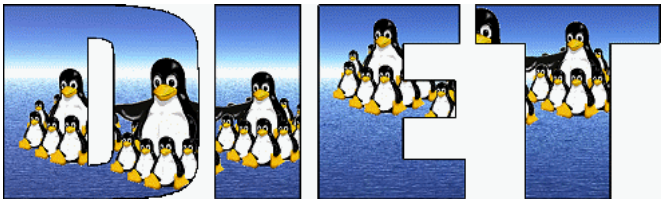


USER'S MANUAL

VERSION	2.8
DATE	November 2011
PROJECT MANAGER	Frédéric Desprez.
EDITORIAL STAFF	Yves Caniou, Eddy Caron and David Loureiro.
AUTHORS STAFF	Abdelkader Amar, Raphaël Bolze, Éric Boix, Yves Caniou, Eddy Caron, Pushpinder Kaur Chouhan, Philippe Combes, Sylvain Dahan, Holly Dail, Bruno Delfabro, Benjamin Depardon, Peter Frauenkron, Georg Hoesch, Benjamin Isnard, Mathieu Jan, Jean-Yves L'Excellent, Gal Le Mahec, Christophe Pera, Cyrille Pontvieux, Alan Su, Cédric Tedeschi, and Antoine Vernois.

Contents

Introduction

Resource management is one of the key issues for the development of efficient Grid environments. Several approaches co-exist in today's middleware platforms. The granularity of computation (or communication) and dependencies between computations can have a great influence on the software choices.

The first approach provides the user with a uniform view of resources. This is the case of GLOBUS [12] which provides transparent MPI communications (with MPICH-G2) between distant nodes but does not manage load balancing issues between these nodes. It's the user's task to develop a code that will take into account the heterogeneity of the target architecture. Grid extensions to classical batch processing provide an alternative approach with projects like Condor-G [9] or Sun GridEngine [13]. Finally, peer-to-peer [20] or Global computing [11] can be used for fine grain and loosely coupled applications.

A second approach provides a semi-transparent access to computing servers by submitting jobs to servers offering specific computational services. This model is known as the Application Service Provider (ASP) model where providers offer, not necessarily for free, computing resources (hardware and software) to clients in the same way as Internet providers offer network resources to clients. The programming granularity of this model is rather coarse. One of the advantages of this approach is that end users do not need to be experts in parallel programming to benefit from high performance parallel programs and computers. This model is closely related to the classical Remote Procedure Call (RPC) paradigm. On a Grid platform, RPC (or GridRPC [15, 17]) offers easy access to available resources from a Web browser, a Problem Solving Environment (PSE), or a simple client program written in C, Fortran, or Java. It also provides more transparency by hiding the selection and allocation of computing resources. We favor this second approach.

In a Grid context, this approach requires the implementation of middleware to facilitate client access to remote resources. In the ASP approach, a common way for clients to ask for resources to solve their problem is to submit a request to the middleware. The middleware will find the most appropriate server that will solve the problem on behalf of the client using a specific software. Several environments, usually called Network Enabled Servers (NES), have developed such a paradigm: NetSolve [1], Ninf [18], NEOS [10], OmniRPC [22], and more recently DIET developed in the GRAAL project. A common feature of these environments is that they are built on top of five components: clients, servers, databases, monitors and schedulers. Clients solve computational requests on servers found by the NES. The NES schedules the requests on the different servers using performance information obtained by monitors and stored in a database.

DIET stands for Distributed Interactive Engineering Toolbox. It is a toolbox for easily developing Application Service Provider systems on Grid platforms, based on the Client/Agent/Server scheme. Agents are the schedulers of this toolbox. In DIET, user requests are served via RPC.

DIET follows the GridRPC API defined within the Open Grid Forum [14].

Chapter 1

A DIET platform

DIET [8] is built upon *Server Daemons*. The process of scheduling the requests is distributed amongst a hierarchy of *Local Agents* and *Master Agents*. The scheduler can use resource availability information collected from different tools like CoRI Easy, which is based on simple system calls and some basic performance tests (see Chapter 9). Figure 1.1 shows the hierarchical organization of DIET.

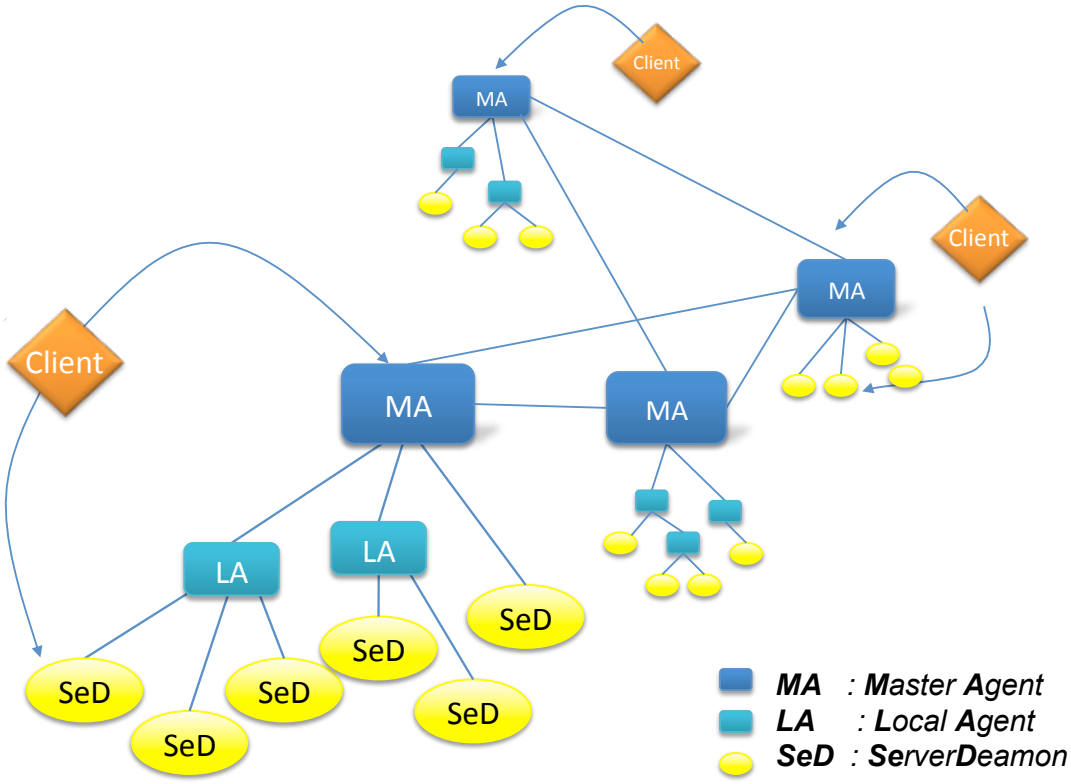


Figure 1.1: A hierarchy of DIET agents

1.1 DIET components

The different components of our software architecture are the following:

Client
A client is an application which uses DIET to solve problems. Many types of clients are able to connect to DIET, from a web page, a PSE such as Matlab or Scilab, or from a compiled program.

Master Agent (MA)
An MA receives computation requests from clients. These requests refer to some DIET problems listed on a reference web page. Then the MA collects computation abilities from the servers and chooses the best one. The reference of the chosen server is returned to the client. A client can be connected to an MA by a specific name server or a web page which stores the various MA locations.

Local Agent (LA)
An LA transmits requests and information between MAs and servers. The information stored on an LA is the list of services available in the subtree rooted at the LA; for each service, LAs store a list of children (agents or servers) that can be contacted to find the service. Depending on the underlying network topology, a hierarchy of LAs may be deployed between an MA and the servers. Of course, the function of an LA is to do a partial scheduling on its subtree, which reduces the workload at the MA.

Server Daemon (*SeD*)
A *SeD* encapsulates a computational server. For instance it can be located on the entry point of a parallel computer. The information stored on a *SeD* is a list of the data available locally, *i.e.,* on the server), the list of problems that can be solved on it, and performance-related information such as the amount of available memory or the number of resources available. When it registers, a *SeD* declares the problems it can solve to its parent LA or MA. A *SeD* can give perfomance and hardware information by using the CoRI module or performance predictions for some types of problems by using the CoRI module. Both modules are described in Chapter 9.

1.2 Communications layer

NES environments can be implemented using a classic socket communication layer. Several problems to this approach have been pointed out such as the lack of portability or limits on the number of sockets that can be opened concurrently. Our aim is to implement and deploy a distributed NES environment that works at a wider scale. Distributed object environments, such as *Java*, *DCOM* or CORBA have proven to be a good base for building applications that manage access to distributed services. They not only provide transparent communications in heterogeneous networks, but they also offer a framework for the large scale deployment of distributed applications. Being open and language independent, CORBA was chosen as the communication layer in DIET.

As recent implementations of CORBA provide communication times close to that of sockets, CORBA is well suited to support distributed applications in a large scale Grid environment. New specialized services can be easily published and existing services can also be used. DIET

is based upon *OmniORB 4* [19] or later, a free CORBA implementation that provides good communication performance.

1.3 DIET initialization

Figure 1.2 shows each step of the initialization of a simple Grid system. The architecture is built in hierarchical order, each component connecting to its parent. The MA is the first entity to be started (1). It waits for connections from LAs or requests from clients.

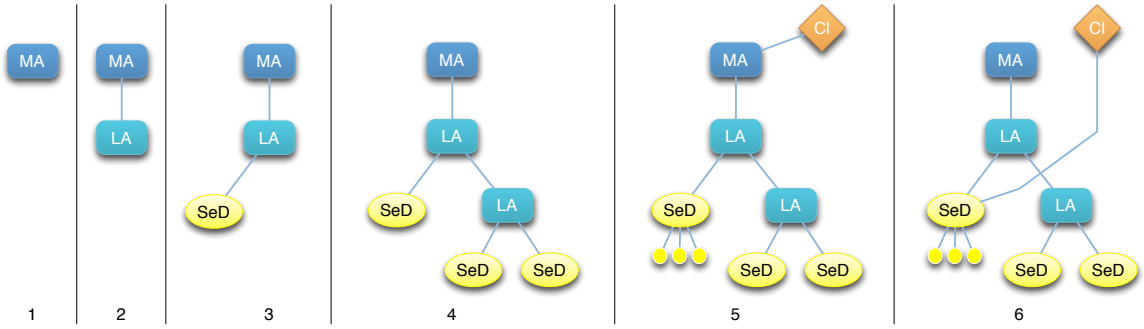


Figure 1.2: Initialization of a DIET system.

In step (2), an LA is launched and registers itself with the MA. At this step of system initialization, two kinds of components can connect to the LA: a *SeD* (3), which manages some computational resource, or another LA (4), to add a hierarchical level in this branch. When the *SeD* registers to its parent LA, it submits a list of the services it offers. The agent then reports the new service offering through its parent agent until the MA. If the service was previously unavailable along that arm of the hierarchy the agents update their records. Finally, clients can access the registered service by contacting the MA (5) to get a reference to the best server available and then directly connect to it (6) to launch the computation.

The architecture of the hierarchy is described in configuration files (see Section 10.1.2) and each component transmits the local configuration to its parent. Thus, the system administration can also be hierarchical. For instance, an MA can manage a domain like a university, providing prioritary access to users of this domain. Then each laboratory can run an LA, while each team of the laboratory can run some other LAs to administrate its own servers. This hierarchical administration of the system allows local changes in the configuration without interfering with the whole platform.

1.4 Solving a problem

Assuming that the architecture described in Section 1.1 includes several servers able to solve the same problem, the algorithm presented below lets an MA select a server for the computation among those available. This decision is made in four steps.

- The MA propagates the client request through its subtrees down to the capable servers; actually, the agents only forward the request on those subtrees offering the service.

- Each server that can satisfy the request can send his performance and hardware information or an estimation of the computation time necessary to process the request to its "parent" (an LA) (via performance prediction tools: see Chapter 9).
- Each LA that receives one or more positive responses from its children sorts the servers and forwards the best responses to the MA through the hierarchy.
- Once the MA has collected all the responses from its direct children, it chooses a pool of "better" servers and sends their references to the client.

1.5 DIET Extensions

1.5.1 Multi-MA

A standard DIET platform gives access to *SeD*s placed under the control of a MA as explained at the beginning of this chapter. Sometime, it is useful to connect several MA together. This happens when several organizations wish to share their resources to offer a larger set of service types and more available servers. The Multi-MA extension allows this by creating a federation which shares resources between several MA.

In multi-MA mode, the behavior of a DIET hierarchy does not change when a client requests a service that is available under the queried MA. However, if a request sent to a MA does not found a *SeD* that can resolve its problem, DIET will forward the request to other MAs of the federation. To read more about multi-MA, see Chapter 12 and Chapter **??**.

1.5.2 CoRI

Collector of Resource Information (CoRI) is a manager for collecting hardware and performance information. When DIET is compiled with the appropriate option, it is possible to get this information via different sub-modules like CoRI-Easy. (* if compiled and configured on the *SeD* machine). See Chapter 9 for details on using CoRI.

Chapter 2

DIET installation

2.1 Dependencies

2.1.1 General remarks on DIET platform dependencies

DIET is itself written in C/C++ and for limited parts in java. DIET is based on CORBA and thus depends on the chosen CORBA implementation. Additionally, some of DIET extensions make a strong use of libraries themselves written in C/C++ and java. Thus, we could expect DIET to be effective on any platform offering decent version of such compilers.

DIET undergoes daily regression tests (see http://cdash.inria.fr/CDash/index.php?project=DIET) on various hardwares, a couple of Un*x based operating systems (under different distributions), MacOSX and AIX, and mainly with GCC. But thanks to users reports (punctual deployments and special tests conduced before every release), DIET is known to be effective on a wide range of platforms.

Nevertheless, if you encounter installation difficulties don't hesitate to post on DIET's users mailing list: `diet-usr@listes.ens-lyon.fr` (for the archives refer to http://graal.ens-lyon.fr/DIET/mail-lists.html). If you find a bug in DIET, please don't hesitate to submit a bug report on http://graal.ens-lyon.fr/bugzilla. If you have multiple bugs to report, please make multiple submissions, rather than submitting multiple bugs in a single report.

2.1.2 Hardware dependencies

DIET is fully tested on Linux/i386 and Linux/i686 platforms. DIET is known to be effective on Linux/Sparc, Linux/i64, Linux/amd64, Linux/Alpha, Linux/PowerPC, AIX/PowerPC, MacOS/PowerPC and Windows XP(Cygwin)/i386 platforms. At some point in DIET history, DIET used to be tested on the Solaris/Sparc platform...

2.1.3 Supported compilers

DIET is supported on GCC with versions ranging from 3.2.X to 4.3.4. Note that due to omniORB 4 (see 2.1.5) requirements towards thread-safe management of exception handling, compiling DIET with GCC requires at least the version 2.96. DIET is also supported on XL compiler (IBM) and Intel compiler.

2.1.4 Operating system dependencies

DIET is fully tested on Linux [with varying distributions like Debian, Red Hat Enterprise Linux (REL-ES-3), Fedora Core (5)], on AIX (5.3) on MacOSX (Darwin 8) and on Windows (Cygwin 1.5.25 and Cygwin 1.7.1).

2.1.5 Software dependencies

As explained in Section 1.2, CORBA is used for all communications inside the platform. The implementations of CORBA currently supported in DIET is **omniORB 4** which itself depends on **Python**.
NB: We have noticed that some problems occur with **Python 2.3**: the C++ code generated by idl could not be compiled. It has been patched in DIET, but some warnings may still appear.

omniORB 4 itself also depends on **OpenSSL** in case you wish to secure your DIET platform. If you want to deploy a secure DIET platform, SSL support is not yet implemented in DIET, but an easy way to do so is to deploy DIET over a VPN.

In order to deploy CORBA services with omniORB, a configuration file and a log directory are required: see Section 10.1.1 for a complete description of the services. Their paths can be given to omniORB either at runtime (through the well-known environment variables `$OMNIORB_CONFIG` and `$OMNINAMES_LOGDIR`), and/or at omniORB compile time (with the `--with-omniORB-config` and `--with-omniNames-logdir` options.) Some examples provided in the DIET sources depend on the BLAS and ScaLAPACK libraries. However the compilation of those BLAS and ScaLAPACK dependent examples are optional.

2.2 Compiling the platform

DIET compilation process moved away from the traditional `autotools` way of things to a tool named `cmake` (mainly to benefit from `cmake`'s built-in regression tests mechanism).

Before compiling DIET itself, first install the above mentioned (cf Section 2.1.5) dependencies. Then untar the DIET archive and change current directory to its root directory.

