bursts" min_duration="3s" />
  </spectral_advanced>
</spectral>
```

The basic configuration options for the spectral analysis are the following:

- `max_periods` Set to the maximum number of periods to trace, or `all` to explore the whole run.
- `num_iters` Set to the number of iterations to trace per period.
- `min_seen` Minimum repetitions of a period before tracing it (0 to trace the first time that you encounter it).
- `min_likeness` Minimum percentage of similarity to compare two equivalent periods.

Also, some advanced settings are tunable in the `<spectral_advanced>` section:

- `enabled` Set to `yes` to activate the spectral analysis advanced options.
- `burst_threshold` Filter threshold to keep all CPU bursts that add up to the given total time percentage.
- `detail_level` Specify the granularity of the data stored for the non-representative iterations of the periodic region, and in the non-periodic regions. Choose from none (everything is discarded), profile (phase profile at the start of each iteration/region) or bursts (trace in bursts mode).
- `min_duration` Minimum duration in seconds of the non-periodic regions for emitting any information regarding that region into the trace.

7.6.3 Gremlins analysis options

```
<gremlins start="0"
          increment="2"
          roundtrip="no"
          loop="no" />
```

- `start` Number of gremlins at the beginning of the execution.
- `increment` Number of extra gremlins at each analysis phase. Can also be a negative value to indicate that you want to remove gremlins.
- `roundtrip` Set to `yes` if you want to start adding gremlins after you decrease to 0, or vice-versa, start removing gremlins after you reach the maximum.
- `loop` Set to `yes` if you want to go back to the initial number of gremlins and repeat the sequence of adding/removing gremlins after you have finished a complete sequence.

CHAPTER

EIGHT

EXAMPLES

Here we present three different examples of generating a **Paraver** tracefile. The first example requires the package to be compiled with DynInst libraries. The second example uses the `LD_PRELOAD` or `LDR_PRELOAD[64]` mechanism to interpose code in the application. Such mechanism is available in Linux and FreeBSD operating systems and only works when the application uses dynamic libraries. Finally, there is an example using the static library of the instrumentation package.

8.1 DynInst based examples

DynInst is a third-party instrumentation library developed at UW Madison which can instrument in-memory binaries. It adds flexibility to add instrumentation to the application without modifying the source code. DynInst is ported to different systems (Linux, FreeBSD) and to different architectures[1] (x86, x86/64, PPC32, PPC64) but the functionality is common to all of them.

8.1.1 Generating intermediate files for serial or OpenMP applications

Listing 8.1: run_dyninst.sh

```
1 #!/bin/sh
2
3 export EXTRAE_HOME=WRITE-HERE-THE-PACKAGE-LOCATION
4 export LD_LIBRARY_PATH=${EXTRAE_HOME}/lib
5 source ${EXTRAE_HOME}/etc/extrae.sh
6
7 ## Run the desired program
8 ${EXTRAE_HOME}/bin/extrae -config extrae.xml $*
```

A similar script can be found in `${EXTRAE_HOME}/share/example/SEQ` just tune the *EXTRAE_HOME* environment variable and make the script executable (using **chmod u+x**). You can either pass the XML configuration file through the `EXTRAE_CONFIG_FILE` instead, if you prefer. Line no. 5 is responsible for loading all the environment variables needed for the DynInst launcher (called **extrae**) that is invoked in line 8.

In fact, there are two examples provided in `${EXTRAE_HOME}/share/example/SEQ`, one for static (or manual) instrumentation and another for the DynInst-based instrumentation. When using the DynInst instrumentation, the user may add new routines to instrument using the existing *function-list* file that is already pointed by the *extrae.xml* configuration file. The way to specify the routines to instrument is add as many lines with the name of every routine to be instrumented.

Running OpenMP applications using DynInst is rather similar to serial codes. Just compile the application with the appropriate OpenMP flags and run as before. You can find an example in `${EXTRAE_HOME}/share/example/OMP`.

[1] The IA-64 architecture support was dropped in DynInst 7.0.

8.1.2 Generating intermediate files for MPI applications

MPI applications can also be instrumented using the DynInst instrumentator. The instrumentation is done independently to each spawned MPI process, so in order to execute the DynInst-based instrumentation package on a MPI application, you must be sure that your MPI launcher supports running shell-scripts. The following scripts show how to run the DynInst instrumentator from the MOAB/Slurm queue system. The first script just sets the environment for the job whereas the second is responsible for instrumenting every spawned task.

Listing 8.2: slurm_trace.sh

```
1  #!/bin/bash
2
3  # @ initialdir = .
4  # @ output = trace.out
5  # @ error =  trace.err
6  # @ total_tasks = 4
7  # @ cpus_per_task = 1
8  # @ tasks_per_node = 4
9  # @ wall_clock_limit = 00:10:00
10 # @ tracing = 1
11
12 srun ./run.sh ./mpi_ping
```

The most important thing in the previous script is the line number 11, which is responsible for spawning the MPI tasks (using the srun command). The spawn method is told to execute **`./run.sh ./mpi_ping`** which in fact refers to instrument the `mpi_ping` binary using the `run.sh` script. You must adapt this file to your queue-system (if any) and to your MPI submission mechanism (i.e., change srun to mpirun, mpiexec, poe, *etc.*). Note that changing the line 11 to read like **`./run.sh srun ./mpi_ping`** would result in instrumenting the `srun` application not `mpi_ping`.

Listing 8.3: run.sh

```
1  #!/bin/bash
2
3  export EXTRAE_HOME=@sub_PREFIXDIR@
4  source ${EXTRAE_HOME}/etc/extrae.sh
5
6  # Only show output for task 0, others task send output to /dev/null
7  if test "${SLURM_PROCID}" == "0" ; then
8    ${EXTRAE_HOME}/bin/extrae -config ../extrae.xml $@ > job.out 2> job.err
9  else
10   ${EXTRAE_HOME}/bin/extrae -config ../extrae.xml $@ > /dev/null 2> /dev/null
11 fi
```

This is the script responsible for instrumenting a single MPI task. In line number 4 we set-up the instrumentation environment by executing the commands from `extrae.sh`. Then we execute the binary passed to the `run.sh` script in lines 8 and 10. Both lines are executing the same command except that line 8 sends all the output to two different files (one for standard output and another for standard error) and line 10 sends all the output to `/dev/null`.

Please note, this script is particularly adapted to the MOAB/Slurm queue systems. You may need to adapt the script to other systems by using the appropiate environment variables. Particularly, `SLURM_PROCID` identifies the MPI task id (i.e., the task rank) and may be changed to the proper environemnt variable (`MPI_RANK` in ParaStation/Torque/MOAB system or MXMPI_ID in systems having Myrinet MX devices, for example).

8.2 LD_PRELOAD based examples

`LD_PRELOAD` (or `LDR_PRELOAD[64]` in AIX) interposition mechanism only works for binaries that are linked against shared libraries. This interposition is done by the runtime loader by substituting the original symbols by those provided by the instrumentation package. This mechanism is known to work on Linux, FreeBSD and AIX

operating systems, although it may be available on other operating systems (even using different names[2]) they are not tested.

We show how this mechanism works on Linux (or similar environments) in *Linux* and on AIX in *AIX*.

8.2.1 Linux

The following script preloads the `libmpitrace` library to instrument MPI calls of the application passed as an argument (tune *EXTRAE_HOME* according to your installation).

Listing 8.4: trace.sh

```
#!/bin/sh

export EXTRAE_HOME=<WRITE-HERE-THE-PACKAGE-LOCATION>
export EXTRAE_CONFIG_FILE=extrae.xml
export LD_PRELOAD=${EXTRAE_HOME}/lib/libmpitrace.so