2.2.1 Obtaining and installing cmake per se

DIET requires using `cmake` at least version `2.4.3`. For many popular distributions `cmake` is incorporated by default or at least `apt-get` (or whatever your distro package installer might be) is `cmake` aware. Still, in case you need to install an up-to-date version `cmake`'s official site distributes many binary versions (alas packaged as tarballs) which are made available at `http://www.cmake.org/HTML/Download.html`. Optionally, you can download the sources and recompile them: this simple process (`./bootstrap; make; make install`) is described at `http://www.cmake.org/HTML/Install.html`.

2.2.2 Configuring DIET's compilation: cmake quick introduction

If you are already experienced with `cmake` then using it to compile DIET should provide no surprise. DIET respects `cmake`'s best practices *e.g.,* by clearly separating the source tree from the

binary tree (or compile tree), by exposing the main configuration optional flag variables prefixed with `DIET_` (and by hiding away the technical variables) and by not postponing configuration difficulties (in particular the handling of external dependencies like libraries) to compile stage.

`cmake` classically provides two ways for setting configuration parameters in order to generate the makefiles in the form of two commands `ccmake` and `cmake` (the first one has an extra "c" character):

`ccmake [options] <path-to-source>`
in order to specify the parameters interactively through a GUI interface

`cmake [options] <path-to-source> [-D<var>:<type>=<value>]`
in order to define the parameters with the `-D` flag directly from the command line.

In the above syntax description of both commands, `<path-to-source>` specifies a path to the top level of the source tree (*i.e.,* the directory where the top level CMakeLists.txt file is to be encountered). Also the current working directory will be used as the root of the build tree for the project (out of source building is generally encouraged especially when working on a CVS tree).
Here is a short list of `cmake` internal parameters that are worth mentioning:

- `CMAKE_BUILD_TYPE` controls the type of build mode among which `Debug` will produce binaries and libraries with the debugging information
- `CMAKE_VERBOSE_MAKEFILE` is a Boolean parameter which when set to ON will generate makefiles without the .SILENT directive. This is useful for watching the invoked commands and their arguments in case things go wrong.
- `CMAKE_C[XX]_FLAGS*` is a family of parameters used for the setting and the customization of various C/C++ compiler options.
- `CMAKE_INSTALL_PREFIX` variable defines the location of the install directory (defaulted to `/usr/local` on Un*x). This is cmake's portable equivalent of the autotools configure's `--prefix=` option.

Eventually, here is a short list of `ccmake` interface tips:

- when lost, look at the bottom lines of the interface which always summarizes `ccmake`'s most pertinent options (corresponding keyboard shortcuts) depending on your current context
- hitting the "h" key will direct you `ccmake` embedded tutorial and a list of keyboard shortcuts (as mentioned in the bottom lines, hit "e" to exit)
- up/down navigation among parameter items can be achieved with the up/down arrows
- when on a parameter item, the line in inverted colors (close above the bottom of the screen) contains a short description of the selected parameter as well as the set of possible/recommended values
- toggling of boolean parameters is made with enter
- press `enter` to edit path variables

- when editing a `PATH` typed parameter the `TAB` keyboard shortcut provides an emacs-like (or bash-like) automatic path completion.
- toggling of advanced mode (press "t") reveals hidden parameters

2.2.3 A ccmake walk-through for the impatients

Assume that `CVS_DIET_HOME` represents a path to the top level directory of DIET sources. This DIET sources directories tree can be obtained by DIET users by expanding the DIET current source level distribution tarball. But for the DIET developers this directories tree simply corresponds to the directory GRAAL/devel/diet/diet of a cvs checkout of the DIET sources hierarchy. Additionally, assume we created a build tree directory and `cd` to it (in the example below we chose `CVS_DIET_HOME/Bin` as build tree, but feel free to follow your conventions):

- `cd CVS_DIET_HOME/Bin`
- `ccmake ..` to enter the GUI
  - press `c` (equivalent of bootstrap.sh of the autotools)
  - toggle the desired options *e.g.,* `DIET_BUILD_EXAMPLES`.
  - specify the `CMAKE_INSTALL_PREFIX` parameter (if you wish to install in a directory different from `/usr/local`)
  - press `c` again, for checking required dependencies
  - check all the parameters preceded with the * (star) character whose value was automatically retrieved by `cmake`.
  - provide the required information *i.e.,* fill in the proper values for all parameters whose value is terminated by NOT-FOUND
  - iterate the above process of parameter checking, toggle/specification and configuration until all configuration information is satisfied
  - press `g` to generate the makefile
  - press `q` to exit ccmake
- `make` in order to classically launch the compilation process
- `make install` when installation is required

2.2.4 DIET's main configuration flags

Here are the main configuration flags:

- `OMNIORB4_DIR` is the path to the omniORB4 installation directory (only relevant when omniORB4 was not installed in /usr/local).
  Example: `cmake .. -DOMNIORB4_DIR:PATH=$HOME/local/omniORB-4.1.5`
- `DIET_BUILD_EXAMPLES` activates the compilation of a set of general client/server examples. Note that some specific examples (*e.g.,* `DIET_BUILD_BLAS_EXAMPLES`) require some additional flag to be activated too.

- DIET_BUILD_LIBRARIES which is enabled by default, activates the compilation of the DIET libraries. Disabling this option is only useful if you wish to restrict the compilation to the construction of the documentation.

2.2.5 DIET's extensions configuration flags

DIET has many extensions (some of them are still) experimental. These extensions most often rely on external packages that need to be pre-installed. One should notice that some of those extensions offer concurrent functionalities. This explains the usage of configuration flags in order to obtain the compilation of the desired extensions.

- DIET_BUILD_BLAS_EXAMPLES option activates the compilation of the BLAS based DIET examples, as a sub-module of examples. The BLAS [1] (Basic Linear Algebra Subprograms) are high quality "building block" routines for performing basic vector and matrix operations. Level 1 BLAS do vector-vector operations, Level 2 BLAS do matrix-vector operations, and Level 3 BLAS do matrix-matrix operations. Because the BLAS are efficient, portable, and widely available, they're commonly used in the development of high quality linear algebra software. DIET uses BLAS to build demonstration examples of client/server. Note that the option DIET_BUILD_BLAS_EXAMPLES can only be effective when DIET_BUILD_EXAMPLES is enabled. DIET_BUILD_BLAS_EXAMPLES is disabled by default.

- DIET_USE_ALT_BATCH enables the transparent submission to batch servers. See Chapter 6 for more details.

- DIET_USE_WORKFLOW enables the support of workflow. For the support of workflows inside DIET, Xerces and Xqilla libraries are mandatory (see http://xerces.apache.org/xerces-c/ and http://xqilla.sourceforge.net/HomePage). For more details about the workflow support in DIET see chapter 13.

- DIET_WITH_MULTI_MA activates the so called MULTI Master Agent support which allows the user to connect several MA for them to act as bounded. When this option is activated, such a bounded MA is allowed to search for a *SeD* into the MA hierarchies it is connected to.

- DIET_WITH_STATISTICS enables the generation of statistics logs. The logs can be obtained for any element in the DIET hierarchy. To do so, you have to define the DIET_STAT_FILE_NAME environment variable. For instance, export DIET_STAT_FILE_NAME=/tmp/client then calling a client will generate the statistics for the client in the /tmp/client file.

2.2.6 DIET's advanced configuration flags

Eventually, some configuration flags control the general result of the compilation or some developers extensions:

- BUILD_TESTING is a conventional variable (which is not a cmake internal variable) which specifies that the regression tests should also be compiled.

[1] http://www.netlib.org/blas/

- `BUILD_SHARED_LIBS` is a cmake internal variable which specifies whether the libraries should be dynamics as opposed to static (on Mac system this option is automatically set to `ON`, as static compilation of binaries seems to be forbidden on these systems)

- `Maintainer` By default cmake offers four different build modes that one toggles by positioning `CMAKE_BUILD_TYPE` built-in variable (to `Debug`, `Release`, `RelWithDebInfo` and `MinSizeRel`). `Maintainer` is an additional mode which fulfills two basic needs of the task of the maintainer of DIET. The first preventive task is to provide code free from any compilation and link warnings. The second corresponds to the snafu stage which is to debug the code. For reaching those goals the `Maintainer` build type sets the compilers flags, respectively the linker flags, with all the possible warning flags activated, resp. with the additional debug flags.

- Several options (not accessible through the ccmake GUI) can control the installation paths for libraries, binaries, includes and modules. By default the value of these install paths are respectively `${CMAKE_INSTALL_PREFIX}/lib${LIB_SUFFIX}`, `${CMAKE_INSTALL_PREFIX}/bin`, `${CMAKE_INSTALL_PREFIX}/include`, `${CMAKE_INSTALL_PREFIX}/share/cmake/Modules`. They can independently be set up using the following variables `LIB_INSTALL_DIR`, `BIN_INSTALL_DIR`, `INSTALL_INSTALL_DIR` and `CMAKE_MOD_INSTALL_DIR`. You can set those on the command line when calling cmake or ccmake, for example `cmake .. -DLIB_INSTALL_DIR=${HOME}/lib`.

2.2.7 Compiling and installing

Summarizing the configuration choices

Once the configuration is properly made one can check the choices made by looking the little summary proposed by cmake. This summary should look like (`[...]` denotes eluded portions):

```
~/DIET > ./cmake ..
[...]
- XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-- XXXXXXXXXXXXXXXXXXXX  DIET configuration summary  XXXXXXXXXXXXXXXXXXXX
-- XXXXXXXXXXXXXXXXXXXXXXXX 2010/03/31-07:47:15 XXXXXXXXXXXXXXXXXXXXXXXX
-- XXX System name Linux
-- XXX - Install prefix: /home/diet/local/diet
-- XXX - C compiler   : /usr/bin/gcc
-- XXX    * version   : 4.3.4
-- XXX    * options   :  -Dinline="static __inline__" -Dconst="" -std=gnu99
-- XXX - CXX compiler : /usr/bin/c++
-- XXX    *  version  : 4.3.4
-- XXX    *  options  : -lpthread -g -D__linux__
-- XXX - OmniORB found: YES
-- XXX   * OmniORB version: 4.1.2
-- XXX   * OmniORB directory:
-- XXX   * OmniORB includes: /usr/include
-- XXX   * OmniORB libraries: [...]libomniDynamic4.so;[...]libomniORB4.so;[...]libomnithread.so
-- XXX - General options:
-- XXX   * Examples: ON
-- XXX   * BLAS Examples: ON
-- XXX - Options set:
-- XXX   * Batch: ON
```

```
-- XXX   * Statistics: ON
-- XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
[...]
```

A more complete, yet technical, way of making sure is to check the content of the file named `CMakeCache.txt` (generated by cmake in the directory from which cmake was invocated). When exchanging with the developers list it is a recommendable practice to join the content of this file which summarizes your options and also the automatic package/library detections made by cmake.

Compiling stage

You are now done with the configuration stage (equivalent of both the `bootstrap.sh` and `./configure` stage of the `autotools`). You are now back to your platform level development tools, *i.e.,* `make` when working on Unices. Hence you can now proceed with the compiling process by launching `make`.

Testing

If you configured DIET with the `BUILD_TESTING` you can easily run the regression tests by invoking the `make test`. This is equivalent to invoking `ctest` command (ctest is part of cmake package). `ctest --help` provides a summary of the advanced options of `ctest` among which we recommend the `--verbose` option.

Installation stage

After compiling (linking, and testing) you can optionally proceed with the installation stage with the `make install` command.

2.3 Diet client/server examples

A set of various examples of DIET server/client are provided within the DIET archive, here are some of the provided examples:

- `Batch`: A simple basic example on how to use the batch API is given here: no IN or INOUT args, the client receives as a result the number of processors on which the service has been executed. The service only writes to a file, with batch-independent mnemonics, some information on the batch system.

- `BLAS`: the server offers the `dgemm` BLAS functionality. We plan to offer all BLAS (Basic Linear Algebraic Subroutines) in the future. Since this function computes $C = \alpha AB + \beta C$, it can also compute a matrix-matrix product, a sum of square matrices, etc. All these services are offered by the BLAS server. Two clients are designed to use these services: one (`dgemm_client.c`) is designed to use the `dgemm_` function only, and the other one (`client.c`) to use all BLAS functions (but currently only `dgemm_`) and sub-services, such as `MatPROD`.

- `dmat_manips`: the server offers matrix manipulation routines: transposition (`T`), product (`MatPROD`) and sum (`MatSUM`, `SqMatSUM` for square matrices, and `SqMatSUM_opt` for square matrices but re-using the memory space of the second operand for the result). Any subset of these operations can be specified on the command line. The last two of them are given for compatibility with a BLAS server as explained below.

- `file_transfer`: the server computes the sizes of two input files and returns them. A third output parameter may be returned; the server decides randomly whether to send back the first file. This is to show how to manage a variable number of arguments: the profile declares all arguments that may be filled, even if they might not be all filled at each request/computation.

- `ScaLAPACK`: the server is designed to offer all ScaLAPACK (parallel version of the LAPACK library) functions but only manages the `pdgemm_` function so far. The `pdgemm_` routine is the parallel version of the `dgemm_` function, so that the server also offers all the same sub-services. Two clients are designed to use these services: one (`pdgemm_client.c`) is designed to use the `pdgemm_` function only, and the other one (`client.c`) to use all ScaLAPACK functions and sub-services, such as `MatPROD`.

- `workflow`: The programs in this directory are examples that demonstrate how to use the workflow feature of diet. The files representing the workflows that can be tested are stored in xml sub-directory. For each workflow, you can find the required services in the corresponding xml file (check the path attribute of each node element). For the scalar manipulation example, you can use `scalar_server` that gathers four different elementary services.

2.3.1 Compiling the examples

`cmake` will set the examples to be compiled when setting the `DIET_BUILD_EXAMPLES` to `ON` which can be achieved by toggling the corresponding entry of `ccmake` GUI's or by adding `-DDIET_BUILD_EXAMPLES:BOOL=ON` to the command line arguments of `[c]cmake` invocation. Note that this option is disabled by default.

The compilation of the examples, respectively the installation, is executed on the above described invocation of `make`, resp. `make install` stages. The binary of the examples are placed in the `<install_dir>/bin/examples` sub-directory of the installation directory. Likewise, the samples of configuration files located in `src/examples/cfgs` are processed by `make install` to create ready-to-use configuration files in `src/examples/cfgs` and then copied into `<install_dir>/etc/cfgs`.

Chapter 3

DIET data

It is important that DIET can manipulate data to optimize copies and memory allocation, to estimate data transfer and computation time, etc. Therefore the data must be fully described in terms of their data types and various attributes associated with these types.

3.1 Data types

DIET defines a precise set of data types to be used to describe the arguments of the services (on the server side) and of the problems (on the client side).

The DIET data types are defined in the file `<install_dir>/include/DIET_data.h`. The user will also find in this file various function prototypes to manipulate all DIET data types. Please refer to this file for a complete and up-to-date API description.

To keep DIET type descriptions generic, two main sets are used: base and composite types.

3.1.1 Base types

Base types are defined in an enum type `diet_base_type_t` and have the following semantics:

Type	Description	Size in octets
DIET_CHAR	Character	1
DIET_SHORT	Signed short integer	2
DIET_INT	Signed integer	4
DIET_LONGINT	Long signed integer	8
DIET_FLOAT	Simple precision real	4
DIET_DOUBLE	Double precision real	8
DIET_SCOMPLEX	Simple precision complex	8
DIET_DCOMPLEX	Double precision complex	16

NB: DIET_SCOMPLEX and DIET_DCOMPLEX are not implemented yet.

3.1.2 Composite types

Composite types are defined in an enum type `diet_type_t`:

Type	Possible base types
DIET_SCALAR	all base types
DIET_VECTOR	all base types
DIET_MATRIX	all base types
DIET_STRING	DIET_CHAR
DIET_PARAMSTRING	DIET_CHAR
DIET_FILE	DIET_CHAR
DIET_CONTAINER	all base types

Each of these types requires specific parameters to completely describe the data (see Figure 3.1).

3.1.3 Persistence mode

Persistence mode is defined in an enum type `diet_persistence_mode_t`

mode	Description
DIET_VOLATILE	not stored
DIET_PERSISTENT_RETURN	stored on server, movable and copy back to client
DIET_PERSISTENT	stored on server and movable
DIET_STICKY	stored and non movable
DIET_STICKY_RETURN	stored, non movable and copy back to client

NB: DIET_STICKY_RETURN only works with DAGDA.

3.2 Data description

Each parameter of a client problem is manipulated by DIET using the following structure:

```
typedef struct diet_arg_s diet_arg_t;
struct diet_arg_s{
  diet_data_desc_t desc;
  void            *value;
};
typedef diet_arg_t diet_data_t;
```

The second field is a pointer to the memory zone where the parameter data are stored. The first one consists of a complete DIET data description, which is better described by a figure than with C code, since it can be set and accessed through API functions. Figure 3.1 shows the data classification used in DIET. Every "class" inherits from the root "class" `data`, and could also be a parent of more detailed classes of data in future versions of DIET.

3.3 Data management

3.3.1 Data identifier

The data identifier is generated by the MA. The data identifier is a string field that contains the MA name, the number of the session plus the number of the data in the problem (incremental) plus the string "id". This is the `id` field of the `diet_data_desc_t` structure.

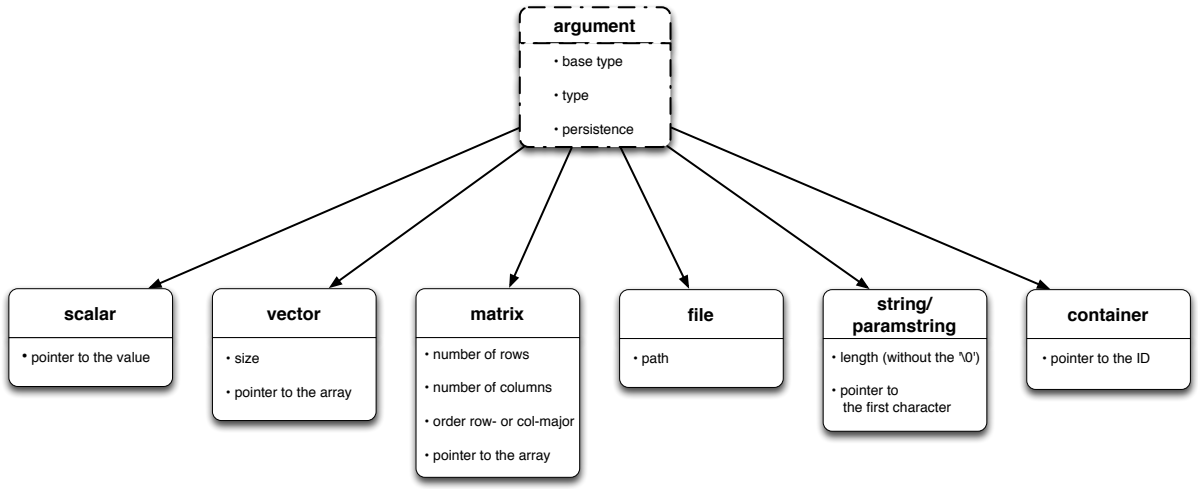


Figure 3.1: Argument/Data structure description.

```
typedef struct {
  char* id;
  diet_persistence_mode_t  mode;
  ....
} diet_data_desc_t;
```

For example, **id.MA1.1.1** will identify the first data in the first session submitted on the Master Agent **MA1**.

NB: the field "id" of the identifier will be next replaced by a client identifier. This is not implemented yet.

3.3.2 Data file

The name of the file is generated by a Master Agent. It is created during the `diet_initialize()` call. The name of the file is the aggregation of the string ID_FILE plus the name of the MA plus the number of the session.

A file is created only when there are some persistent data in the session.

For example, **ID_FILE.MA1.1** means the identifiers of the persistent data stored are in the file corresponding to the first session in the Master Agent **MA1**.

The file is stored in the `/tmp` directory.

NB: for the moment, when a data item is erased from the platform, the file isn't updated.

3.4 Manipulating DIET structures

The user will notice that the API to the DIET data structures consists of modifier and accessor functions only: no allocation function is required, since `diet_profile_alloc` (see Section 3.6) allocates all necessary memory for all argument **descriptions**. This avoids the temptation for

the user to allocate the memory for these data structures twice (which would lead to DIET errors while reading profile arguments). Please see the example in Section 3.7 for a typical example.

Moreover, the user should know that arguments of the `_set` functions that are passed by pointers are **not** copied, in order to save memory. This is true for the *value* arguments, but also for the *path* in `diet_file_set`. Thus, the user keeps ownership of the memory zones pointed at by these pointers, and he/she must be very careful not to alter it during a call to DIET.

3.4.1 Set functions

```
/**
 * On the server side, these functions should not be used on arguments, but only
 * on convertors (see section 5.5).
 * If mode                                 is DIET_PERSISTENCE_MODE_COUNT,
 * or if base_type                         is DIET_BASE_TYPE_COUNT,
 * or if order                             is DIET_MATRIX_ORDER_COUNT,
 * or if size, nb_rows, nb_cols or length is 0,
 * or if path                              is NULL,
 * then the corresponding field is not modified.
 */

int
diet_scalar_set(diet_arg_t* arg, void* value, diet_persistence_mode_t mode,
                diet_base_type_t base_type);
int
diet_vector_set(diet_arg_t* arg, void* value, diet_persistence_mode_t mode,
                diet_base_type_t base_type, size_t size);

/* Matrices can be stored by rows or by columns */
typedef enum {
  DIET_COL_MAJOR = 0,
  DIET_ROW_MAJOR,
  DIET_MATRIX_ORDER_COUNT
} diet_matrix_order_t;

int
diet_matrix_set(diet_arg_t* arg, void* value, diet_persistence_mode_t mode,
                diet_base_type_t base_type,
                size_t nb_rows, size_t nb_cols, diet_matrix_order_t order);
int
diet_string_set(diet_arg_t* arg, char* value, diet_persistence_mode_t mode);

/* The file size is computed and stocked in a field of arg
   ! Warning ! The path is not duplicated !!! */
int
diet_file_set(diet_arg_t* arg, cont char* path, diet_persistence_mode_t mode);
```

3.4.2 Access functions

```
/**
 * A NULL pointer is not an error (except for arg): it is simply IGNORED.
```

```
 * For instance,
 *   diet_scalar_get(arg, &value, NULL),
 * will only set the value to the value field of the (*arg) structure.
 *
 * NB: these are macros that let the user not worry about casting (int **)
 * or (double **) etc. into (void **).
 */

/**
 * Type: int diet_scalar_get((diet_arg_t *), (void *),
 *                           (diet_persistence_mode_t *))
 */
#define diet_scalar_get(arg, value, mode) \
        _scalar_get(arg, (void *)value, mode)
/**
 * Type: int diet_vector_get((diet_arg_t *), (void **),
 *                           (diet_persistence_mode_t *), (size_t *))
 */
#define diet_vector_get(arg, value, mode, size) \
        _vector_get(arg, (void **)value, mode, size)
/**
 * Type: int diet_matrix_get((diet_arg_t *), (void **),
 *                           (diet_persistence_mode_t *),
 *                           (size_t *), (size_t *), (diet_matrix_order_t *))
 */
#define diet_matrix_get(arg, value, mode, nb_rows, nb_cols, order) \
        _matrix_get(arg, (void **)value, mode, nb_rows, nb_cols, order)
/**
 * Type: int diet_string_get((diet_arg_t *), (char **),
 *                           (diet_persistence_mode_t *))
 */
#define diet_string_get(arg, value, mode) \
        _string_get(arg, (char **)value, mode)
/**
 * Type: int diet_file_get((diet_arg_t *),
 *                         (diet_persistence_mode_t *), (size_t *), (char **))
 */
#define diet_file_get(arg, mode, size, path) \
        _file_get(arg, mode, size, (char **)path)
```

3.5 Data Management functions

- The `store_id` method is used to store the identifier of persistent data. It also accepts a description of the data stored. This method has to be called after the `diet_call()` so that the identifier exists.

  ```
  store_id(char* argID,char *msg);
  ```

- The `diet_use_data` method allows the client to use a data item that is already stored in the platform.

```
diet_use_data(diet_arg_t* arg,char* argID);
```

This function replaces the set functions (see Section 3.4.1).

NB: a mechanism for data identifier publication hasn't been implemented yet. So, exchanges of identifiers between end-users that want to share data must be done explicitly.

- The `diet_free_persistent_data` method allows the client to remove a persistent data item from the platform.

```
diet_free_persistent_data(char *argID);
```

```
/*****************************************************************
 *   Add handler argID and text message msg in the identifier file *
 *****************************************************************/

void
store_id(char* argID, char* msg);


/** sets only identifier : data is present inside the platform */

void
diet_use_data(diet_arg_t* arg, char* argID);


/*****************************************************************
 *  Free persistent data identified by argID                     *
 *****************************************************************/
int
diet_free_persistent_data(char* argID);
```

3.5.1 Free functions

The amount of data pointed at by value fields should be freed through a DIET API function:

```
/*****************************************************************************/
/* Free the amount of data pointed at by the value field of an argument.     */
/* This should be used ONLY for VOLATILE data,                               */
/*    - on the server for IN arguments that will no longer be used           */
/*    - on the client for OUT arguments, after the problem has been solved,  */
/*      when they will no longer be used.                                    */
/* NB: for files, this function removes the file and frees the path (since   */
/*     it has been dynamically allocated by DIET in both cases)              */
/*****************************************************************************/

int
diet_free_data(diet_arg_t* arg);
```

3.6 Problem description

For DIET to match the client problem with a service, servers and clients must "speak the same language", *i.e.,* they must use the same problem description. A unified way to describe problems is to use a name and define its profile with the type `diet_profile_t`:

```
typedef struct {
  char*       pb_name;
  int         last_in, last_inout, last_out;
  diet_arg_t *parameters;
} diet_profile_t;
```

The field *parameters* consists of a `diet_arg_t` array of size $last\_out + 1$. Arguments can be:

IN: The data are sent to the server. The memory is allocated by the user.

INOUT: The data are allocated by the user as for the IN arguments, then sent to the server and brought back into the same memory zone after the computation has completed, without any copy. Thus freeing this memory on the client side while the computation is performed on the server would result in a segmentation fault when the data are brought back onto the client.

OUT: The data are created on the server and brought back into a newly allocated memory zone on the client. This allocation is performed by DIET. After the call has returned, the user can find the result in the zone pointed at by the *value* field. Of course, DIET cannot guess how long the user will need these data, so the user must free the memory him/herself with `diet_free_data`.

The fields *last_in*, *last_inout* and *last_out* of the `diet_profile_t` structure respectively point at the indexes in the *parameters* array of the last IN, INOUT and OUT arguments.

Functions to create and destroy such profiles are defined with the prototypes below:

```
diet_profile_t *diet_profile_alloc(char* pb_name, int last_in, int last_inout, int last_out);
int diet_profile_free(diet_profile_t *profile);
```

The values of *last_in*, *last_inout* and *last_out* are respectively:

last_in: -1 + number of input data.

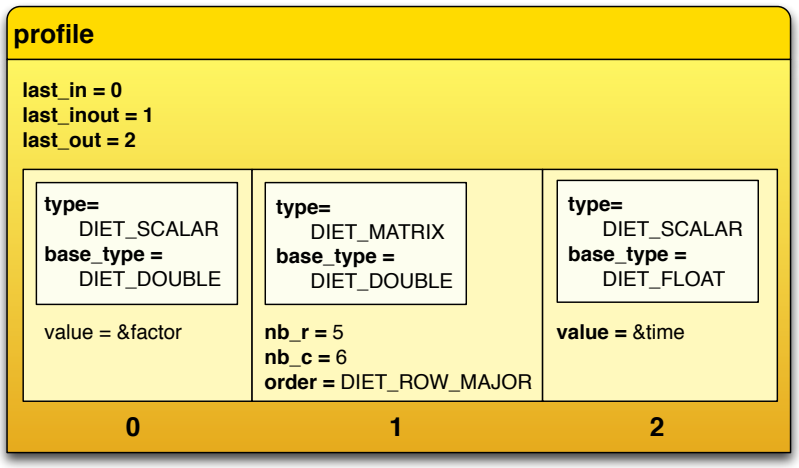
last_inout: *last_in* + number of inout data.

last_out: *last_inout* + number of out data.

3.7 Examples

3.7.1 Example 1: without persistency

Let us consider the product of a scalar by a matrix: the matrix must be multiplied in-place, and the computation time must be returned. This problem has one IN argument (the scalar factor), one INOUT argument (the matrix) and one OUT argument (the computation time), so its profile will be built as follows:



Here are the lines of C code to generate such a profile:

```
double  factor;
double *matrix;
float  *time;
// Init matrix at least, factor and time too would be better ...
// ...
diet_profile_t profile = diet_profile_alloc(0, 1, 2); // last_in, last_inout, last_out
diet_scalar_set(diet_parameter(profile,0), &factor, 0, DIET_DOUBLE);
diet_matrix_set(diet_parameter(profile,1), matrix,  0, DIET_DOUBLE, 5, 6, DIET_ROW_MAJOR);
diet_scalar_set(diet_parameter(profile,2), NULL,    0, DIET_FLOAT);
```

NB1: If there is no IN argument, *last_in* must be set to -1, if there is no INOUT argument, *last_inout* must be equal to *last_in*, and if there is no OUT argument, *last_out* must be equal to *last_inout*.

NB2: The *value* argument for `_set` functions (3.4.1) is ignored for OUT arguments, since DIET allocates the necessary memory space when the corresponding data are transferred from the server, so set value to NULL.

3.7.2 Example 2: using persistency

Let us consider the following problem : $C = A * B$, with A,B and C persistent matrices.

```
double *A, *B, *C;
// matrices initialization
...
diet_initialize();
strcpy(path,"MatPROD");
profile = diet_profile_alloc(path, 1, 1, 2);
diet_matrix_set(diet_parameter(profile,0),
                A, DIET_PERSISTENT, DIET_DOUBLE, mA, nA, oA);
print_matrix(A, mA, nA, (oA == DIET_ROW_MAJOR));
diet_matrix_set(diet_parameter(profile,1),
                B, DIET_PERSISTENT, DIET_DOUBLE, mB, nB, oB);
print_matrix(B, mB, nB, (oB == DIET_ROW_MAJOR));
```

```
diet_matrix_set(diet_parameter(profile,2),
                NULL, DIET_PERSISTENT_RETURN, DIET_DOUBLE, mA, nB, oC);

if (!diet_call(profile)) {
  diet_matrix_get(diet_parameter(profile,2),&C, NULL, &mA, &nB, &oC);
  store_id(profile->parameters[2].desc.id,"matrix C of doubles");
  store_id(profile->parameters[1].desc.id,"matrix B of doubles");
  store_id(profile->parameters[0].desc.id,"matrix A of doubles");
  print_matrix(C, mA, nB, (oC == DIET_ROW_MAJOR));

}
diet_profile_free(profile);
// free matrices memory
...
diet_finalize();
```

Then, a client submits the problem : $D = E + C$ with C already present in the platform. We consider that the handle of C is "id.MA1.1.3".

```
double *C, *D, *E;
// matrices initialization
...
diet_initialize();

strcpy(path,"MatSUM");
profile2 = diet_profile_alloc(path, 1, 1, 2);

printf("second pb\n\n");
diet_use_data(diet_parameter(profile2,0), "id.MA1.1.3");
diet_matrix_set(diet_parameter(profile2,1),
                E, DIET_PERSISTENT, DIET_DOUBLE, mA, nB, oE);
print_matrix(E, mA, nB, (oE == DIET_ROW_MAJOR));
diet_matrix_set(diet_parameter(profile2,2),
                NULL, DIET_PERSISTENT_RETURN, DIET_DOUBLE, mA, nB, oD);

if (!diet_call(profile2)) {
 diet_matrix_get(diet_parameter(profile2,2), &D, NULL, &mA, &nB, &oD);
 print_matrix(D, mA, nB, (oD == DIET_ROW_MAJOR));
 store_id(profile2->parameters[2].desc.id,"matrix D of doubles");
 store_id(profile2->parameters[1].desc.id,"matrix E of doubles");

}
diet_profile_free(profile2);
diet_free_persistent_data("id.MA1.1.3");
// free matrices memory
...
diet_finalize();
```

Note that when a single client creates persistent data with a first DIET call and uses that data with a second DIET call, we will not know in advance the identifier of the data. However, the identifier is stored in the structure of the first profile. For example, consider a matrix A built with `diet_matrix_set()` method as follows:

```
...
diet_profile_t *profile;
...
diet_matrix_set(diet_parameter(profile,0),
                E, DIET_PERSISTENT, DIET_DOUBLE, mA, nA, oA);
...
```

After the first `diet_call`, the identifier of A is stored in the profile (in `profile->parameters[0].desc.id`). So, for the second call we will have the following instruction in order to use A:

```
...
diet_profile_t *profile2;
...
diet_use_data(diet_parameter(profile2,0),profile->parameters[0].desc.id);
...
```

NB: when using this method, the first profile (here `profile`) must not be freed before using or making a copy of the data identifier.