## Run the desired program
$*
```

The previous script can be found in `${EXTRAE_HOME}/share/example/MPI/ld-preload` in your tracing package directory. Copy the script to one of your directories, tune the *EXTRAE_HOME* environment variable and make the script executable (using **`chmod u+x`**). Also copy the XML configuration `extrae.xml` file from `${EXTRAE_HOME}/share/example/MPI` to the current directory. This file is used to configure the whole behavior of the instrumentation package (there is more information about the XML file on chapter *Extrae XML configuration file*). The last line in the script, **`$*`**, executes the arguments given to the script, so as you can run the instrumentation by simply adding the script in between your execution command.

Regarding the execution, if you run MPI applications from the command-line, you can issue the typical **`mpirun`** command as:

```
${MPI_HOME}/bin/mpirun -np N ./trace.sh mpi-app
```

where `${MPI_HOME}` is the directory for your MPI installation, `N` is the number of MPI tasks you want to run, and `mpi-app` is the binary of the MPI application you want to run.

However, if you execute your MPI applications through a queue system you may need to write a submission script. The following script is an example of a submission script for MOAB/Slurm queuing system using the aforementioned *trace.sh* script for an execution of the `mpi-app` on two processors.

Listing 8.5: slurm-trace.sh

```
#! /bin/bash

#@ job_name         = trace_run
#@ output           = trace_run%j.out
#@ error            = trace_run%j.out
#@ initialdir       = .
#@ class            = bsc_cs
#@ total_tasks      = 2
#@ wall_clock_limit = 00:30:00

srun ./trace.sh mpi_app
```

If your system uses LoadLeveler your job script may look like:

[2] Look at http://www.fortran-2000.com/ArnaudRecipes/sharedlib.html for further information.

Listing 8.6: ll.sh

```
1  #! /bin/bash
2  #@ job_type = parallel
3  #@ output = trace_run.ouput
4  #@ error = trace_run.error
5  #@ blocking = unlimited
6  #@ total_tasks = 2
7  #@ class = debug
8  #@ wall_clock_limit = 00:10:00
9  #@ restart = no
10 #@ group = bsc41
11 #@ queue
12
13 export MLIST=/tmp/machine_list ${$}
14 /opt/ibmll/LoadL/full/bin/ll_get_machine_list > ${MLIST}
15 set NP = `cat ${MLIST} | wc -l`
16
17 ${MPI_HOME}/mpirun -np ${NP} -machinefile ${MLIST} ./trace.sh ./mpi-app
18
19 rm ${MLIST}
```

Besides the job specification given in lines 1-11, there are commands of particular interest. Lines 13-15 are used to know which and how many nodes are involved in the computation. Such information information is given to the **mpirun** command to proceed with the execution. Once the execution finished, the temporal file created on line 14 is removed on line 19.

8.2.2 CUDA

There are two ways to instrument CUDA applications, depending on how the package was configured. If the package was configured with *--with-cuda* only interposition on binaries using shared libraries are available. If the package was configured with *--with-cupti* any kind of binary can be instrumented because the instrumentation relies on the CUPTI library to instrument CUDA calls. The example shown below is intended for the former case.

Listing 8.7: run.sh

```
1 #!/bin/bash
2
3 export EXTRAE_HOME=/home/harald/extrae
4 export PAPI_HOME=/home/harald/aplic/papi/4.1.4
5
6 EXTRAE_CONFIG_FILE=extrae.xml
7 LD_LIBRARY_PATH=${EXTRAE_HOME}/lib:${PAPI_HOME}/lib:${LD_LIBRARY_PATH} ./hello
8 ${EXTRAE_HOME}/bin/mpi2prv -f TRACE.mpits -e ./hello
```

In this example, the hello application is compiled using the **nvcc** compiler and linked against the `cudatrace` library (`-lcudatrace`). The binary contains calls to `Extrae_init` and `Extrae_fini` and then executes a CUDA kernel. Line number 6 refers to the execution of the application itself. The **Extrae** configuration file and the location of the shared libraries are set in this line. Line number 7 invokes the merge process to generate the final tracefile.

8.2.3 AIX

AIX typically ships with POE and LoadLeveler as MPI implementation and queue system respectively. An example for a system with these software packages is given below. Please, note that the example is intended for 64 bit applications, if using 32 bit applications then `LDR_PRELOAD64` needs to be changed in favour of `LDR_PRELOAD`.

Listing 8.8: ll-aix64.sh

```
1  #@ job_name = basic_test
2  #@ output = basic_stdout
3  #@ error = basic_stderr
4  #@ shell = /bin/bash
5  #@ job_type = parallel
6  #@ total_tasks = 8
7  #@ wall_clock_limit = 00:15:00
8  #@ queue
9
10 export EXTRAE_HOME=<WRITE-HERE-THE-PACKAGE-LOCATION>
11 export EXTRAE_CONFIG_FILE=extrae.xml
12 export LDR_PRELOAD64=${EXTRAE_HOME}/lib/libmpitrace.so
13
14 ./mpi-app
```

Lines 1-8 contain a basic LoadLeveler job definition. Line 10 sets the **Extrae** package directory in *EXTRAE_HOME* environment variable. Follows setting the XML configuration file that will be used to set up the tracing. Then follows setting `LDR_PRELOAD64` which is responsible for instrumentation using the shared library `libmpitrace.so`. Finally, line 14 executes the application binary.

8.3 Statically linked based examples

This is the basic instrumentation method suited for those installations that neither support DynInst nor `LD_PRELOAD`, or require adding some manual calls to the **Extrae** API.

8.3.1 Linking the application

To get the instrumentation working on your code, first you have to link your application with the **Extrae** libraries. There are installed examples in your package distribution under *$EXTRAE_HOME*`/share/examples`. There you can find MPI, OpenMP, pthread and sequential examples depending on the support at configure time.

Consider the example Makefile found in *$EXTRAE_HOME*`/share/examples/MPI/static`:

Listing 8.9: Makefile

```
1  MPI_HOME = /gpfs/apps/MPICH2/mx/1.0.7..2/64
2  EXTRAE_HOME = /home/bsc41/bsc41273/foreign-pkgs/extrae-11oct-mpich2/64
3  PAPI_HOME = /gpfs/apps/PAPI/3.6.2-970mp-patched/64
4  XML2_LDFLAGS = -L/usr/lib64
5  XML2_LIBS = -lxml2
6
7  F77 = $(MPI_HOME)/bin/mpif77
8  FFLAGS = -O2
9  FLIBS = $(EXTRAE_HOME)/lib/libmpitracef.a \
10         -L$(PAPI_HOME)/lib -lpapi -lperfctr \
11         $(XML2_LDFLAGS) $(XML2_LIBS)
12
13 all: mpi_ping
14
15 mpi_ping: mpi_ping.f
16           $(F77) $(FFLAGS) mpi_ping.f $(FLIBS) -o mpi_ping
17
18 clean:
19        rm -f mpi_ping *.o pingtmp? TRACE.*
```

Lines 2-5 are definitions of some Makefile variables to set up the location of different packages needed by the instrumentation. In particular, *EXTRAE_HOME* sets where the **Extrae** package directory is located. In order to

link your application with **Extrae** you have to add its libraries in the link stage (see lines 9-11 and 16). Besides file:*libmpitracef.a* we also add some PAPI libraries (`-lpapi`), and its dependency (which you may or not need (`-lperfctr`), the libxml2 parsing library (`-lxml2`), and finally, the bfd and liberty libraries (`-lbfd` and `-liberty`), if the instrumentation package was compiled to support merge after trace (see chapter *Configuration, build and installation* for further information).

8.3.2 Generating the intermediate files

Executing an application with the statically linked version of the instrumentation package is very similar as the method shown in *LD_PRELOAD based examples*. There is, however, a difference: do not set `LD_PRELOAD` in *trace.sh*.

Listing 8.10: trace.sh