Chapter 4

Building a client program

The most difficult part of building a client program is to understand how to describe the problem interface. Once this step is done, it is fairly easy to build calls to DIET.

4.1 Structure of a client program

Since the client side of DIET is a library, a client program has to define a `main` function that uses DIET through function calls. The complete client-side interface is described in the files `DIET_data.h` (see Chapter 3) and `DIET_client.h` found in `<install_dir>/include`. Please refer to these two files for a complete and up-to-date API [1] description, and include at least the latter at the beginning of your source code (`DIET_client.h` includes `DIET_data.h`):

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

#include "DIET_client.h"

int main(int argc, char *argv[])
{
  diet_initialize(configuration_file, argc, argv);
  // Successive DIET calls ...
  diet_finalize();
}
```

The client program must open its DIET session with a call to `diet_initialize`, which parses the configuration file to set all options and get a reference to the DIET Master Agent. The session is closed with a call to `diet_finalize`, which frees all resources associated with this session on the client. Note that memory allocated for all INOUT and OUT arguments brought back onto the client during the session is not freed during `diet_finalize`; this allows the user to continue to use the data, but also requires that the user explicitly free the memory. The user must also free the memory he or she allocated for IN arguments.

[1] Application programming interface

4.2 Client API

The client API follows the GridRPC definition [23]: all `diet_` functions are "duplicated" with `grpc_` functions. Both `diet_initialize`/`grpc_initialize` and `diet_finalize`/`grpc_finalize` belong to the GridRPC API.

A problem is managed through a *function_handle*, that associates a server to a problem name. For compliance with GridRPC DIET accepts `diet_function_handle_init`, but the server specified in the call will be ignored; DIET is designed to automatically select the best server. The structure allocation is performed through the function `diet_function_handle_default`.

The *function_handle* returned is associated to the problem description, its profile, in the call to `diet_call`.

4.3 Examples

Let us consider the same example as in Section 3.7, but for synchronous and asynchronous calls. Here, the client configuration file is given as the first argument on the command line, and we decide to hardcode the matrix, its factor, and the name of the problem.

4.3.1 Synchronous call

`smprod` for scalar by matrix product.

```
#include <stdio.h>
#include <stdlib.h>
#include <math.h>
#include "DIET_client.h"

int main(int argc, char **argv)
{
  int i;
  double  factor = M_PI; /* Pi, why not ? */
  double *matrix;        /* The matrix to multiply */
  float  *time   = NULL; /* To check that time is set by the server */

  diet_profile_t         *profile;

  /* Allocate the matrix: 60 lines, 100 columns */
  matrix = malloc(60 * 100 * sizeof(double));
  /* Fill in the matrix with dummy values (who cares ?) */
  for (i = 0; i < (60 * 100); i++) {
    matrix[i] = 1.2 * i;
  }

  /* Initialize a DIET session */
  if (diet_initialize("./client.cfg", argc, argv)) {
    printf("A problem occured during DIET initialization.\n"
           "Make sure that a configuration file named client.cfg is present in this directory.\n");
    return 1;
  }
```

```
  /* Create the profile as explained in Chapter 3 */
  profile = diet_profile_alloc("smprod",0, 1, 2); // last_in, last_inout, last_out

  /* Set profile arguments */
  diet_scalar_set(diet_parameter(profile,0), &factor, 0, DIET_DOUBLE);
  diet_matrix_set(diet_parameter(profile,1), matrix,  0, DIET_DOUBLE, 60, 100, DIET_COL_MAJOR);
  diet_scalar_set(diet_parameter(profile,2), NULL,    0, DIET_FLOAT);

  if (!diet_call(profile)) { /* If the call has succeeded ... */

    /* Get and print time */
    diet_scalar_get(diet_parameter(profile,2), &time, NULL);
    if (time == NULL) {
      printf("Error: time not set !\n");
    } else {
      printf("time = %f\n", *time);
    }

    /* Check the first non-zero element of the matrix */
    if (fabs(matrix[1] - ((1.2 * 1) * factor)) > 1e-15) {
      printf("Error: matrix not correctly set !\n");
    }
  }

  /* Free profile */
  diet_profile_free(profile);
  diet_finalize();
  free(matrix);
  free(time);
}
```

4.3.2 Asynchronous call

`smprod` for scalar by matrix product.

```
#include <stdio.h>
#include <stdlib.h>
#include <math.h>
#include "DIET_client.h"

int main(int argc, char **argv)
{
  int i, j;
  double  factor = M_PI; /* Pi, why not ? */
  size_t m, n; /* Matrix size */
  double *matrix[5];        /* The matrix to multiply */
  float  *time   = NULL; /* To check that time is set by the server */

  diet_profile_t         *profile[5];
  diet_reqID_t rst[5] = {0,0,0,0,0};

  m = 60;
  n = 100;
```

```
/* Initialize a DIET session */
if (diet_initialize("./client.cfg", argc, argv)) {
  printf("A problem occured during DIET initialization.\n"
         "Make sure that a configuration file named client.cfg is present in this directory.\n");
  return 1;
}

/* Create the profile as explained in Chapter 3 */
for (i = 0; i < 5; i++){
  /* Allocate the matrix: m lines, n columns */
  matrix[i] = malloc(m * n * sizeof(double));
  /* Fill in the matrix with dummy values (who cares ?) */
  for (j = 0; j < (m * n); j++) {
    matrix[i][j] = 1.2 * j;
  }
  profile[i] = diet_profile_alloc("smprod",0, 1, 2); // last_in, last_inout, last_out

  /* Set profile arguments */
  diet_scalar_set(diet_parameter(profile[i],0), &factor, 0, DIET_DOUBLE);
  diet_matrix_set(diet_parameter(profile[i],1), matrix[i],  0, DIET_DOUBLE,
                  m, n, DIET_COL_MAJOR);
  diet_scalar_set(diet_parameter(profile[i],2), NULL,    0, DIET_FLOAT);
}

/* Call DIET */
int rst_call = 0;

for (i = 0; i < 5; i++){
   if ((rst_call = diet_call_async(profile[i], &rst[i])) != 0)
      printf("Error in diet_call_async return -%d-\n", rst_call);
   else {
     printf("request ID value = -%d- \n", rst[i]);
     if (rst[i] < 0) {
       printf("error in request value ID\n");
       return 1;
     }
   }
   rst_call = 0;
}

/* Wait for DIET answers */
if ((rst_call = diet_wait_and((diet_reqID_t*)&rst, (unsigned int)5)) != 0)
   printf("Error in diet_wait_and\n");
else {
  printf("Result data for requestID");
  for (i = 0; i < 5; i++) printf(" %d ", rst[i]);
  for (i = 0; i < 5; i++){
    /* Get and print time */
    diet_scalar_get(diet_parameter(profile[i],2), &time, NULL);
    if (time == NULL) {
      printf("Error: time not set !\n");
    } else {
```

```
        printf("time = %f\n", *time);
      }

      /* Check the first non-zero element of the matrix */
      if (fabs(matrix[i][1] - ((1.2 * 1) * factor)) > 1e-15) {
        printf("Error: matrix not correctly set !\n");
      }
    }
  }
  /* Free profiles */
  for (i = 0; i < 5; i++){
    diet_cancel(rst[i]);
    diet_profile_free(profile[i]);
    free(matrix[i]);
  }
  free(time);
  diet_finalize();
  return 0;
}
```

4.4 Compilation

After compiling the client program, the user must link it with the DIET libraries and the CORBA libraries.

4.4.1 Compilation using cmake

The `doc/ExternalExample` directory also contains a `CMakeFile.txt` file which illustrates the cmake way of compiling this simple client/server example:

```
PROJECT( DIETSIMPLEEXAMPLE )

cmake_minimum_required(VERSION 2.6)

# This example needs the FindDiet.cmake package detection script. We placed
# this script in the cmake sub-directory:
SET( CMAKE_MODULE_PATH ${DIETSIMPLEEXAMPLE_SOURCE_DIR}/cmake )

# Try to automaticaly detect a DIET installation...
FIND_PACKAGE( Diet )

# ...and on failure provide the user with some hints:
IF( NOT DIET_FOUND )
  IF( DIET_DIR )
    MESSAGE( "The provided DIET_DIR parameter seems NOT correct." )
  ELSE( DIET_DIR )
    MESSAGE("Could NOT find any DIET installation among the well known paths.")
    MESSAGE("If your DIET installation is in a non canonical place, please provide DIET_DIR:")
    MESSAGE("  - through the GUI when working with ccmake, ")
    MESSAGE("  - as a command line argument when working with cmake e.g. ")
    MESSAGE("    cmake .. -DDIET_DIR:PATH=/home/<your_login_name>/local/diet ")
```

```
  ENDIF( DIET_DIR )
ENDIF( NOT DIET_FOUND )

# On success use the information we just recovered:
INCLUDE_DIRECTORIES( ${DIET_INCLUDE_DIR} )
LINK_DIRECTORIES( ${DIET_LIBRARY_DIR} )

### Define a simple server...
ADD_EXECUTABLE( simple_server simple_server.c )
TARGET_LINK_LIBRARIES( simple_server ${DIET_SERVER_LIBRARIES} )
INSTALL( TARGETS simple_server DESTINATION bin )

### ... and it's associated simple client.
ADD_EXECUTABLE( simple_client simple_client.c )
TARGET_LINK_LIBRARIES( simple_client ${DIET_CLIENT_LIBRARIES} )
INSTALL( TARGETS simple_client DESTINATION bin )
```

In order to test drive the cmake configuration of this example, and assuming the DIET_HOME points to a directory containing an installation of DIET, simply try:

```
export DIET_HOME=<path_to_a_DIET_instal_directory>
cd doc/ExternalExample
mkdir Bin
cd Bin
cmake -DDIET_DIR:PATH=$DIET_HOME -DCMAKE_INSTALL_PREFIX:PATH=/tmp/DIETSimple ..
make
make install
```

Chapter 5

Building a server application

A DIET server program is the link between the DIET Server Deamon (SeD) and the libraries that implement the service to offer.

5.1 Structure of the program

Much like the client side, the DIET SeD is a library. So the server developer needs to define the `main` function. Within the `main`, the DIET server will be launched with a call to `diet_SeD` which will never return (except if some errors occur, or if a SIGINT or SIGTERM signal is sent to the *SeD*). The complete server side interface is described in the files `DIET_data.h` (see Chapter 3) and `DIET_server.h` found in `<install_dir>/include`. Do not forget to include the `DIET_server.h` (`DIET_server.h` includes `DIET_data.h`) at the beginning of your server source code.

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

#include "DIET_server.h"
```

The second step is to define a function whose prototype is "DIET-normalized" and which will be able to convert the function into the library function prototype. Let us consider a library function with the following prototype:

```
int service(int arg1, char *arg2, double *arg3);
```

This function cannot be called directly by DIET, since such a prototype is hard to manipulate dynamically. The user must define a "solve" function whose prototype only consists of a `diet_profile_t`. This function will be called by the DIET *SeD* through a pointer.

```
int solve_service(diet_profile_t *pb)
{
   int    *arg1;
   char   *arg2;
   double *arg3;

   diet_scalar_get(diet_parameter(pb,0), &arg1, NULL);
   diet_string_get(diet_parameter(pb,1), &arg2, NULL);
```

```
   diet_scalar_get(diet_parameter(pb,2), &arg3, NULL);
   return service(*arg1, arg2, arg3);
}
```

Several API functions help the user to write this "solve" function, particularly for getting IN arguments as well as setting OUT arguments.

Getting IN, INOUT and OUT arguments

The `diet_*_get` functions defined in `DIET_data.h` are still usable here. Do not forget that the necessary memory space for OUT arguments is allocated by DIET. So the user should call the `diet_*_get` functions to retrieve the pointer to the zone his/her program should write to.

Setting INOUT and OUT arguments

To set INOUT and OUT arguments, use the `diet_*_desc_set` defined in `DIET_server.h`, these are helpful for writing "solve" functions only. Using these functions, the server developer must keep in mind the fact that he cannot alter the memory space pointed to by value fields on the server. Indeed, this would make DIET confused about how to manage the data[1].

```
/**
 * If value                 is NULL,
 * or if order              is DIET_MATRIX_ORDER_COUNT,
 * or if nb_rows or nb_cols is 0,
 * or if path               is NULL,
 * then the corresponding field is not modified.
 */

int
diet_scalar_desc_set(diet_data_t* data, void* value);

// No use of diet_vector_desc_set: size should not be altered by server

// You can alter nb_r and nb_c, but the total size must remain the same
int
diet_matrix_desc_set(diet_data_t* data,
                     size_t nb_r, size_t nb_c, diet_matrix_order_t order);

// No use of diet_string_desc_set: length should not be altered by server

int
diet_file_desc_set(diet_data_t* data, char* path);
```

[1] And the server developer should not be confused by the fact that `diet_scalar_desc_set` uses a value, since scalar values are copied into the data descriptor.

5.2 Server API

Defining services

First, declare the service(s) that will be offered[2]. Each service is described by a profile description called `diet_profile_desc_t` since the service does not specify the sizes of the data. The `diet_profile_desc_t` type is defined in `DIET_server.h`, and is very similar to `diet_profile_t`. The difference is that the prototype is described with the generic parts of *diet_data_desc* only, whereas the client description uses full *diet_data*.

```
file DIET_data.h:
     struct diet_data_generic {
       diet_data_type_t type;
       diet_base_type_t base_type;
     };

file DIET_server.h:
     typedef struct diet_data_generic diet_arg_desc_t;

     typedef struct {
       char*            path;
       int              last_in, last_inout, last_out;
       diet_arg_desc_t* param_desc;
     } diet_profile_desc_t;

diet_profile_desc_t* diet_profile_desc_alloc(const char* path,
                       int last_in, int last_inout, int last_out);
int diet_profile_desc_free(diet_profile_desc_t* desc);

diet_profile_desc_t *diet_profile_desc_alloc(int last_in, int last_inout, int last_out);

int diet_profile_desc_free(diet_profile_desc_t *desc);
```

Each profile can be allocated with `diet_profile_desc_alloc` with the same semantics as for `diet_profile_alloc`. Every argument of the profile will then be set with `diet_generic_desc_set` defined in `DIET_server.h`.

Declaring services

Every service must be added in the service table before the server is launched. The complete service table API is defined in `DIET_server.h`:

```
typedef int (* diet_solve_t)(diet_profile_t *);
int diet_service_table_init(int max_size);
int diet_service_table_add(diet_profile_desc_t *profile,
                           diet_convertor_t    *cvt,
                           diet_solve_t         solve_func);
void diet_print_service_table();
```

The parameter `diet_solve_t solve_func` is the type of the `solve_service` function: a function pointer used by DIET to launch the computation.

[2] It is possible to declare several services in a single SeD.

The parameter `diet_convertor_t *cvt` is to be used in combination with scheduling facilities (if available). It is there to allow profile conversion (for multiple services, or when differences occur between the DIET and the scheduling facility profile). Profile conversion is complicated and will be treated separately in Chapter 9.

5.3 Example

Let us consider the same example as in Chapter 4, where a function `scal_mat_prod` performs the product of a matrix and a scalar and returns the time required for the computation:

```
int scal_mat_prod(double alpha, double *M, int nb_rows, int nb_cols, float *time);
```

Our program will first define the solve function that consists of the link between DIET and this function. Then, the `main` function defines one service and adds it in the service table with its associated solve function.

```
#include <stdio.h>
#include "DIET_server.h"
#include "scal_mat_prod.h"

int solve_smprod(diet_profile_t *pb)
{
  double *alpha;
  double *M;
  float  time;
  size_t m, n;
  int res;

  /* Get arguments */
  diet_scalar_get(diet_parameter(pb,0), &alpha, NULL);
  diet_matrix_get(diet_parameter(pb,1), &M, NULL, &m, &n, NULL);
  /* Launch computation */
  res = scal_mat_prod(*alpha, M, m, n, &time);
  /* Set OUT arguments */
  diet_scalar_desc_set(diet_parameter(pb,2), &time);
  /* Free IN data */
  diet_free_data(diet_parameter(pb,0));

  return res;
}

int main(int argc, char* argv[])
{
  diet_profile_desc_t *profile;

  /* Initialize table with maximum 1 service */
  diet_service_table_init(1);
  /* Define smprod profile */
  profile = diet_profile_desc_alloc("smprod",0, 1, 2);
  diet_generic_desc_set(diet_param_desc(profile,0), DIET_SCALAR, DIET_DOUBLE);
  diet_generic_desc_set(diet_param_desc(profile,1), DIET_MATRIX, DIET_DOUBLE);
  diet_generic_desc_set(diet_param_desc(profile,2), DIET_SCALAR, DIET_FLOAT);
```

```
  /* Add the service (the profile descriptor is deep copied) */
  diet_service_table_add(profile, NULL, solve_smprod);
  /* Free the profile descriptor, since it was deep copied. */
  diet_profile_desc_free(profile);

  /* Launch the SeD: no return call */
  diet_SeD("./SeD.cfg", argc, argv);

  return 0;
}
```

5.4 Compilation

After compiling her/his server program, the user must link it with the DIET and CORBA libraries. This process is very similar to the one described for the client in section 4.4. Please refer to this section for details.

Chapter 6

Batch and parallel submissions

6.1 Introduction

Most of resources in a grid are parallel, either clusters of workstations or parallel machines. Computational grids are even considered as hierachical sets of parallel resources, as we can see in ongoing project like the french research grid project, Grid'5000 [2] (for the moment, 9 sites are involved), or like the EGEE[1] project (*Enabling Grids for E-science in Europe*), composed of more than a hundred centers in 48 countries. Then, in order to provide transparent access to resources, grid middleware must supply efficient mechanisms to provide parallel services.

Because parallel resources are managed differently on each site, it is neither the purpose of DIET to deal with the deployment of parallel tasks inside the site, nor manage copies of data which can possibly be on NFS. DIET implements mechanisms for a *SeD* programmer to easily provide a service that can be portable on different sites; for clients to request services which can be explicitly sequential, parallel or solved in the real transparent and efficient metacomputing way: only the name of the service is given and DIET chooses the best resource where to solve the problem.

6.2 Terminology

Servers provide *services*, *e.g.,* instanciation of problems that a server can solve: for example, two services can provide the resolution of the same problem, one being sequential and the other parallel. A DIET *task*, also called a *job*, is created by the *request* of a client: it refers to the resolution of a service on a given server.

A service can be sequential or parallel, in which case its resolution requires numerous processors of a parallel resource (a parallel machine or a cluster of workstations). If parallel, the task can be modeled with the MPI standard, or composed of multiple sequential tasks (deployed for example with `ssh`) resolving a single service: it is often the case with data parallelism problems.

Note that when dealing with batch reservation systems, we will likely speak about *jobs* rather than about *tasks*.

[1] http://public.eu-egee.org/

6.3 Configuration for compilation

You must enable the batch flag in cmake arguments. Typically, if you build DIET from the command line, you can use the following:

```
ccmake $diet_src_path
   -DDIET_USE_ALT_BATCH:BOOL=ON
```

6.4 Parallel systems

Single parallel systems are surely the less deployed in actual computing grids. They are usually composed of a frontal node where clients log in, and from which they can log on numerous nodes and execute their parallel jobs, *without any kind of reservation (time and space)*. Some problems occur with such a use of parallel resources: multiple parallel tasks can share a single processor, hence delaying the execution of all applications using it; during the deployment, the application must at least check the connectivity of the resources; if performance is wanted, some monitoring has to be performed by the application.

6.5 Batch system

Generally, a parallel resource is managed by a batch system, and jobs are submitted to a site queue. The batch system is responsible for managing parallel jobs: it schedules each job, and determines and allocates the resources needed for the execution of the job.

There are many batch system, among which Torque[2] (a fork of PBS[3]), Loadleveler[4] (developped by IBM), Oracle Grid Engine[5] (formerly SunGrid Engine[6]: SGE, developped by Sun), OAR[7] (developped at the IMAG lab). Each one implements its own language syntax (with its own mnemonics), as well as its own scheduler. Jobs can generally access the identity of the reserved nodes through a file during their execution, and are assured to exclusively possess them.

6.6 Client extended API

Even if older client codes must be recompiled (because internal structures have evolved), they do not necessarily need modifications.

DIET provides means to request exclusively sequential services, parallel services, or let DIET choose the best implementation of a problem for efficiency purposes (according to the scheduling metric and the performance function).

```
/* To explicitly call a sequential service */
```

[2] http://old.clusterresources.com/products/torque/
[3] http://www.clusterresources.com/pages/products/torque-resource-manager.php
[4] http://www-03.ibm.com/servers/eserver/clusters/software/loadleveler.html
[5] http://www.oracle.com/technetwork/oem/grid-engine-166852.html
[6] http://www.sun.com/software/gridware/
[7] http://oar.imag.fr

```
diet_error_t
diet_parallel_call(diet_profile_t * profile) ;

diet_error_t
diet_sequential_call_async(diet_profile_t* profile, diet_reqID_t* reqID);

/* To explicitly call a parallel service in sync or async way */
diet_error_t
diet_sequential_call(diet_profile_t * profile) ;

diet_error_t
diet_parallel_call_async(diet_profile_t* profile, diet_reqID_t* reqID);

/* To mark a profile as parallel or sequential. The default call to
   diet_call() or diet_call_async() will perform a call to the correct
   previous call */
int
diet_profile_set_parallel(diet_profile_t * profile) ;
int
diet_profile_set_sequential(diet_profile_t * profile) ;

/* To let the user choose a given amount of resources */
int
diet_profile_set_nbprocs(diet_profile_t * profile, int nbprocs) ;
```

6.7 Batch server extended API and configuration file

There are too many diverse scenarii about the communication and execution of parallel applications: the code can be a MPI code or composed of different interacting programs possibly launched via `ssh` on every nodes; input and output files can use NFS if this file system is present, or they can be splitted and uploaded to each node participating to the calculus.

Then, we will see: what supplementary information has to be provided in the server configuration file; how to write a batch submission meta-script in a *SeD*; and how to record the parallel/batch service.

6.8 Server API

```
/* Set the status of the SeD among SERIAL and BATCH */
void
diet_set_server_status( diet_server_status_t st ) ;

/* Set the nature of the service to be registered to the SeD */
int
diet_profile_desc_set_sequential(diet_profile_desc_t * profile) ;
```

```
int
diet_profile_desc_set_parallel(diet_profile_desc_t * profile) ;

/* A service MUST call this command to perform the submission to the batch system */
int
diet_submit_parallel(diet_profile_t * profile, const char * command) ;
```

6.8.1 Registering the service

A server is mostly built like described in section 5. In order to let the *SeD* know that the service defined within the profile is a parallel one, the *SeD* programmer **must** use the function:

```
void diet_profile_desc_set_parallel(diet_profile_desc_t* profile)
```

By default, a service is registered as sequential. Nevertheless, for code readability reasons, we also give the pendant function to explicitly register a sequential service:

```
void diet_profile_desc_set_sequential(diet_profile_desc_t* profile)
```

6.8.2 Server configuration file

The programmer of a batch service available in a *SeD* do not have to worry about which batch system to submit to, except for its name, because DIET provides all the mechanisms to transparently submit the job to them.

DIET is currently able to submit batch scripts to OAR (version 1.6 and 2.0), PBS/Torque, LoadLeveler, and SGE. The name of the batch scheduler managing the parallel resource where the *SeD* is running has to be incorporated with the keyword `batchName` in the server configuration file. This is how the *SeD* knows the correct way of submitting a job.

Furthermore, if there is no default queue, the DIET deployer must also provide the queue on which jobs have to be submitted, with the keyword `batchQueue`.

You also have to provide a directory where the *SeD* can read and write data on the parallel resource. Please note that this directory is used by DIET to store the new built script that is submitted to the batch scheduler. In consequence, because certain batch schedulers (like OAR) need the script to be available on all resources, *this directory might be on NFS* (remember that DIET cannot replicate the script on all resources before submission because of access rights). Note that concerning OAR (v1.6), in order to use the CoRI_batch features for 0AR 1.6 (see Section 9.2.3), the Batch *SeD* deployer must also provide the keyword `internQueue` with the corresponding name. For example, the server configuration file can contain the following lines:

```
batchName = oar
batchQueue = queue_9_13
pathToNFS = /home/ycaniou/tmp/nfs
pathToTmp = /tmp/YC/
internOARbatchQueueName = 913
```

6.8.3 Server API for writing services

The writing of a service corresponding to a parallel or batch job is very simple. The *SeD* programmer builds a shell script that he would have normally used to execute the job, *i.e.,* a

script that must take care of data replication and executable invocation depending on the site.

In order for the service to be system independent, the *SeD* API provides some meta-variables which can be used in the script.

- `$DIET_NAME_FRONTALE`: frontale name
- `$DIET_USER_NBPROCS`: number of processors
- `$DIET_BATCH_NODESLIST`: list of reserved nodes
- `$DIET_BATCH_NBNODES`: number of reserved nodes
- `$DIET_BATCH_NODESFILE`: name of the file containing the identity of the reserved nodes
- `$DIET_BATCH_JOBID`: batch job ID
- `$DIET_BATCHNAME`: name of the batch system

Once the script written in a string, it is given as an argument to the following function:

```
int
diet_submit_parallel(diet_profile_t * pb, char * script)
```

6.8.4 Example of the client/server 'concatenation' problem

There are fully commented client/server examples in `<diet_src>/src/examples/Batch` directory. The root directory contains a simple example, and `TestAllBatch` and `Cori_cycle_stealing` are more practical, the latter being a code to explain the `CoRI_batch` API.

The root directory contains a simple basic example on how to use the batch API is given here: no IN or INOUT args, the client receives as a result the number of processors on which the service has been executed. The service only writes to a file, with batch-independent mnemonics, some information on the batch system.

The `<diet_src>/src/examples/Batch/file_transfer` directory contains 3 servers, one sequential, one parallel and one batch, and one synchronous and one asynchronous client. The client is configurable to simply ask for only sequential, or explicitly parallel services, or to let DIET choose the best (by default, two processors are used and the scheduling algorithm is Round-Robin). We consequently give the MPI code which is called from the batch *SeD*, which realizes the concatenation of two files sent by the client. Note that the user *must change* some paths in the *SeD* codes, according to the site where he deploys DIET.

Chapter 7

Cloud submissions

7.1 Introduction

The user must understand the relationship between DIET Cloud and the Cloud system it is using. A Cloud system is seen as a provider of on-demand resources and as such, the DIET Cloud SeD is the front-end to the Cloud system from the DIET user's point of view.

The DIET platform remains completely outside of the Cloud system and virtual resources are instantiated based on how they are needed. These virtual resources contain the task that solves the service required by the DIET client. It is the responsibility of the DIET service creator to provide Virtual Machine images that contain the service implementation.

The DIET Cloud system is part of the DIET Barch system and it is recommended that the user reads the corresponding chapter before the current.

7.2 Compatibility and requirements

The current version of DIET Cloud has been built on top of the Amazon EC2 SOAP interface, version 2009-08-15 and is compatible with any cloud system that offers a front-end with this interface.

We have used our own installation of EUCALYPTUS[1] as well as AMAZONEC2[2] for testing and development. The installation process of the cloud system will not be detailed as it is outside the scope of the current topic. For details on the installation and usage of the cloud system please refer to your Cloud provider's documentation. The rest of this chapter assumes the existing installation and correct functioning of a Cloud system that the user can access.

To be able to reserve virtual resources on an Amazon EC2 compatible cloud system, the Cloud user mush have knowledge of the following resources:

- `The URL of the Cloud system`
- `Virtual machine images' names`: the user should know what virtual resources she wants to instantiate. To be more precise, the user must know the names associated to the virtual machine images, machine kernel images and machine ramdisk images that she wants to use.

[1] http://open.eucalyptus.com/
[2] http://aws.amazon.com/fr/ec2/

- `Virtual machine instance type`: if the user requires a specific type of virtual machine that is specialized with larger quantities of virtual CPUs, memory space or disk space offered. An Amazon EC2 compatible Cloud system offers 5 different types of virtual machines that vary these three quantities. The exact values are not standard. Eucalyptus provides the possibility of per-installation configuration of these types.
- `The number of virtual resources to instantiate`
- `The X509 certificate that is associated to the Cloud installation`: this is provided by the Cloud system after its installation and the user's registration in the system.
- `The user's key`: after registering in the Cloud system, each user receives a key that is used for signing all the requests that she makes to the Cloud system.
- `A keypair to use for the reservation`: the user must create a keypair that is to be used when performing reservations.

7.3 Configuration for compilation

In order to enable the compilation and installation of the DIET Cloud system, its corresponding make flag must be enabled when configuring. This flag is named `DIET_USE_CLOUD`. This is a part of the alternate batch system so it also needs to be installed (the `DIET_USE_ALT_BATCH` flag). The DIET batch system is dependent on CORI so it also needs to be installed (the `DIET_USE_CORI` flag).

The installation of the Cloud system is dependent on an installation of gSOAP[3] that contains the WSSE plugin. This is the Web Service Security plugin. It is the responsibility of the DIET user to ensure a propper installation of gSOAP and its WSSE plugin. The will try to automatically detect an installation of gSOAP with its components. If this fails, then the DIET user will have to manually specify the installation path of the gSOAP package and its WSSE plugin.

Please note that DIET Clour has been tested with gSOAP version 2.7.16.

Examples of the use of the DIET Cloud system will also be compiled if the `DIET_BUILD_EXAMPLES` flag is triggered.

For more information on compiling and installing DIET please see the section dedicated specifically to that purpose.

7.4 Server configuration file

At the time this documentation has been written, Eucalyptus and Amazon EC2 supported 5 different types of Virtual Machines to instantiate. These differ from one-another by CPU, memory and disk characteristics. Eucalyptus allows the modification of these characteristics. The 5 VM types and their associated default characteristics inside **Eucalyptus** are:

1. m1.small: 1 VCPU, 128 MB RAM, 2 GB Disk
2. c1.medium: 1 VCPU, 256 MB RAM, 5 GB Disk

[3] http://www.cs.fsu.edu/~engelen/soap.html

3. m1.large: 2 VCPU, 512 MB RAM, 10 GB Disk
4. m1.xlarge: 2 VCPU, 1024 MB RAM, 20 GB Disk
5. c1.xlarge: 4 VCPU, 2048 MB RAM, 20 GB Disk

Configuring the server part is done by using the following options:

- batchName: the name of the batch system to be used. This is recognized internally by the Diet Batch System and should always have the value **eucalyptus**.
- pathToNFS: path to a temporary directory
- cloudURL: the URL of the Cloud System's management service
- emiName: the name of the Virtual Machine Image containing the service
- eriName: the name of the Ramdisk image to be used when instantiating the service
- ekiName: the name of the Kernel image to be used when instantiating the service
- vmType: the type of the Virtual Machine to be instantiated
- keyName: the name of the keypair created for use in the Cloud System
- vmMinCount: minimum number of VM instances that is acceptable for the current service call to succede
- vmMaxCount: maximum number of VM instances for the current service call
- pathToCert: path to the X.509 certificate given by the Cloud System
- pathToPK: path to the private key that the current Cloud user has associated to the Cloud System

An example of a valid configuration is the following:

```
batchName = eucalyptus
pathToNFS = /tmp
cloudURL = http://140.77.13.186:8773/services/Eucalyptus
emiName = emi-82011336
eriName = eri-0ADF1561
ekiName = eki-CBC01482
vmType = m1.small
keyName = mykey
vmMinCount = 1
vmMaxCount = 1
pathToCert = /home/adi/.euca/euca2-admin-0b298100-cert.pem
pathToPK = /home/adi/.euca/euca2-admin-0b298100-pk.pem
```

7.5 Registering the service

DIET's Cloud module behaves like any other Batch System. A *SeD* programed this way is actually a service residing at the front-end of a Cloud. It will be able to access directly all the Virtual Machines that the Cloud has instantiated. Defining and registering the Cloud-enabled DIET service is done in the same way as defining a batch service. DIET's Batch System module will internally invoke the **Eucalyptus** Batch System which will instantiate the Virtual Resources corresponding to the current service.

7.6 Service API

Programming the *SeD* Cloud is done in the same way as programming normal Batch System. The programmer builds a shell script that will execute his job. To facilitate access to the instantiated Virtual Machines, the `DIET_CLOUD_VMS` meta-variable can be used inside the shell script. This will automatically be replaced upon submission with a list of the IP addresses of all the instantiated virtual resources.

7.7 Example of client/server

The DIET sources also contain working examples for the *SeD* Cloud. These can be found in: `<diet_src>/src/examples/cloud`. The examples are built automatically if the `DIET_BUILD_EXAMPLES` and `DIET_HAVE_CLOUD` make flags are selected. Note that the user *must change* the service configuration file to match his own Cloud installation.

Chapter 8

Scheduling in DIET

8.1 Introduction

We introduce a *plugin scheduling* facility, designed to allow DIET service developers to define application-specific performance measures and to implement corresponding scheduling strategies. This section describes the default scheduling policy in DIET and the interface to the plugin scheduling facility.