```
1  #!/bin/sh
2
3  export EXTRAE_HOME=WRITE-HERE-THE-PACKAGE-LOCATION
4  export EXTRAE_CONFIG_FILE=extrae.xml
5  export LD_LIBRARY_PATH=${EXTRAE_HOME}/lib: \
6                         /gpfs/apps/MPICH2/mx/1.0.7..2/64/lib: \
7                         /gpfs/apps/PAPI/3.6.2-970mp-patched/64/lib
8
9  ## Run the desired program
10 $*
```

See section *LD_PRELOAD based examples* to know how to run this script either through command line or queue systems.

8.4 Generating the final tracefile

Independently from the tracing method chosen, it is necessary to translate the intermediate tracefiles into a **Paraver** tracefile. The **Paraver** tracefile can be generated automatically (if the tracing package and the XML configuration file were set up accordingly, see chapters *Configuration, build and installation* and *Extrae XML configuration file*) or manually. In case of using the automatic merging process, it will use all the resources allocated for the application to perform the merge once the application ends.

To manually generate the final **Paraver** tracefile issue the following command:

```
${EXTRAE_HOME}/bin/mpi2prv -f TRACE.mpits -e mpi-app -o trace.prv
```

This command will convert the intermediate files generated in the previous step into a single **Paraver** tracefile. The `TRACE.mpits` is a file generated automatically by the instrumentation and contains a reference to all the intermediate files generated during the execution run. The `-e` parameter receives the application binary `mpi-app` in order to perform translations from addresses to source code. To use this feature, the binary must have been compiled with debugging information. Finally, the `-o` flag tells the merger how the **Paraver** tracefile will be named (`trace.prv` in this case).

CHAPTER

NINE

AN EXAMPLE OF EXTRAE XML CONFIGURATION FILE

```
<?xml version='1.0'?>

<trace enabled="yes"
  home="@sed_MYPREFIXDIR@"
  initial-mode="detail"
  type="paraver"
>
  <mpi enabled="yes">
    <counters enabled="yes" />
  </mpi>

  <pthread enabled="yes">
    <locks enabled="no" />
    <counters enabled="yes" />
  </pthread>

  <openmp enabled="yes">
    <locks enabled="no" />
    <counters enabled="yes" />
  </openmp>

  <callers enabled="yes">
    <mpi enabled="yes">1-3</mpi>
    <sampling enabled="no">1-5</sampling>
  </callers>

  <user-functions enabled="no"
    list="/home/bsc41/bsc41273/user-functions.dat"
    exclude-automatic-functions="no">
    <counters enabled="yes" />
  </user-functions>

  <counters enabled="yes">
    <cpu enabled="yes" starting-set-distribution="1">
      <set enabled="yes" domain="all" changeat-globalops="5">
        PAPI_TOT_INS,PAPI_TOT_CYC,PAPI_L1_DCM
        <sampling enabled="no" period="100000000">PAPI_TOT_CYC</sampling>
      </set>
      <set enabled="yes" domain="user" changeat-globalops="5">
        PAPI_TOT_INS,PAPI_FP_INS,PAPI_TOT_CYC
      </set>
    </cpu>
    <network enabled="yes" />
    <resource-usage enabled="yes" />
  </counters>

  <storage enabled="no">
    <trace-prefix enabled="yes">TRACE</trace-prefix>
    <size enabled="no">5</size>
```

```
    <temporal-directory enabled="yes">/scratch</temporal-directory>
    <final-directory enabled="yes">/gpfs/scratch/bsc41/bsc41273</final-directory>
  </storage>

  <buffer enabled="yes">
    <size enabled="yes">150000</size>
    <circular enabled="no" />
  </buffer>

  <trace-control enabled="yes">
    <file enabled="no" frequency="5M">/gpfs/scratch/bsc41/bsc41273/control</file>
    <global-ops enabled="no">10</global-ops>
    <remote-control enabled="yes">
      <mrnet enabled="yes" target="150" analysis="spectral" start-after="30">
        <clustering max_tasks="26" max_points="8000"/>
        <spectral min_seen="1" max_periods="0" num_iters="3" signals="DurBurst,
↪InMPI"/>
      </mrnet>
    </remote-control>
  </trace-control>

  <others enabled="yes">
    <minimum-time enabled="no">10M</minimum-time>
    <finalize-on-signal enabled="yes"
      SIGUSR1="no" SIGUSR2="no" SIGINT="yes"
      SIGQUIT="yes" SIGTERM="yes" SIGXCPU="yes"
      SIGFPE="yes" SIGSEGV="yes" SIGABRT="yes"
    />
    <flush-sampling-buffer-at-instrumentation-point enabled="yes" />
  </others>

  <burst enabled="no" threshold="500u" mpi-statistics="yes" omp-statistics="yes"␣
↪omp-summarization="no" />


  <sampling enabled="no" type="default" period="50m" variability="10m"/>

  <opencl enabled="no" />

  <openacc enabled="no" />

  <cuda enabled="no" />

        <!-- Beware: High overhead! -->
        <cpu-events enabled="no" frequency="0" emit-always="no" poi="openmp"/>

  <merge enabled="yes"
    synchronization="default"
    binary="mpi_ping"
    tree-fan-out="16"
    max-memory="512"
    joint-states="yes"
    keep-mpits="yes"
    sort-addresses="yes"
    overwrite="yes"
  >
    mpi_ping.prv
  </merge>