8.2 Default Scheduling Strategy

The DIET scheduling subsystem is based on the notion that, for the sake of system efficacy and scalability, the work of determining the appropriate schedule for a parallel workload should be distributed across the computational platform. When a task in such a parallel workload is submitted to the system for processing, each Server Daemon (*SeD*) provides a *performance estimate* – a collection of data pertaining to the capabilities of a particular server in the context of a particular client request – for that task. These estimates are passed to the server's parent agent; agents then sort these responses in a manner that optimizes certain performance criteria. Effectively, candidate *SeD*s are identified through a distributed scheduling algorithm based on pairwise comparisons between these performance estimations; upon receiving server responses from its children, each agent performs a local scheduling operation called *server response aggregation*. The end result of the agent's aggregation phase is a list of server responses (from servers in the subtree rooted at said agent), sorted according to the aggregation method in effect. By default, the aggregation phase implements the following ordered sequence of tests:

1. **Least recently used**: In the absence of application- and platform-specific performance data, the DIET scheduler attempts to probabilistically achieve load balance by assigning client requests based on the time they last finished to compute. Essentially each server records a timestamp indicating the last time at which it was assigned a job for execution. Each time a request is received, the *SeD* computes the time elapsed since its last execution, and among the responses it receives, DIET agents select *SeD*s with a longer elapsed time.

2. **Random**: If the *SeD* is unable to store timestamps, the DIET scheduler will chose randomly when comparing two otherwise equivalent *SeD* performance estimations.

In principle, this scheduling policy prioritizes servers that are able to provide useful performance prediction information. In general, this approach works well when all servers in a given DIET hierarchy are capable of making such estimations. However, in platforms composed of *SeD*s with varying capabilities, load imbalances may occur: since DIET systematically prioritizes server responses containing scheduling data, servers that do not respond with such performance data will never be chosen.

We have designed a plugin scheduler facility to enable the application developer to tailor the DIET scheduling to the targeted application. This functionality provides the application developer the means to extend the notion of a performance estimation to include metrics that are application-specific, and to instruct DIET how to treat those data in the aggregation phase. We describe these interfaces in the following sections.

8.3 Plugin Scheduler Interface

Distributed applications are varied and often exhibit performance behavior specific to the domain from which they arise. Consequently, application-specific scheduling approaches are often necessary to achieve high-performance execution. We propose an extensible framework to build *plugin schedulers*, enabling application developers to specify performance estimation metrics that are tailored to their individual needs.

8.3.1 Estimation Metric Vector

The type `estVector_t` represents an *estimation vector*, logically a structure that can manage a dynamic collection of performance estimation values. It contains values that represent the performance profile provided by a *SeD* in response to a DIET service request. This collection of values may include either standard performance measures that are available through DIET, or developer-defined values that are meaningful solely in the context of the application being developed.

8.3.2 Standard Estimation Tags

To access to the different fields of the `estVector_t`, it is necessary to specify the tag that correspond to a specific information type. Table 8.1 describes this correspondence. Some tags represent a list of values, one has to use the `diet_est_array_*` functions to have access to them. In Table 8.1, the second column marks these multi-value tags.

The tag *ALLINFOS* is a special: his field is always empty, but it allows to fill the vector with all known tags by the particular collector.

Standard Performance Metrics

To access to the existing default performance estimation routines (as described in Chapter 9), the following functions are available to facilitate the construction of custom performance estimation functions:

- The time elapsed since the last execution (to enable the "least recently used" scheduler) is stored in an estimation metric vector by calling

TCOMP		the predicted time to solve a problem
TIMESINCELASTSOLVE		time since last solve has been made (sec)
FREECPU		amount of free CPU power between 0 and 1
FREEMEM		amount of free memory (Mb)
NBCPU		number of available processors
CPUSPEED	x	frequency of CPUs (MHz)
TOTALMEM		total memory size (Mb)
AVGFREECPU		average amount of free CPU power in [0..1]
BOGOMIPS	x	CPUs' bogomips
CACHECPU	x	cache size CPUs (Kb)
TOTALSIZEDISK		size of the partition (Mb)
FREESIZEDISK		amount of free place on partition (Mb)
DISKACCESREAD		average time to read on disk (Mb/sec)
DISKACCESWRITE		average time to write to disk (sec)
ALLINFOS	x	[empty] fill all possible fields
PARAL_NB_FREE_RESOURCES_IN_DEFAULT_QUEUE		number of idle resources

Table 8.1: Estimation tags

```
int diet_estimate_lastexec(estVector_t ev,
                           const diet_profile_t* const profilePtr);
```

with an appropriate value for `ev` and the `profilePtr` corresponding to the current DIET request.

- The number of waiting jobs when using the maximum concurrent jobs limit is stored in an estimation metric vector by calling

  ```
  int diet_estimate_waiting_jobs(estVector_t ev);
  ```

- CoRI allows to access in an easy way to basic performance prediction. See Chapter 9.2 to know more about the use of it.

In the future, we plan to expand the suite of default estimation metrics to include dynamic internal DIET system state information (*e.g.,* queue lengths).

Developer-defined Performance Metrics

Application developers may also define performance values to be included in a *SeD* response to a client request. For example, a DIET *SeD* that provides a service to query particular databases may need to include information about which databases are currently resident in its disk cache, in order that an appropriate server be identified for each client request. To store such values, the *SeD* developer should first choose a unique integer identifier, referred to as the *tag* to denote each logical datum to be stored. Values are associated with tags using the following interface:

```
int diet_est_set(estVector_t ev, int userTag, double value);
```

The `ev` parameter is the estimation vector where the value will be stored, the `userTag` parameter denotes the chosen tag, and `value` indicates the value to be associated with the tag. Tagged data are used to effect scheduling policies by defining custom server response aggregation methods, described in Section 8.3.4.

8.3.3 Estimation Function

The default behavior of a *SeD* when a service request arrives from its parent agent is to store the following information in the request profile:

1. **Elapsed time since last execution**: To implement the default round-robin behavior in absence of scheduling facilities, each *SeD* stores a timestamp of its last execution. When a service request arrives, the difference between that timestamp and the current time is added to the performance estimate.

This is accomplished by using the `diet_estimate_lastexec` functions described in Section 8.3.1.

To implement a plugin scheduler, we define an interface that admits customizable performance estimation routines:

```
typedef void (* diet_perfmetric_t)( diet_profile_t*,
                                    estVector_t);


diet_perfmetric_t
diet_service_use_perfmetric(diet_perfmetric_t perfmetric_fn);
```

Thus, the type `diet_perfmetric_t` is a function pointer that takes as arguments a performance estimation (represented by the `estVector_t` object) and a DIET service request profile. The application developer can associate such a function, or *performance estimation routine*, with DIET services via the `diet_service_use_perfmetric` interface. This interface returns the previously registered performance estimation routine, if one was defined (and `NULL` otherwise). At this point, a service added using the `diet_service_table_add` function will be associated with the declared performance estimation routine. Additionally, a performance estimation routine so specified will be associated with *all* services added into the service table until another call to the `diet_service_use_perfmetric` interface is made. In the performance estimation routine, the *SeD* developer should store in the provided estimation vector any performance data used in the server response aggregation methods (described in the next section).

8.3.4 Aggregation Methods

At the time a DIET service is defined, an *aggregation method* – the logical mechanism by which *SeD* responses are sorted – is associated with the service; the default behavior was described in Section 8.2.

If application-specific data *are* supplied (*i.e.,* the estimation function has been redefined), an alternative method for aggregation is needed. Currently, a basic *priority scheduler* has been implemented, enabling an application developer to specify a series of performance values that are to be optimized in succession. A developer may implement a priority scheduler using the following interface:

```
diet_aggregator_desc_t*
diet_profile_desc_aggregator(diet_profile_desc_t* profile);

int diet_aggregator_set_type(diet_aggregator_desc_t* agg,
```

```
                                diet_aggregator_type_t atype);

int diet_aggregator_priority_max(diet_aggregator_desc_t* agg,
                                 diet_est_tag_t tag);

int diet_aggregator_priority_min(diet_aggregator_desc_t* agg,
                                 diet_est_tag_t tag);

int diet_aggregator_priority_maxuser(diet_aggregator_desc_t* agg,
                                     int val);

int diet_aggregator_priority_minuser(diet_aggregator_desc_t* agg,
                                     int val);
```

The `diet_profile_desc_aggregator` and `diet_aggregator_set_type` functions fetch and configure the aggregator corresponding to a DIET service profile, respectively. In particular, a priority scheduler is declared by invoking the latter function with `DIET_AGG_PRIORITY` as the `agg` parameter. Recall that from the point of view of an agent, the aggregation phase is essentially a sorting of the server responses from its children. A priority scheduler logically uses a series of user-specified tags to perform the pairwise server comparisons needed to construct the sorted list of server responses.

To define the tags and the order in which they should be compared, four functions are introduced. These functions, of the form `diet_aggregator_priority_*`, serve to identify the estimation values to be optimized during the aggregation phase. The `_min` and `_max` forms indicate that a standard performance metric (*e.g.,* time elapsed since last execution, from the `diet_estimate_lastexec` function) is to be either minimized or maximized, respectively. Similarly, the `_minuser` and `_maxuser` forms indicate the analogous operations on user-supplied estimation values. Calls to these functions indicate the order of **precedence** of the tags.

Each time two server responses need to be compared, the values associated with the tags specified in the priority aggregator are retrieved. In the specified order, pairs of corresponding values are successively compared, passing to the next tag only if the values for the current tag are identical. If one server response contains a value for the metric currently being compared, and another does not, the response with a valid value will be selected. If at any point during the treatment of tags *both* responses lack the necessary tag, the comparison is declared indeterminate. This process continues until one response is declared superior to the other, or all tags in the priority aggregator are exhausted (and the responses are judged equivalent).

8.4 Example

An example is present in the DIET distribution to illustrate the usage of the plugin scheduler functionality; this code is available in the directory

```
src/examples/plugin_example/
```

A DIET server and client corresponding to a simulation of a database research application are provided. If the construction of examples was enabled during DIET configuration, two binaries

`server` and `client` will be built in this directory. Having deployed a DIET agent hierarchy, the server may be instantiated:

```
$ server <SeD_config> <DB> [ <DB> ...  ]
```

where `<DB>` are string(s) that represent the existence of a particular database at the *SeD*'s site. A client would pose a query against a set of databases:

```
$ client <client_config> <DB> [ <DB> ...  ]
```

The application uses the plugin scheduling facility to prioritize the existence of databases in selecting a server, and thus, the expected result is that one of the *SeD*s with the fewest number of database mismatches will be selected.

In the `main` function of the `server.c` file, the following block of code (a) specifies the use of the priority aggregator for this service, (b) declares a performance estimation function to supply the necessary data at request-time, and (c) defines the order of precedence of the performance values (*i.e.,* minimizing the number of database mismatches, and then maximizing the elapsed execution time).

```
{
  /* new section of the profile: aggregator */
  diet_aggregator_desc_t *agg;
  agg = diet_profile_desc_aggregator(profile);

  /* for this service, use a priority scheduler */
  diet_aggregator_set_type(agg, DIET_AGG_PRIORITY);          /* (a) */

  /* install our custom performance function */
  diet_service_use_perfmetric(performanceFn);                /* (b) */

  /* define the precedence order */
  diet_aggregator_priority_minuser(agg, 0);                  /* (c) */
  diet_aggregator_priority_max(agg, EST_TIMESINCELASTSOLVE); /* (c) */
}
```

The performance function `performanceFn` is defined as follows:

```
static void performanceFn(diet_profile_t* pb, estVector_t perfValues);

[...]

/*
** performanceFn: the performance function to use in the DIET
**   plugin scheduling facility
*/
static void
performanceFn(diet_profile_t* pb, estVector_t perfValues)
{
  const char *target;
```

```
  int numMismatch;

  /* string value must be fetched from description; value is NULL */
  target = (diet_paramstring_get_desc(diet_parameter(pb, 0)))->param;
  numMismatch = computeMismatches(target);

  /*
  ** store the mismatch value in the user estimate space,
  ** using tag value 0
  */
  diet_est_set(perfValues, 0, numMismatch);

  /* also store the timestamp since last execution */
  diet_estimate_lastexec(perfValues, pb);
}
```

The function `computeMismatches` (defined earlier in `server.c`) calculates the number of requested databases that are not present on the *SeD* making the evaluation. Together, these two code segments serve to customize the generation of performance information and the treatment of these data in the context of the simulated database search. Finally, it should be noted that the existence of a plugin scheduler is completely transparent to the client, and thus client code need not be changed.

8.5 Scheduler at agents level

In this section we introduce the way to define a scheduling policy in DIET. Some scheduling strategies could not be developed using only the DIET*SeD*s plugins. The schedulers at agents level allow the developer to design every scheduler strategies, even the centralized ones. The first two sections explain precisely how DIET performs the scheduling. The third section enters in the DIET source code and can be ignored by most of the users. The fourth section presents the tools provided to make an agent scheduler easily. The fifth section deals with the scheduler module compilation and usage. The last section presents some scheduler examples.

8.5.1 Scheduling from the agents side.

In DIET, the scheduling works as follows (see Figure 8.1 for a representation of each step):

- A request is submitted to the Master Agent (step 1).
- The Master Agent forwards the request to the Local Agents and *SeD*s that it manages (step 2).
- The *SeD*s which dispose of the asked service return a CORBA response structure which contains an estimation metric vector (step 3).
- According to a default policy or a user-defined one, the responses from the *SeD*s are aggregated. Then the responses sequence is sent to the parent agent which aggregates all the results of its children (step 4).

- When the aggregated responses reach the Master Agent, it returns the aggregated list of all responses to the client (step 5).
- Finally, the client chooses the better server, according to the chosen aggregation method (step 6).

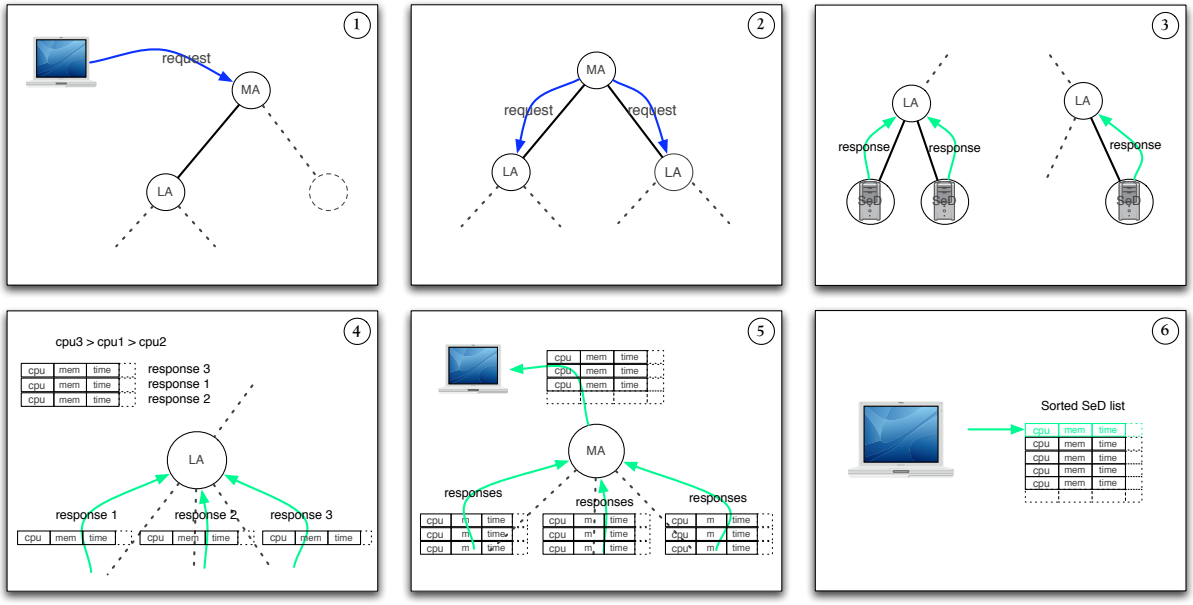


Figure 8.1: Scheduling steps in DIET.

8.5.2 Aggregation methods overloading

To aggregate the responses of the *SeD*s, DIET uses an aggregation method which is called by the agents. This method is chosen from the *SeD*s by defining the aggregator type (see Section 8.3.2). By default, two aggregator types are proposed by DIET: DIET_AGG_DEFAULT and DIET_AGG_PRIORITY. Another aggregator type is also available: DIET_AGG_USER. Using this aggregator, the user can define her own aggregation method to be used by the agents. Figure 8.2 presents the global schedulers classes organization in DIET. By choosing the DIET_AGG_USER aggregator, the user commands the GlobalScheduler class to load an external module containing a UserScheduler class overloading the *aggregate* method.