</trace>
```

CHAPTER

TEN

ENVIRONMENT VARIABLES

Althouth **Extrae** is configured through an XML file (which is pointed by `EXTRAE_CONFIG_FILE`), it also supports minimal configuration via environment variables for those systems that do not have the library responsible for parsing the XML files (*i.e.*, libxml2).

This appendix presents the environment variables **Extrae** package uses if `EXTRAE_CONFIG_FILE` is not set and their description. For those environment variables that refer to XML `enabled` attributes (*i.e.*, that can be set to "yes" or "no") are considered to be enabled if their value is defined to 1.

EXTRAE_BUFFER_SIZE

Sets the number of records that the instrumentation buffer can hold before flushing them.

EXTRAE_COUNTERS

See section *Processor performance counters*. Just one set can be defined. Counters (in PAPI) groups (in PMAPI) are given separated by commas.

EXTRAE_CONTROL_FILE

The instrumentation will be enabled only when the pointed file exists.

EXTRAE_CONTROL_GLOPS

Starts the instrumentation when the specified number of global collectives have been executed.

EXTRAE_CONTROL_TIME

Checks the file pointed by *EXTRAE_CONTROL_FILE* at this period.

EXTRAE_DIR

Specifies where temporal files will be created during instrumentation.

EXTRAE_DISABLE_MPI

Disables MPI instrumentation.

EXTRAE_DISABLE_OMP

Disables OpenMP instrumentation.

EXTRAE_DISABLE_PTHREAD

Disables pthread instrumentation.

EXTRAE_FILE_SIZE

Sets the maximum size (in Mbytes) for the intermediate trace file.

EXTRAE_FUNCTIONS

List of routines to be instrumented, as described in section *XML Section: User functions*, using the GNU C compiler `-finstrument-funtions` option, or the IBM XL compiler `-qdebug=function_trace` option at compile and link time.

EXTRAE_FUNCTIONS_COUNTERS_ON

Specifies if the performance counters should be collected when a user function event is emitted.

EXTRAE_FINAL_DIR

Specifies where files will be stored when the application ends.

EXTRAE_GATHER_MPITS

Gathers intermediate trace files into a single directory. Only available when instrumenting MPI applications.

EXTRAE_HOME

Points where **Extrae** is installed.

EXTRAE_INITIAL_MODE

Chooses whether the instrumentation runs in `detail` or in `bursts` mode.

EXTRAE_BURST_THRESHOLD

Specifies the threshold time to filter running bursts.

EXTRAE_MAX_MPI_HANDLES

Specifies the threshold from which proxy handles for MPI_Request and MPI_Status objects will be allocated dynamically (set to 0 for all). Only available when instrumenting MPI applications.

EXTRAE_MINIMUM_TIME

Specifies the minimum amount of instrumentation time.

EXTRAE_MPI_CALLER

Chooses which MPI calling routines should be dumped to the tracefile.

EXTRAE_MPI_COUNTERS_ON

Set to 1 if MPI must report performance counter values.

EXTRAE_MPI_STATISTICS

Set to 1 if basic MPI statistics must be collected in burst mode. Only available in systems with Myrinet GM/MX networks.

EXTRAE_NETWORK_COUNTERS

Set to 1 to dump network performance counters values.

EXTRAE_PTHREAD_COUNTERS_ON

Set to 1 if pthread must report performance counters values.

EXTRAE_OMP_COUNTERS_ON

Set to 1 if OpenMP must report performance counters values.

EXTRAE_PTHREAD_LOCKS

Set to 1 if pthread locks have to be instrumented.

EXTRAE_OMP_LOCKS

Set to 1 if OpenMP locks have to be instrumented.

EXTRAE_ON

Enables instrumentation.

EXTRAE_PROGRAM_NAME

Specifies the prefix of the resulting intermediate trace files.

EXTRAE_SAMPLING_CALLER

Determines the callstack segment stored through time-sampling capabilities.

EXTRAE_SAMPLING_CLOCKTYPE

Determines domain for sampling clock. Options are: `DEFAULT`, `REAL`, `VIRTUAL` and `PROF`.

EXTRAE_SAMPLING_PERIOD

Enables time-sampling capabilities with the indicated period.

EXTRAE_SAMPLING_VARIABILITY

Adds some variability to the sampling period.

EXTRAE_RUSAGE

Instrumentation emits resource usage at flush points if set to 1.

EXTRAE_SKIP_AUTO_LIBRARY_INITIALIZE

Do not init instrumentation automatically in the main symbol.

EXTRAE_TRACE_TYPE

Chooses whether the resulting tracefiles are intended for **Paraver** or **Dimemas**.

CHAPTER

ELEVEN

RUNNING EXTRAE ON TOP OF PNMPI

11.1 Introduction

Most tools targeting MPI rely on the MPI Profiling Interface (PMPI), which allows tools to transparently intercept invocations to MPI routines and with that to establish wrappers around MPI calls to gather execution information. However, the usage of this interface is limited to a single tool. PnMPI eliminates the restriction of a single PMPI tool layer per execution. It can dynamically load and chain multiple PMPI tools into a single tool stack and then interject this complete stack between the target application and the library without changing the view for each individual tool. It enables the user to combine arbitrary MPI tools without having to reimplement them. When **Extrae** is operating through `LD_PRELOAD` interposition it also supports to run on top of PnMPI.

11.2 Instructions to run with PnMPI

Extrae tracing libraries have to be processed with the **`patch`** tool that comes included with PnMPI. Just run this utility, passing as argument the tracing library that you want to load under the PnMPI environment and the output name for the patched library.

```
$PNMPI_HOME/patch/patch libmpitrace.so libmpitrace-pnmpi.so
```

At execution time the `PNMPI_CONF` environment variable has to be defined, pointing to a file that specifies all the tools that will be loaded with PnMPI.

```
export PNMPI_CONF=$PNMPI_HOME/demo/.pnmpi-conf
```

In this file we have to add the patched tracing library at the beginning of the list.

```
module libmpitrace-pnmpi
module another-tool
...
```

CHAPTER

TWELVE

REGRESSION TESTS

Extrae includes a battery of regression tests to evaluate whether recent versions of the instrumentation package keep their compatibility and that new changes on it have not introduced new faults.

These tests are meant to be executed in the same machine on which **Extrae** was compiled and they are not intended to support its execution through batch-queuing systems nor cross-compilation processes.

To invoke the tests, simply run from the terminal the following command:

```
make check
```

after the configuration and building process. It will automatically invoke all the tests one after another and will produce several summaries.

These tests are divided into different categories that stress different parts of **Extrae**.

The current categories tested include, but are not limited to:

- Clock routines
- Instrumentation support
  - Event definition in the PCF from the **Extrae** API
  - pthread instrumentation
  - MPI instrumentation
  - Java instrumentation
- Merging process (*i.e.*, **`mpi2prv`**)
- Callstack unwinding (either using libunwind library or backtrace)
- Performance hardware counters through PAPI library
- XML parsing through libxml2

These tests may change during the development of **Extrae**.

If the reader has a particular suggestion on a particular test, please consider sending it to tools@bsc.es for its consideration.

CHAPTER

THIRTEEN

OVERHEAD

Extrae includes a set of tests to evaluate the overhead imposed to the application by different components.

These tests are installed in `$EXTRAE_HOME/share/tests/overhead` and can be run by executing the `run_overhead_tests.sh` script within this directory.

Note that this script compiles and executes the generated binaries on the same system, so this script will require some tuning to run in a system that uses a batch-queuing system and/or needs cross-compiling.

Currently there are the following tests the evaluate the necessary time to perform certain operations:

- **posix_clock** grab the current time using the posix clock. Even the simpler emitted event requires gathering a timestamp.
- **extrae_event** emit one event (without performance counters) into the tracing buffer using the *Extrae_event* API call.
- **extrae_nevent4** emit four events (without performance counters) into the tracing buffer using the *Extrae_nevent4* API call.
- **extrae_eventandcounters** emit one event (and reading 4 peformance counters) into the tracing buffer through the *Extrae_eventandcounters* call.
- **papi_read1** capture the value of one performance counter through PAPI.
- **papi_read4** capture the value of four performance counters through PAPI.
- **extrae_user_function** involves traversing the processor call-stack while searching the frame that points to the current routine (as the *Extrae_user_function* API call).
- **extrae_get_caller1** traverses one level of the processor call-stack.
- **extrae_get_caller6** traverses six levels of the processor call-stack.
- **extrae_trace_callers** collects three frames from the processor call-stack.
- **extrae_event_Java** measures the time required to emit one event (without performance counters) from Java through the JNI connector.
- **extrae_nevent4_Java** measures the time needed to emit four events (without performance counters) from Java through the JNI connector.

Figure 13.1 depicts the overhead of **Extrae** 5.1.5 in the following systems:

- System based on `Intel Xeon E5649` (*Nehalem*) processors. **Extrae** was compiled with support for libunwind 1.1 and PAPI 5.0.1.
- System based on `Intel Xeon E5-2670` (*SandyBridge*) processors. **Extrae** was compiled with support for libunwind 1.1, PAPI 5.4.1 and IBM's Java7.
- System based on `Intel Xeon E5-2680` (*Haswell*) processors. **Extrae** was compiled with support for libunwind 1.1 and PAPI 5.4.1 and OpenJDK's Java 1.8.
- System based on `IBM Power8`. **Extrae** was compiled with support for libunwind (downloaded from GIT) and PAPI 5.4.1.

- System based on `Cortex-A15` (*Samsung Exynos 5*). **Extrae** was compiled with support for libunwind (downloaded from GIT) and PAPI 5.4.1.

The reader may notice that the ARM processor requires more time to execute the tests than the rest, even for the simpler cases (`posix_clock` and `extrae_event`). The Power8-based system takes a similar amount of time than Intel-based systems except for the call-stack traversal. Within Intel-based systems, the *SandyBridge* processor reduced the time significantly from the *Nehalem* processor but the *Haswell* does not show a great reduction from *SandyBridge*.

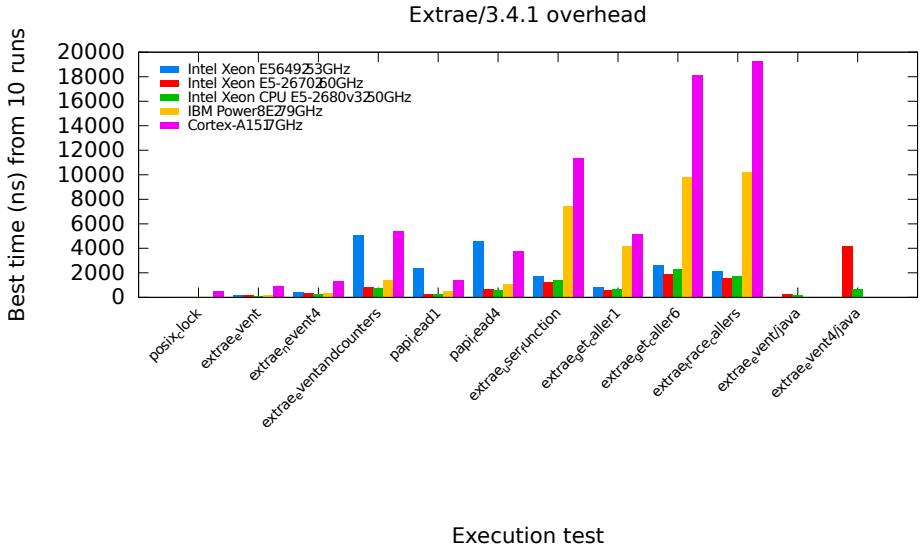


Figure 13.1: Overhead result in a variety of systems for **Extrae** 5.1.5

CHAPTER

FOURTEEN

FREQUENTLY ASKED QUESTIONS

14.1 Configure, compile and link FAQ

Question:

The **bootstrap** script claims **libtool** errors like:

- `src/common/Makefile.am:9: Libtool library used but 'LIBTOOL' is undefined`
- `src/common/Makefile.am:9: The usual way to define 'LIBTOOL' is to add 'AC_PROG_LIBTOOL'`
- `src/common/Makefile.am:9: to 'configure.ac' and run 'aclocal' and 'autoconf' again.`
- `src/common/Makefile.am:9: If 'AC_PROG_LIBTOOL' is in 'configure.ac', make sure`
- `src/common/Makefile.am:9: its definition is in aclocal's search path.`

Answer: Add to the `aclocal` (which is called in `bootstrap`) the directory where it can find the M4-macro files from `libtool`. Use the `-I` option to add it.

Question:

The **bootstrap** script claims that some macros are not found in the library, like:

- `aclocal:configure.ac:338: warning: macro 'AM_PATH_XML2' not found in library`

Answer: Some M4 macros are not found. In this specific example, the libxml2 is not installed or cannot be found in the typical installation directory. To solve this issue, check whether the libxml2 is installed and modify the line in the `bootstrap` script that reads `aclocal -I config` to `aclocal -I config -I/path/to/xml/m4/macros` where `/path/to/xml/m4/macros` is the directory where the libxml2 M4 got installed (for example `/usr/local/share/aclocal`).

Question:

The application cannot be linked succesfully. The link stage complains about, or something similar, to:

- `ld: 0711-317 ERROR: Undefined symbol: .__udivdi3.`
- `ld: 0711-317 ERROR: Undefined symbol: .__mulvsi3.`

Answer: The instrumentation libraries have been compiled with GNU compilers whereas the application is compiled using IBM XL compilers. Add the libgcc's library to the link stage of the application. This library can be found under the installation directory of the GNU compiler.

Question:

The application cannot be linked. The linker misses some routines like:

- `src/common/utils.c:122: undefined reference to '__intel_sse2_strlen'.`
- `src/common/utils.c:125: undefined reference to '__intel_sse2_strdup'.`
- `src/common/utils.c:132: undefined reference to '__intel_sse2_strtok'.`
- `src/common/utils.c:100: undefined reference to '__intel_sse2_strncpy'.`
- `src/common/timesync.c:211: undefined reference to '__intel_fast_memset'.`

Answer: The instrumentation libraries have been compiled using Intel compilers (*i.e.*, `icc`, `icpc`) whereas the application is being linked through non-Intel compilers or `ld` directly. You can proceed in three directions, you can either compile your application using the Intel compilers, or add an Intel library that provides these routines (`libintlc.so` and `libirc.so`, for instance), or even recompile **Extrae** using the GNU compilers. Note, nonetheless, that using Intel MPI compiler does not guarantee using the Intel compiler backends, just run the MPI compiler (**`mpicc`**, **`mpiCC`**, **`mpif77`**, **`mpif90`**, ...) with the `-v` flag to get information on what compiler backend relies.

Question:

The make command dies when building libraries belonging **Extrae** in an AIX machine with messages like:

- `libtool: link: ar cru libcommon.a libcommon_la-utils.o libcommon_la-events.o`
- `ar: 0707-126 libcommon\_la-utils.o is not valid with the current object file mode.`

  `Use the -X option to specify the desired object mode.`
- `ar: 0707-126 libcommon\_la-events.o is not valid with the current object file mode.`

  `Use the -X option to specify the desired object mode.`

Answer: `libtool` uses the **`ar`** command to build static libraries. However, **`ar`** does need special flags (`-X64`) to deal with 64 bit objects. To workaround this problem, just set the environment variable `OBJECT_MODE` to 64 before executing **`gmake`**. The **`ar`** command honors this variable to properly handle the object files in 64 bit mode.

Question:

The **`configure`** script dies saying:

```
configure: error: Unable to determine pthread library support.
```

Answer: Some systems (like BG/L) does not provide a pthread library and **`configure`** claims that cannot find it. Launch the **`configure`** script with the `-disable-pthread` parameter.

Question:

gmake command fails when compiling the instrumentation package in a machine running AIX operating system, using 64 bit mode and IBM XL compilers complaining about Profile MPI (PMPI) symbols.

Answer: Use the reentrant version of IBM compilers (`xlc_r` and `xlC_r`). Non reentrant versions of MPI library do not include 64 bit MPI symbols, whereas reentrant versions do. To use these compilers, set the CC (C compiler) and CXX (C++ compiler) environment variables before running the **configure** script.

Question:

The compiler fails complaining that some parameters can not be understood when compiling the parallel merge.

Answer: If the environment has more than one compiler (for example, IBM and GNU compilers), is it possible that the parallel merge compiler is not the same as the rest of the package. There are two ways to solve this:

- Force the package compilation with the same backend as the parallel compiler. For example, for IBM compiler, set `CC=xlc` and `CXX=xlC` at the configure step.
- Tell the parallel compiler to use the same compiler as the rest of the package. For example, for IBM compiler mpcc, set `MP_COMPILER=gcc` when issuing the make command.

Question:

The instrumentation package does not generate the shared instrumentation libraries but generates the satatic instrumentation libraries.

Answer 1: Check that the configure step was compiled without `--disable-shared` or force it to be enabled through `--enable-shared`.

Answer 2: Some MPI libraries (like MPICH 1.2.x) do not generate the shared libraries by default. The instrumentation package rely on them to generate its shared libraries, so make sure that the shared libraries of the MPI library are generated.

Question:

In BlueGene systems where the libxml2 (or any optional library for extrae) the linker shows error messages like when compiling the final application with the **Extrae** library:

- `../libxml2/lib/libxml2.a(xmlschemastypes.o): In function '_xmlSchemaDateAdd'`
- `../libxml2-2.7.2/xmlschemastypes.c:3771: undefined reference to '__uitrunc'`
- `../libxml2-2.7.2/xmlschemastypes.c:3796: undefined reference to '__uitrunc'`
- `../libxml2-2.7.2/xmlschemastypes.c:3801: undefined reference to '__uitrunc'`
- `../libxml2-2.7.2/xmlschemastypes.c:3842: undefined reference to '__uitrunc'`
- `../libxml2-2.7.2/xmlschemastypes.c:3843: undefined reference to '__uitrunc'`

- `../libxml2/lib/libxml2.a(xmlschemastypes.o): In function 'xmlSchemaGetCanonValue'`
- `../libxml2-2.7.2/xmlschemastypes.c:5840: undefined reference to '__f64tou64rz'`
- `../libxml2-2.7.2/xmlschemastypes.c:5843: undefined reference to '__f64tou64rz'`
- `../libxml2-2.7.2/xmlschemastypes.c:5846: undefined reference to '__f64tou64rz'`
- `../libxml2-2.7.2/xmlschemastypes.c:5849: undefined reference to '__f64tou64rz'`
- `../libxml2/lib/libxml2.a(debugXML.o): In function 'xmlShell'`
- `../libxml2-2.7.2/debugXML.c:2802: undefined reference to '_fill'`
- `collect2: ld returned 1 exit status`

Answer: The libxml2 library (or any other optional library) has been compiled using the IBM XL compiler. There are two alternatives to circumvent the problem: add the XL libraries into the link stage when building your application, or recompile the libxml2 library using the GNU gcc cross compiler for BlueGene.

Question:

Where do I get the procedure and constant declarations for Fortran?

Answer: You can find a module (ready to be compiled) in `$EXTRAE_HOME/include/extrae_module.f`. To use the module, just compile it (do not link it), and then use it in your compiling / linking step. If you do not use the module, the trace generation (specially for those routines that expect parameters which are not `INTEGER*4`) can result in type errors and thus generate a tracefile that does not honor the **Extrae** calls.

14.2 Execution FAQ

Question:

I executed my application instrumenting with **Extrae**, even though it appears that **Extrae** is not intrumenting anything. There is neither any **Extrae** message nor any **Extrae** output files (file:*set-X/*.mpit).

Answer 1: Check that environment variables are correctly passed to the application.

Answer 2: If the code is Fortran, check that the number of underscores used to decorate routines in the instrumentation library matches the number of underscores added by the Fortran compiler you used to compile and link the application. You can use the **nm** and **grep** commands to check it.

Answer 3: If the code is MPI and Fortran, check that you're using the proper Fortran library for the instrumentation.

Answer 4: If the code is MPI and you are using `LD_PRELOAD`, check that the binary is linked against a shared MPI library (you can use the **ldd** command).

Question:

Why are the environment variables not exported?

Answer: MPI applications are launched using special programs (like **mpirun**, **poe**, **mprun**, **srun**, ...) that spawn the application for the selected resources. Some of these programs do not export all the environment variables to the spawned processes. Check if the the launching program does have special parameters to do that, or use the approach used on section *Examples* based on launching scripts instead of MPI applications.

Question:

The instrumentation begins for a single process instead for several processes.

Answer 1: Check that you place the appropriate parameter to indicate the number of tasks (typically `-np`).

Answer 2: Some MPI implementation require the application to receive special MPI parameters to run correctly. For example, MPICH based on CH-P4 device require the binary to receive som paramters. The following example is an sh-script that solves this issue:

```
#!/bin/sh
EXTRAE_CONFIG_FILE=extrae.xml ./mpi_program $@ real_params
```

Question:

The application blocks at the beginning.

Answer: The application may be waiting for all tasks to startup but only some of them are running. Check for the previous question.

Question:

The resulting traces do not contain the routines that have been instrumented.

Answer 1: Check that the routines have been actually executed.

Answer 2: Some compilers do automatic inlining of functions at some optimization levels (*e.g.*, Intel Compiler at `-O2`). When functions are inlined, they do not have entry and exit blocks and cannot be instrumented. Turn off inlining or decrease the optimization level.

Question:

Number of threads = 1?

Answer: Some MPI launchers (*i.e.,* **mpirun**, **poe**, **mprun**, ...)

Question:

When running the instrumented application, the loader complains about: `undefined symbol: clock_gettime`

Answer: The instrumentation package was configured using `--enable-posix-clock` and on many systems this implies the inclusion of additional libraries (namely, `-lrt`)

Question:

Extrae asks to run *genstubs-kmpc-11.sh* increasing the value of *MAX_WRAPPERS*.

Answer: Get the sources from GitHub and modify the file `src/tracer/wrappers/OMP/genstubs-kmpc-11.sh` changing *MAX_WRAPPERS* to the desired number. After modifying with above changes, run the file `./genstubs-kmpc-11.sh` which will generate files that are

necesary to recompile **Extrae**. To recompile **Extrae**, check how **Extrae** is configured by running `${EXTRAE_HOME}/etc/configured.sh`. This will show the compiler, the flags associated with **Extrae** and various paths to different libraries. If everything looks correct, proceed with the recompilation of **Extrae** by running *configure*, *make* and *make install*.

Question:

Extrae asks to run *genstubs-libgomp.sh* increasing the value of *DOACROSS_MAX_NESTING*.

Answer: Get the sources from GitHub and modify the file `src/tracer/wrappers/OMP/genstubs-libgomp.sh` changing *DOACROSS_MAX_NESTING* to the desired number. After modifying with above changes, run the file `./genstubs-libgomp.sh` which will generate files that are necesary to recompile **Extrae**. To recompile **Extrae**, check how **Extrae** is configured by running `${EXTRAE_HOME}/etc/configured.sh`. This will show the compiler, the flags associated with **Extrae** and various paths to different libraries. If everything looks correct, proceed with the recompilation of **Extrae** by running *configure*, *make* and *make install*

14.3 Performance monitoring counters FAQ

Question:

How do I know the available performance counters on the system?

Answer 1: If using PAPI, check the **`papi_avail`** or **`papi_native_avail`** commands found in the PAPI installation directory.

Answer 2: If using PMAPI (on AIX systems), check for the **`pmlist`** command. Specifically, check for the available groups running **`pmlist -g -1`**.

Question:

How do I know how many performance counters can I use?

Answer: The **Extrae** package can gather up to eight (8) performance counters at the same time. This also depends on the underlying library used to gather them.

Question:

When using PAPI, I cannot read eight performance counters or the specified in **`papi_avail`** output.

Answer 1: There are some performance counters (those listed in **`papi_avail`**) that are classified as derived. Such performance counters depend on more than one counter increasing the number of real performance counters used. Check for the derived column within the list to check whether a performance counter is derived or not.

Answer 2: On some architectures, like the PowerPC, the performance counters are grouped in a such way that choosing a performance counter precludes others from being elected in the same set. A feasible work-around is to create as many sets in the XML file to gather all the required hardware counters and make sure that the sets change from time to time.

14.4 Merging traces FAQ

Question:

The **mpi2prv** command shows the following messages at the start-up:

```
PANIC! Trace file TRACE.0000011148000001000000.mpit is 16 bytes
too big!  PANIC! Trace file TRACE.0000011147000002000000.mpit is 32
bytes too big!  PANIC! Trace file TRACE.0000011146000003000000.mpit
is 16 bytes too big!
```

and it dies when parsing the intermediate files.

Answer 1: The aforementioned messages are typically related with incomplete writes in disk. Check for enough disk space using the **quota** and **df** commands.

Answer 2: If your system supports multiple ABIs (for example, linux x86-64 supports 32 and 64 bits ABIs), check that the ABI of the target application and the ABI of the merger match.

Question:

The resulting **Paraver** tracefile contains invalid references to the source code.

Answer: This usually happens when the code has not been compiled and linked with the `-g` flag. If your code invokes CUDA kernels you may also need to link with the `--generate-line-info` flag to generate debug symbols for device code. Moreover, some high level optimizations (which includes inlining, inter-procedural analysis, and so on) can lead to generate bad references.

Question:

The resulting trace contains information regarding the stack (like callers) but their value does not coincide with the source code.

Answer: Check that the same binary is used to generate the trace and referenced with the the **-e** parameter when generating the **Paraver** tracefile.

CHAPTER

FIFTEEN

SUBMITTING A BUG REPORT

Whenever encountering that **Extrae** fails while instrumenting an application or generating a trace-file, you may consider to submit a bug report to tools@bsc.es.

Before submitting a bug report, consider looking at the Frequently Asked Questions in appendix *Frequently Asked Questions* because it may contain valuable information to address the failure you observe.

In any case, if you find that **Extrae** fails and you want to submit a bug report, please collect as much as information possible to ease the bug-hunting process.

The information required depen whether the bug refers to a compilation or an execution issue.

15.1 Reporting a compilation issue

The following list of items are valuable when reporting a compilation problem:

- **Extrae** version (this information appears in the first messages of the execution).
- **Extrae** configuration information, such as:
  - the configure output and the generated `config.log` file.
  - versions of any additional libraries (PAPI, libunwind, DynInst, CUDA, OpenACC, OpenCL, libxml2, libdwarf, libelf, . . .)
- The compilation error itself as reported by invoking **`make V=1`**.

15.2 Reporting an execution issue

The following list of items are valuable when reporting an execution problem:

- **Extrae** version (this information appears in the first messages of the execution).
- **Extrae** configuration information, such as:
  - the configure output and the generated `config.log` file,
  - versions of any additional libraries (PAPI, libunwind, DynInst, CUDA, OpenACC, OpenCL, libxml2, libdwarf, libelf, . . .), and/or
  - the **`${EXTRAE_HOME}/etc/configured.sh`** output.
- The result of the **`make check`** command after the **Extrae** compilation process.
- Does the application successfully executes with and without **Extrae**?
- Any valuable information from the system (type of processor, network, . . .).
- Which type of parallel programming paradigm does the application use: MPI, OpenMP, OmpSs, pthreads, . . . , hybrid?
- How do you execute the application? Which instrumentation library do you use?

- The **Extrae** configuration file used.
- Any output generated by the application execution (in either the output or error channels).
- If the execution generates a core dump, a backtrace of the dump using the **`where`** command of the `gdb` debugger.

CHAPTER

SIXTEEN

INSTRUMENTED ROUTINES

16.1 MPI

These are the instrumented MPI routines in the **Extrae** package:

- MPI_Init
- MPI_Init_thread[1]
- MPI_Finalize
- MPI_Bsend
- MPI_Ssend
- MPI_Rsend
- MPI_Send
- MPI_Bsend_init
- MPI_Ssend_init
- MPI_Rsend_init
- MPI_Send_init
- MPI_Ibsend
- MPI_Issend
- MPI_Irsend
- MPI_Isend
- MPI_Recv
- MPI_Irecv
- MPI_Recv_init
- MPI_Reduce
- MPI_Ireduce
- MPI_Reduce_scatter
- MPI_Ireduce_scatter
- MPI_Allreduce
- MPI_Iallreduce
- MPI_Barrier
- MPI_Ibarrier

[1] The MPI library must support this routine

- MPI_Cancel
- MPI_Test
- MPI_Wait
- MPI_Waitall
- MPI_Waitany
- MPI_Waitsome
- MPI_Bcast
- MPI_Ibcast
- MPI_Alltoall
- MPI_Ialltoall
- MPI_Alltoallv
- MPI_Ialltoallv
- MPI_Allgather
- MPI_Iallgather
- MPI_Allgatherv
- MPI_Iallgatherv
- MPI_Gather
- MPI_Igather
- MPI_Gatherv
- MPI_Igatherv
- MPI_Scatter
- MPI_Iscatter
- MPI_Scatterv
- MPI_Iscatterv
- MPI_Comm_rank
- MPI_Comm_size
- MPI_Comm_create
- MPI_Comm_create_group
- MPI_Comm_free
- MPI_Comm_dup
- MPI_Comm_dup_with_info
- MPI_Comm_split
- MPI_Comm_split_type
- MPI_Comm_spawn
- MPI_Comm_spawn_multiple
- MPI_Cart_create
- MPI_Cart_sub
- MPI_Start
- MPI_Startall

- MPI_Request_free
- MPI_Scan
- MPI_Iscan
- MPI_Sendrecv
- MPI_Sendrecv_replace
- MPI_File_open[2]
- MPI_File_close[2]
- MPI_File_read[2]
- MPI_File_read_all[2]
- MPI_File_read_all_begin[2]
- MPI_File_read_all_end[2]
- MPI_File_read_at[2]
- MPI_File_read_at_all[2]
- MPI_File_read_at_all_begin[2]
- MPI_File_read_at_all_end[2]
- MPI_File_read_ordered[2]
- MPI_File_read_ordered_begin[2]
- MPI_File_read_ordered_end[2]
- MPI_File_read_shared[2]
- MPI_File_write[2]
- MPI_File_write_all[2]
- MPI_File_write_all_begin[2]
- MPI_File_write_all_end[2]
- MPI_File_write_at[2]
- MPI_File_write_at_all[2]
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- MPI_File_write_at_all_end[2]
- MPI_File_write_ordered[2]
- MPI_File_write_ordered_begin[2]
- MPI_File_write_ordered_end[2]
- MPI_File_write_shared[2]
- MPI_Compare_and_swap[3]
- MPI_Fetch_and_op[3]
- MPI_Get[3]
- MPI_Put[3]
- MPI_Win_complete[3]
- MPI_Win_create[3]

[2] The MPI library must support MPI/IO routines
[3] The MPI library must support 1-sided (or RMA -remote memory address-) routines

- MPI_Win_fence[3]
- MPI_Win_flush[3]
- MPI_Win_flush_all[3]
- MPI_Win_flush_local[3]
- MPI_Win_flush_local_all[3]
- MPI_Win_free[3]
- MPI_Win_post[3]
- MPI_Win_start[3]
- MPI_Win_wait[3]
- MPI_Probe