The user-defined aggregation method just needs to sort the responses from the *SeD*s. By locating the aggregation method on the agent, we can use different scheduling strategies which could not be implemented at the *SeD* level. These schedulers can also avoid some scheduling problems while submitting asynchronous jobs (with "least recently used" scheduler for example).

8.5.3 The UserScheduler class

This section presents how the scheduling process is managed in DIET. Most of the developers can go directly to the next section.

All the schedulers developed by users have to inherit from the *UserScheduler* class. This class furnishes the methods to load its subclasses as a Scheduler class for DIET without error.

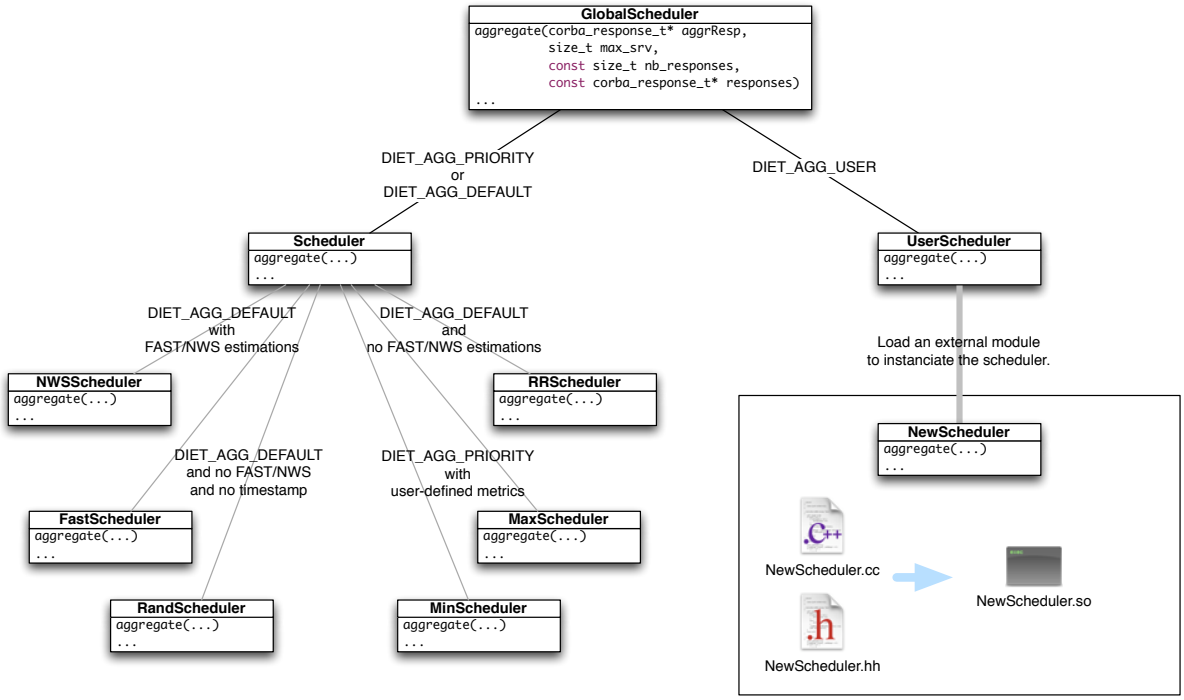


Figure 8.2: Schedulers classes organization in DIET.

The only method a user has to overload is the *aggregate* method. Several useful functions and macros are defined in the *UserScheduler.hh* file. The *UserScheduler* class is defined as follows:

```
class UserScheduler : public GlobalScheduler
{
  typedef GlobalScheduler* constructor();
  typedef void destructor(UserScheduler*);

public:
  static const char* stName;
  UserScheduler();
  virtual
  ~UserScheduler();
  /** These methods are used to load the user module and to obtain an
     instance of the scheduler. */
  static UserScheduler* getInstance(const char* moduleName);
  static GlobalScheduler * instanciate(const char* moduleName);
  void destroy(GlobalScheduler* scheduler);

  static
  GlobalScheduler* deserialize(const char* serializedScheduler,
       const char* moduleName);
  static
  char* serialize(GlobalScheduler* GS);
```

```
  /** The method that has to be overloaded to define a new scheduler. */
  virtual int
  aggregate(corba_response_t* aggrResp,
            size_t max_srv,
            const size_t nb_responses,
            const corba_response_t* responses);

private:
  /** The UserScheduler class is a singleton class. Its constructor is
   private. */
  UserScheduler(const char* moduleName);
  static UserScheduler* instance;
  void* module;
  /** These two methods are obtained from the loaded module. */
  constructor* constructs;
  destructor* destroys;
};
```

The *aggregate* method takes 4 arguments:

- *corba_response_t** **aggrResp**: the result of the aggregation has to be set in this argument. **aggrResp** is an array of *corba_server_estimation_t* objects.
- *size_t* **max_srv**: this argument gives the maximum number of responses to return in **aggrResp**. This value can be ignored without any risk and it is sometimes useful to ignore it because this parameter is hard-coded in the DIET sources.
- *const size_t* **nb_responses**: this argument gives the number of responses in **responses**.
- *const corba_response_t** **responses**: the responses are stored in this argument. It is an array of *corba_response_t* which is a CORBA structure containing a CORBA sequence of *corba_server_estimation_t*.

The *corba_response_t* structure is defined as follows:

```
struct corba_response_t {
  typedef _CORBA_ConstrType_Variable_Var<corba_response_t> _var_type;
  CORBA::ULong reqID;
  CORBA::Long myID;
  SeqServerEstimation_t servers;
  void operator>>= (cdrStream &) const;
  void operator<<= (cdrStream &);
};
```

The **_var_type** field is an internal CORBA object. The scheduler developer does not have to use it. The two operators **operator**>>= and **operator**>>= can be ignored too.

- *CORBA::ULong* **reqID**: this field contains the ID of the request.
- *CORBA::Long* **myID**: this field is for DIET internal usage. The developer should ignore it.

- *SeqServerEstimation_t* **servers**: this field is a sequence of *corba_server_estimation_t*. It is used to store the *SeD*s references returned by the *aggregate* method. This is the field that has to be sorted/filtered.

The *corba_server_estimation_t* is defined as follows:

```
struct corba_server_estimation_t {
  typedef _CORBA_ConstrType_Variable_Var<corba_server_estimation_t> _var_type;
  corba_server_t loc;
  corba_estimation_t estim;
  void operator>>= (cdrStream &) const;
  void operator<<= (cdrStream &);
};
```

- *corba_server_t* **loc**: this field is used to designate a particular *SeD*.
- *corba_estimation_t estim*: this field contains the estimation vector for the designated *SeD*.

The *corba_server_t* **loc** structure is defined as follows:

```
struct corba_server_t {
  typedef _CORBA_ConstrType_Variable_Var<corba_server_t> _var_type;
  _CORBA_ObjRef_Member< _objref_SeD, SeD_Helper>  ior;
  CORBA::String_member hostName;
  CORBA::Long port;
  void operator>>= (cdrStream &) const;
  void operator<<= (cdrStream &);
};
```

The two interesting fields are:

- **ior** which is a CORBA reference to the *SeD*.
- **hostName** which is the hostname of the *SeD*.

The *corba_estimation_t* structure is defined as follows:

```
struct corba_estimation_t {
  typedef _CORBA_ConstrType_Variable_Var<corba_estimation_t> _var_type;
  SeqEstValue_t estValues;
  void operator>>= (cdrStream &) const;
  void operator<<= (cdrStream &);
};
```

SeqEstValue_t **estValues**: This field is a CORBA sequence of estimation values. These estimation values are accessed through the specific functions: *diet_est_get_internal* and *diet_est_array_get_internal* defined in scheduler/est_internal.hh.
These functions prototypes are:

```
double diet_est_get_internal(estVectorConst_t ev, int tag, double errVal);
double diet_est_array_get_internal(estVectorConst_t ev, int tag,
                                   int idx, double errVal);
```

- *ev*: the estimation vector to evaluate.
- *tag*: the estimation tag.
- *idx*: the index of the value when available. For example, to obtain the frequency of the second processor, we have to set *idx* to 1.
- *errVal*: the value returned by the function if an error occurred.

The *tag* argument may be assigned one of the following values:

- EST_TIMESINCELASTSOLVE: The time elapsed since this *SeD* solved a request. This value is used by the default Round-Robin scheduler when available.
- EST_COMMPROXIMITY:
- EST_TRANSFEREFFORT:
- EST_FREECPU: The free CPU computation power.
- EST_FREEMEM: The free memory on the node.
- EST_NBCPU: The number of CPU installed on the node.
- EST_CPUSPEED[1]: The frequencies of the CPUs of the node.
- EST_TOTALMEM: The total memory of the node.
- EST_AVGFREEMEM: The average free memory on the node.
- EST_AVGFREECPU: The average free CPU computation power on the node.
- EST_BOGOMIPS[1]: The computation power of the nodes CPUs given in bogomips.
- EST_TOTALSIZEDISK: The total disk size on the node.
- EST_FREESIZEDISK: The available disk space on the node.
- EST_DISKACCESREAD: An evaluation of the disk read access performance.
- EST_DISKACCESWRITE: An evaluation of the disk write access performance.
- EST_USERDEFINED: The first user-defined value.
- EST_USERDEFINED + n: The n^{th} user-defined value.

To make the new scheduler class loadable by the GlobalScheduler class, the developer has to define these two functions outside the class definition:

```
extern "C" GlobalScheduler* constructor() {
    return new MyScheduler();
}
extern "C" void destructor(UserScheduler* scheduler) {
  delete scheduler;
}
```

[1]This value is accessed using the *diet_est_array_get_internal* function

No C++ implementation of dynamic class loading are defined in the C++ standard. So, the UserScheduler class has to use C functions to load an external module containing the new scheduler class. A macro defined in *UserScheduler.hh* automates this declaration. You can simply define your class as a scheduler class by calling *SCHEDULER_CLASS(MyScheduler)*, where *MyScheduler* is the name of the class which inherits of the *UserScheduler* class.

8.5.4 Easy definition of a new scheduler class

The previous section presented how the scheduler class loader is working. Many things presented before can be automated. The UserScheduler.hh file defines some useful functions and macros to make a new scheduler class easily. In this section we will present how to create a new scheduler class using these functions and macros.

The new class definition

Every scheduler class has to inherit from the UserScheduler class. The only redefinition needed is the *aggregate* function. But, the *init*, *serialize* and *deserialize* functions have to be declared conforming to the C++ standard (but not defined - the inherited functions are sufficient). The following example shows a simple scheduler class implementation.

```
class MyScheduler : public UserScheduler {
public:
  static const char* stName;

  MyScheduler();
  ~MyScheduler();
  void init();

  static char* serialize(MyScheduler* GS);
  static MyScheduler* deserialize(const char* serializedScheduler);
  /* Overriden UserScheduler class aggregate method. */
  int aggregate(corba_response_t* aggrResp, size_t max_srv,
                const size_t nb_responses, const corba_response_t* responses);
};

const char* MyScheduler::stName="UserGS";

MyScheduler::~MyScheduler() {

}

MyScheduler::MyScheduler() {
  this->name = this->stName;
  this->nameLength = strlen(this->name);
}

int MyScheduler::aggregate(corba_response_t* aggrResp, size_t max_srv,
```

```
                              const size_t nb_responses,
                              const corba_response_t* responses)
{
  ...
}

SCHEDULER\_CLASS(MyScheduler)
```

After defining the scheduler class, the developer just has to use the *SCHEDULER_CLASS* macro to define it as a scheduler class loadable from an agent.

In our example, the call to *SCHEDULER_CLASS(MyScheduler)* – after the class declaration – makes the class loadable by a DIET agent.

The aggregation method redefinition

The *aggregate* function has the following prototype:

```
int MyScheduler::aggregate(corba_response_t* aggrResp, size_t max_srv,
                              const size_t nb_responses,
                              const corba_response_t* responses)
{
  ...
}
```

The *aggregate* method takes 4 arguments:

- *corba_response_t** **aggrResp**: the result of the aggregation has to be set in this argument. **aggrResp** is an array of *corba_server_estimation_t* objects.
- *size_t* **max_srv**: this argument gives the maximum number of responses to return in **aggrResp**. This value can be ignored without any risk and it is sometimes useful to ignore it because this parameter is hard-coded in the DIET sources.
- *const size_t* **nb_responses**: this argument gives the number of responses in **responses**.
- *const corba_response_t** **responses**: the responses are stored in this argument. It is an array of *corba_response_t* which is a CORBA structure containing a CORBA sequence of *corba_server_estimation_t*.

Two functions are defined to simplify the aggregation of the results:

```
typedef list<corba_server_estimation_t> ServerList;
ServerList CORBA_to_STL(const corba_response_t* responses, int nb_responses);
void STL_to_CORBA(ServerList &servers, corba_response_t* &aggrResp);
```

The first function converts the received CORBA sequence into a STL list. This function make the first aggregation of the results by marshalling all the sequences into one.
The second function converts a STL list into a CORBA sequence that can be transfer ed by DIET.

Then, an *aggregate* function should start by a call to the *CORBA_to_STL* function. The obtained list can then be sorted/filtered using all the STL list facilities. And to finish, the result list is computed by the *STL_to_CORBA* function.

Several macros are defined to simplify the sort of a STL list:

```
SORTFUN(name, metric)
SORTFUN_NB(name, metric, nb)
REV_SORTFUN(name, metric)
REV_SORTFUN_NB(name, metric, nb)
```

These macros allow the developer to automatically define a sort function using a metric value. For example, to define a sort function using the number of CPUs, the developer just has to declare:

```
SORTFUN(compfun, NBCPU)
```

The *SORTFUN_NB* macro is used for the multi-values metrics (for example the CPU cache for each CPU). The *nb* value designates which value has to be used to sort the list. The *REV_** functions are used to sort in ascending order.

To see all the metrics available for the *SORTFUN* macro, see Section 8.5.4.

When a sort function has been defined, the developer can use the *SORT* macro to sort the STL list. For example with our *compfun* function:

```
SORT(serverList, compfun);
```

This call sorts the server STL list in decreasing order of the number of CPU.

An example of *aggregate* method definition

We will now present an example of an *aggregate* method using the functions and macro defined in the UserScheduler.hh file.

```
SORTFUN(compCPU, NBCPU)
SORTFUN_NB(compCache, CACHECPU, 0)
REV_SORTFUN(compDiskRead, DISKACCESSREAD)

int MyScheduler::aggregate(corba_response_t* aggrResp, size_t max_srv,
                           const size_t nb_responses,
                           const corba_response_t* responses)
{
  ServerList candidates = CORBA_to_STL(responses, nb_responses);

  SORT(candidates, compCache);
  SORT(candidates, compCPU);
  SORT(candidates, compDiskRead);

  STL_to_CORBA(candidates, aggrResp);

  return 0;
}
```

This function returns a list sorted by increasing disk access for first criteria and by decreasing CPU number and decreasing CPU cache.

Access the metric values through macros

To simplify the access to some specific values defined inside the *SeD*, you can use these macros:

- TOTALTIME(SeD)
- COMMTIME(SeD)
- TCOMP(SeD)
- TIMESINCELASTSOLVE(SeD)
- COMMPROXIMITY(SeD)
- TRANSFEREFFORT(SeD)
- FREECPU(SeD)
- FREEMEM(SeD)
- NBCPU(SeD)
- CPUSPEED(SeD, idx)
- TOTALMEM(SeD)
- AVGFREEMEM(SeD)
- AVGFREECPU(SeD)
- BOGOMIPS(SeD, idx)
- CACHECPU(SeD, idx)
- TOTALSIZEDISK(SeD)
- FREESIZEDISK(SeD)
- DISKACCESSREAD(SeD)
- DISKACCESSWRITE(SeD)
- USERDEFINED(SeD, idx)

The macros taking two arguments need an index to choose which CPU measurement is needed. Two extra macros are defined:

- HOSTNAME(server): The hostname of the *SeD*.
- SED_REF(server): A CORBA reference to the *SeD*.

Here is an example of an *aggregate* function using these macros:

```
SORTFUN(compBogo, BOGOMIPS)

int MyScheduler::aggregate(corba_response_t* aggrResp, size_t max_srv,
                           const size_t nb_responses,
                           const corba_response_t* responses)
{
  ServerList candidates = CORBA_to_STL(responses, nb_responses);
  ServerList chosen;
  ServerList::iterator it;

  for (it=candidates.begin(); it!=candidates.end(); ++it)
    if (NBCPU(*it)>=2) chosen.push_back(*it);
  SORT(chosen, compBogo);

  STL_to_CORBA(chosen, aggrResp);
  return 0;
}
```

This aggregation method first selects only the *SeD* which have more than 1 CPU and sorts them according to their number of Bogomips.