- MPI_Iprobe
- MPI_Testall
- MPI_Testany
- MPI_Testsome
- MPI_Request_get_status
- MPI_Intercomm_create
- MPI_Intercomm_merge
- MPI_Graph_create
- MPI_Dist_graph_create
- MPI_Neighbor_allgather
- MPI_Ineighbor_allgather
- MPI_Neighbor_allgatherv
- MPI_Ineighbor_allgatherv
- MPI_Neighbor_alltoall
- MPI_Ineighbor_alltoall
- MPI_Neighbor_alltoallv
- MPI_Ineighbor_alltoallv
- MPI_Neighbor_alltoallw
- MPI_Ineighbor_alltoall

16.2 OpenMP

16.2.1 Intel compilers - icc, iCC, ifort

The instrumentation of the Intel OpenMP runtime for versions 8.1 to 10.1 is only available using the **Extrae** package based on DynInst library.

These are the instrument routines of the Intel OpenMP runtime functions using DynInst:

- __kmpc_fork_call
- __kmpc_barrier
- __kmpc_invoke_task_func

- __kmpc_set_lock[4]
- __kmpc_unset_lock[4]

The instrumentation of the Intel OpenMP runtime for version 11.0 to 12.0 is available using the **Extrae** package based on the `LD_PRELOAD` and also the DynInst mechanisms. The instrumented routines include:

- __kmpc_fork_call
- __kmpc_barrier
- __kmpc_dispatch_init_4
- __kmpc_dispatch_init_8
- __kmpc_dispatch_next_4
- __kmpc_dispatch_next_8
- __kmpc_dispatch_fini_4
- __kmpc_dispatch_fini_8
- __kmpc_single
- __kmpc_end_single
- __kmpc_critical[4]
- __kmpc_end_critical[4]
- omp_set_lock[4]
- omp_unset_lock[4]
- __kmpc_omp_task_alloc
- __kmpc_omp_task_begin_if0
- __kmpc_omp_task_complete_if0
- __kmpc_omp_taskwait

16.2.2 IBM compilers - xlc, xlC, xlf

Extrae supports IBM OpenMP runtime 1.6.

These are the instrumented routines of the IBM OpenMP runtime:

- _xlsmpParallelDoSetup_TPO
- _xlsmpParRegionSetup_TPO
- _xlsmpWSDoSetup_TPO
- _xlsmpBarrier_TPO
- _xlsmpSingleSetup_TPO
- _xlsmpWSSectSetup_TPO
- _xlsmpRelDefaultSLock[4]
- _xlsmpGetDefaultSLock[4]
- _xlsmpGetSLock[4]
- _xlsmpRelSLock[4]

[4] The instrumentation of OpenMP locks can be enabled/disabled

16.2.3 GNU compilers - gcc, g++, gfortran

Extrae supports GNU OpenMP runtime 4.2 and 4.9.

These are the instrumented routines of the GNU OpenMP runtime:

- GOMP_parallel_start
- GOMP_parallel_sections_start
- GOMP_parallel_end
- GOMP_sections_start
- GOMP_sections_next
- GOMP_sections_end
- GOMP_sections_end_nowait
- GOMP_loop_end
- GOMP_loop_end_nowait
- GOMP_loop_static_start
- GOMP_loop_dynamic_start
- GOMP_loop_guided_start
- GOMP_loop_runtime_start
- GOMP_loop_ordered_static_start
- GOMP_loop_ordered_dynamic_start
- GOMP_loop_ordered_guided_start
- GOMP_loop_ordered_runtime_start
- GOMP_loop_static_next
- GOMP_loop_dynamic_next
- GOMP_loop_guided_next
- GOMP_loop_runtime_next
- GOMP_parallel_loop_static_start
- GOMP_parallel_loop_dynamic_start
- GOMP_parallel_loop_guided_start
- GOMP_parallel_loop_runtime_start
- GOMP_barrier
- GOMP_critical_start[4]
- GOMP_critical_end[4]
- GOMP_critical_name_start[4]
- GOMP_critical_name_end[4]
- GOMP_atomic_start[4]
- GOMP_atomic_end[4]
- GOMP_task
- GOMP_taskwait
- GOMP_parallel
- GOMP_taskgroup_start

- GOMP_taskgroup_end

16.3 pthread

These are the instrumented routines of the pthread runtime:

- pthread_create
- pthread_detach
- pthread_join
- pthread_exit
- pthread_barrier_wait
- pthread_mutex_lock
- pthread_mutex_trylock
- pthread_mutex_timedlock
- pthread_mutex_unlock
- pthread_rwlock_rdlock
- pthread_rwlock_tryrdlock
- pthread_rwlock_timedrdlock
- pthread_rwlock_wrlock
- pthread_rwlock_trywrlock
- pthread_rwlock_timedwrlock
- pthread_rwlock_unlock

16.4 CUDA

These are the instrumented CUDA routines in the **Extrae** package:

- cudaLaunch
- cudaConfigureCall
- cudaThreadSynchronize
- cudaThreadExit
- cudaStreamCreate
- cudaStreamCreateWithFlags
- cudaStreamCreateWithPriority
- cudaStreamSynchronize
- cudaStreamDestroy
- cudaMemcpy
- cudaMemcpyAsync
- cudaDeviceReset
- cudaDeviceSynchronize

The CUDA accelerators do not have memory for the tracing buffers, so the tracing buffer resides in the host side.

Typically, the CUDA tracing buffer is flushed at `cudaThreadSynchronize`, `cudaStreamSynchronize` and `cudaMemcpy` calls, so it is possible that the tracing buffer for the device gets filled if no calls to this routines are executed.

These are the instrumented OpenACC routines in the **Extrae** package:

- OACC_init
- OACC_compute
- OACC_data
- OACC_data_alloc
- OACC_data_update
- OACC_launch
- OACC_update
- OACC_wait

16.5 OpenCL

These are the instrumented OpenCL routines in the **Extrae** package:

- clBuildProgram
- clCompileProgram
- clCreateBuffer
- clCreateCommandQueue
- clCreateContext
- clCreateContextFromType
- clCreateKernel
- clCreateKernelsInProgram
- clCreateProgramWithBinary
- clCreateProgramWithBuiltInKernels
- clCreateProgramWithSource
- clCreateSubBuffer
- clEnqueueBarrierWithWaitList
- clEnqueueBarrier
- clEnqueueCopyBuffer
- clEnqueueCopyBufferRect
- clEnqueueFillBuffer
- clEnqueueMarkerWithWaitList
- clEnqueueMarker
- clEnqueueMapBuffer
- clEnqueueMigrateMemObjects
- clEnqueueNativeKernel
- clEnqueueNDRangeKernel

- clEnqueueReadBuffer
- clEnqueueReadBufferRect
- clEnqueueTask
- clEnqueueUnmapMemObject
- clEnqueueWriteBuffer
- clEnqueueWriteBufferRect
- clFinish
- clFlush
- clLinkProgram
- clSetKernelArg
- clWaitForEvents
- clRetainCommandQueue
- clReleaseCommandQueue
- clRetainContext
- clReleaseContext
- clRetainDevice
- clReleaseDevice
- clRetainEvent
- clReleaseEvent
- clRetainKernel
- clReleaseKernel
- clRetainMemObject
- clReleaseMemObject
- clRetainProgram
- clReleaseProgram

The OpenCL accelerators have small amounts of memory, so the tracing buffer resides in the host side.

Typically, the accelerator tracing buffer is flushed at each `cl_Finish` call, so it is possible that the tracing buffer for the accelerator gets filled if no calls to this routine are executed.

However if the operated OpenCL command queue is tagged as not Out-of-Order, then flushes will also happen at `clEnqueueReadBuffer`, `clEnqueueReadBufferRect` and `clEnqueueMapBuffer` if their corresponding blocking parameter is set to true.

CHAPTER

SEVENTEEN

SEE ALSO

mpi2prv(1)

extrae_event(3), *extrae_counters(3)*, *extrae_eventandcounters(3)*, *extrae_shutdown(3)*, *extrae_restart(3)*, *extrae_set_tracing_tasks(3)*, *extrae_set_options(3)*,

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