8.5.5 Creation and usage of a scheduler module

How to compile a scheduler module

The first step is to compile DIET activating the "USERSCHED" option. With this option, you'll find a subdirectory "scheduler" in the include directory of the DIET installation. This directory contains all the headers needed to develop the basis class of the scheduler module.

A scheduler module needs to be linked with some libraries to compile:

- omniORB4: The basis omniORB library.
- omnithread: The omniORB thread library.
- DIET libraries:
  - CorbaCommon: The basis DIET Corba library.
  - UtilsCommon & UtilsNodes: The DIET utilities libraries.
  - IDLAgent & IDLCommon: The IDL DIET libraries.
  - UtilsVector: The vector library internally used in DIET.
  - IDLLA & IDLMA: The agents libraries.

When using g++ as compiler the option *"-shared"* has to be used to compile the module under Linux and *"-dynamiclib"* under Mac OS X. The *"-fPIC"* has to be used for both operating systems.

How to configure the agent and the *SeD* to use a scheduler module

On the agent side, the parameter *schedulerModule* has to be set to the path of the module scheduler (in the agent configuration file). This option uses the same syntax than the other agents and ORB options:

schedulerModule = <path to module>

On the *SeD* side, the developer has to choose *DIET_AGG_USER* as aggregator:

```
diet_aggregator_desc_t *agg;

diet_service_table_init(1);
profile = diet_profile_desc_alloc("serviceName", ...);
diet_generic_desc_set(diet_param_desc(profile, 0), ...);
...

agg = diet_profile_desc_aggregator(profile);
diet_aggregator_set_type(agg, DIET_AGG_USER);

diet_service_table_add(profile, ...);
...
```

Usually, the developer should define a performance metric function to communicate with the agent scheduler. For example, if the scheduler uses the number of waiting jobs in the FIFO queue, the performance metric could be:

```
void metric(diet_profile_t * profile, estVector_t values) {
  diet_estimate_waiting_jobs(values);
}
```

This metric just fixes the number of waiting jobs in the FIFO queue of the *SeD*. Now, at the agent side, the scheduler can use this value to aggregate, sort and filter the *SeD*s responses. More details are given in the following section about how to use the *SeD*s plugin schedulers to communicate with the agent scheduler module.

8.5.6 *SeD* plugin schedulers and agent schedulers interactions

Most of the time, a scheduler needs some information from the nodes, to choose where a job should be executed. By using the plugin scheduler capacities of the *SeD*s, DIET allows to communicate some useful information for the scheduling. The developer just has to define a performance metric function and select *DIET_AGG_USER* as aggregator.

Information obtained from the *SeD*

Your plugin scheduler can access to the information obtained from CoRI by initializing the estimation vector using the *diet_estimate_cori* function on the *SeD*. For more information about CoRI, see Section 9.2. Then, on the agents scheduler side, these information are accessed using one of the previously presented macro. You also can obtain the user-defined information by using the *USERDEFINED(SeD, nb)* macro. These information have been defined on the *SeD*s metric function using the *diet_est_set(estVector t ev, int nb, double value)*.

For more information on how to get performance prediction values, please consult Chapter 9.

8.5.7 A complete example of scheduler

This example source code is available on the src/examples/agent_scheduler directory. The scheduler performs a Round-Robin on the *SeD*s using their hostname to evaluate the number of executions. For example, if the agent is connected to three *SeD*s, with two launched on the same machine, the number of jobs executed on the machine with two *SeD*s will be at most one more than the number of executed jobs on the other machine.

Hostname based Round-Robin plugin scheduler.

```
#include "GlobalSchedulers.hh"
#include "UserScheduler.hh"
#include "est_internal.hh"
#include <map>

std::map<std::string, unsigned int> hostCounter;

class HostnameRR : public UserScheduler {
public:
  static const char* stName;

  HostnameRR();
  ~HostnameRR();
  void init();

  static char* serialize(HostnameRR* GS);
  static HostnameRR* deserialize(const char* serializedScheduler);
  /* Overriden aggregate method to schedule jobs with the SRA policy. */
  int aggregate(corba_response_t* aggrResp, size_t max_srv,
const size_t nb_responses, const corba_response_t* responses);
};

using namespace std;

const char* HostnameRR::stName="UserGS";

HostnameRR::~HostnameRR() {

}

HostnameRR::HostnameRR() {
  this->name = this->stName;
  this->nameLength = strlen(this->name);
}

int HostnameRR::aggregate(corba_response_t* aggrResp, size_t max_srv,
    const size_t nb_responses,
```

```
    const corba_response_t* responses)
{
  ServerList::iterator itSeD;
  unsigned int nbUsage=0;
  corba_server_estimation_t selected;


  cout << "******************* HostnameRR ******************" << endl;
  ServerList candidates = CORBA_to_STL(responses, nb_responses);

  for (itSeD=candidates.begin(); itSeD!=candidates.end(); ++itSeD)
    // We select the SeD by its host usage.
    if (hostCounter[HOSTNAME(*itSeD)]<=nbUsage)
  selected=*itSeD<;

  aggrResp->servers.length(1);
  aggrResp->servers[0]=selected;

  return 0;
}

SCHEDULER_CLASS(HostnameRR)
```

8.6 Future Work

We have two primary efforts planned for extensions to the plugin scheduler.

- **Additional information services**: We plan to add functionalities to enable the application developer to access and use data concerning the internal state of the DIET server (*e.g.,* the current length of request queues). As other performance measurement and evaluation tools are developed both within and external to the DIET project (see Chapter 9), some tools are already available to enable such information to be incorporated in the context of the plugin scheduler.

- **Enhanced aggregation methods**: The plugin scheduler implemented in the current release enables the DIET system to account for user-defined factors in the server selection process. However, the priority aggregation method is fairly rudimentary and lacks the power to express many imaginable comparison mechanisms. We plan to investigate methods to embed code into DIET agents (*e.g.,* a simple expression interpreter) in a manner that is secure and that preserves performance.

Chapter 9

Performance prediction

9.1 Introduction

As we have seen in Chapter 8 the agent needs some information from the *SeD* to make an optimal scheduling. This information is a performance prediction of the *SeD*. The agent will ask the *SeD* to fill the data structure defined in Chapter 8 with the information it needs. The *SeD* returns the information and the agent can make the scheduling.
Performance prediction can be based on hardware information, the load of the *SeD* (the CPU load, the memory availability, *etc.*) or an advanced performance prediction can combine a set of basic performance predictions. A performance prediction scheduler module named CoRI is available.
CoRI is described in Section 9.2.
By default DIET is compiled with CoRI enabled. In table 9.1 you can see which information is available with each compilation option.

	-DDIET_USE_CORI:			
	BOOL=OFF		BOOL=ON	
TCOMP		x		
FREECPU		x	x	x
FREEMEM		x	x	x
NBCPU		x	x	x
CPUSPEED			x	x
TOTALMEM			x	x
AVGFREECPU			x	x
BOGOMIPS			x	x
CACHECPU			x	x
TOTALSIZEDISK			x	x
FREESIZEDISK			x	x
DISKACCESREAD			x	x
DISKACCESWRITE			x	x
ALLINFOS			x	x
	-DDIET_USE_BATCH=ON			
PARAL_NB_FREE_RESOURCES_IN_DEFAULT_QUEUE			x	x

Table 9.1: Dependencies of the available information on the compiling options

Using convertors

The service profiles offered by DIET are sometimes not understandable by the service implementations. To solve this problem, a convertor processes each profile before it is passed to the implementation. This is mainly used to hide the implementation specific profile of a service from the user. It allows different servers to declare the same service with the same profile using different implementations of the service. If no convertor is passed when declaring a new service, a default convertor is assigned to it that does not change its profile nor its path.

To translate a profile, the convertor defines a new destination profile with a new path. It then chooses for each argument of the new profile a predefined function to assign this argument from the source profile. This allows the following operations:

Permutation of arguments. This is done implicitly by specifying which argument in the source profile corresponds to which argument in the destination profile.

Copy of arguments. Arguments can be simply used by applying the `DIET_CVT_IDENTITY` function. If the same source argument corresponds to two destination arguments it is automatically copied.

Creation of new arguments. New arguments can either contain static values or the properties of existing arguments. To create a new static value, the index for the source argument must be invalid (*e.g.,*-1) and the arg parameter must be set to the static argument. To extract a property of an existing argument, other functions than `DIET_CVT_IDENTITY` must be applied. The result of this function will then be used as the value for the destination argument. Corresponding to the DIET datatypes, the following functions exist:

- `DIET_CVT_IDENTITY` Copy the argument
- `DIET_CVT_VECT_SIZE` Get the size of a vector
- `DIET_CVT_MAT_NB_ROW` Get the number of rows of a matrix
- `DIET_CVT_MAT_NB_COL` Get the number of columns of a matrix
- `DIET_CVT_MAT_ORDER` Get the order of a matrix
- `DIET_CVT_STR_LEN` Get the length of the string
- `DIET_CVT_FILE_SIZE` Get the size of the file

Only the `DIET_CVT_IDENTITY` function can be applied to any argument; all other functions only operate on one type of argument.

9.1.1 Example with convertors

A short example is available below:

```
/**
 * Example 1
 * Assume we declared a profile (INOUT MATRIX) with the path 'solve_T'.
 * This profile will be called by the client. Our implementation expects
 * a profile (IN INT, IN INT, INOUT MATRIX). This profile is known to
```

```
 * FAST with the path 'T_solve'.
 * We will write a convertor that changes the name and extracts the
 * matrix's dimensions.
 */
    // declare a new convertor with 2 IN, 1 INOUT and 0 OUT arguments
    cvt = diet_convertor_alloc("T_solve", 0, 1, 1);

    // apply the function DIET_CVT_MAT_NB_ROW to determine the
    // 0th argument of the converted profile. The function's
    // argument is the 0th argument of the source profile. As it
    // is an IN argument, the last parameter is not important.
    diet_arg_cvt_set(&(cvt->arg_convs[0]), DIET_CVT_MAT_NB_ROW, 0, NULL, 0);

    // apply the function DIET_CVT_MAT_NB_COL to determine the
    // 1st argument of the converted profile. The function's
    // argument is the 0th argument of the source profile. As it
    // is a IN argument, the last parameter is not important.
    diet_arg_cvt_set(&(cvt->arg_convs[1]), DIET_CVT_MAT_NB_COL, 0, NULL, 0);

    // apply the function DIET_CVT_IDENTITY to determine the
    // 2nd argument of the converted profile. The function's
    // argument is the 0th argument of the source profile and
    // it will be written back to the 0th argument of the source
    // profile when the call has finished.
    diet_arg-cvt_set(&(cvt->arg_convs[2]), DIET_CVT_IDENTITY, 0, NULL, 0);

    // NOTE: The last line could also be written as:
    //diet_arg_cvt_short_set(&(cvt->arg_convs[2]), 0, NULL);

    // add the service using our convertor
    diet_service_table_add(profile, cvt, solve_T);

    // free our convertor
    diet_convertor_free(cvt);
```

More examples on how to create and use convertors are given in the files `examples/dmat_manips/server.c` and `examples/BLAS/server.c`.

9.2 CoRI: Collectors of Ressource Information

CoRI manages the access to different tools for collecting information about the *SeD*. Currently, various tools, called collectors, are implemented: CoRI Easy and CoRI batch. The user can choose which collector will provide the information.

9.2.1 Functions and tags

The tags for information are of type `integer` and defined in the table 8.1. The second type of tag `diet_est_collect_tag_t` is used to specify which collector will provide the information: `EST_COLL_EASY` or `EST_COLL_BATCH`. Three different functions are provided with CoRI.

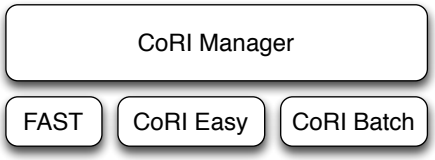


Figure 9.1: CoRI overview

The first function initializes a specific collector.

```
int
diet_estimate_cori_add_collector(diet_est_collect_tag_t collector_type,
                                 void * data);
```

The second parameter is reserved for initializing collectors which need additional information on initialization. For example, the BATCH collector needs for its initialization the profile of the service to be solved.

After the initialization, accessing to the information is done by specifying the collector and the information type.

```
int
diet_estimate_cori(estVector_t ev,
                   int info_type,
                   diet_est_collect_tag_t collector_type,
                   void* data);
```

Cori-Easy doesn't need more information, but BATCH need a profile of type "diet_profile_t". The last parameter is reserved for it.
The last function is used to test Cori-Easy. It prints all information Cori-Easy finds to the standard output.

```
void
diet_estimate_coriEasy_print();
```

A result could be the following output:

```
start printing CoRI values..
cpu average load : 0.56
CPU 0 cache : 1024 Kb
number of processors : 1
CPU 0 Bogomips : 5554.17
diskspeed in reading : 9.66665 Mbyte/s
diskspeed in writing : 3.38776 Mbyte/s
total disk size : 7875.51 Mb
available disk size  :373.727 Mb
total memory : 1011.86 Mb
available memory : 22.5195 Mb
end printing CoRI values
```

9.2.2 CoRI-Easy

The CoRI-Easy collector makes some basic system calls to gather the information. CoRI-Easy is available by default. The last column of the table 9.1 corresponds to the CoRI-Easy's functionality.

There is an example on how to use CoRI-Easy in the `<diet_src>/src/examples/cori/` directory.

9.2.3 CoRI batch

With the help of the CoRI batch collector, a *SeD* programmer can use some information obtained from the batch system. It is only available if DIET is compiled with the option `-DDIET_USE_BATCH` set to `ON`. Currently, only simple information can be accessed but functionalities will be improved along with the number of batch systems DIET is able to address.

There is an example on how to use CoRI batch in the `<diet_src>/src/examples/Batch/Cori_cycle_stealing/` directory.

9.3 Future Work

There are two primary efforts for the CoRI manager:

- **Improving CoRI-Easy**: Some evaluation functions are very basic and should be revised to increase their response time speed and the accuracy of the information. There is a need for other information (*i.e.,* information about the network). Every operating systems provide other basic functions to get the information. CoRI-Easy doesn't know all functions. Use the `diet_estimate_cori_print()` function to test what CoRI-Easy can find on your *SeD*. Send us a mail if not all functions are working properly.
- **Improving CoRI batch**: add new functionalities to access dynamic information as well as some kind of performance predictions for more batch systems.
- **New collectors**: Integrating other external tools like Ganglia [21] or Nagios [16] to the CoRI Manager can provide more useful and exact information.

Chapter 10

Deploying a DIET platform

Deployment is the process of launching a DIET platform including agents and servers. For DIET, this process includes writing configuration files for each element and launching the elements in the correct hierarchical order. There are three primary ways to deploy DIET.

Launching **by hand** is a reasonable way to deploy DIET for small-scale testing and verification. This chapter explains the necessary services, how to write DIET configuration files, and in what order DIET elements should be launched. See Section 10.1 for details.

GoDIET is a Java-based tool for automatic DIET deployment that manages configuration file creation, staging of files, launch of elements, monitoring and reporting on launch success, and process cleanup when the DIET deployment is no longer needed. See Section 10.2 for details.

Writing your own scripts is a surprisingly popular approach. This approach often looks easy initially, but can sometimes take much, much longer than you predict as there are many complexities to manage. Learn GoDIET– it will save you time!

10.1 Deployment basics

10.1.1 Using CORBA

CORBA is used for all communications in DIET and for communications between DIET and accessory services such as LogService, VizDIET, and GoDIET. This section gives basic information on how to use DIET with CORBA. Please refer to the documentation of your ORB if you need more details.

The naming service

DIET uses a standard CORBA naming service for translating an user-friendly string-based name for an object into an Interoperable Object Reference (IOR) that is a globally unique identifier incorporating the host and port where the object can be contacted. The naming service in omniORB is called `omniNames` and it must be launched before any

other DIET entities. DIET entities can then locate each other using only a string-based name and the <host:port> of the name server.

To launch the omniORB name server, first check that the path of the omniORB libraries is in your environment variable `LD_LIBRARY_PATH`, then specify the log directory, through the environment variable `OMNINAMES_LOGDIR` (or, with **omniORB 4**, at compile time, through the `--with-omniNames-logdir` option of the omniORB configure script). If there are no log files in this directory, `omniNames` needs to be intialized. It can be launched as follows:

```
~ > omniNames -start

Tue Jun 28 15:56:50 2005:

Starting omniNames for the first time.
Wrote initial log file.
Read log file successfully.
Root context is IOR:010000002b00000049444c3a6f6d672e6f72672f436f734e616d696e672f4e61
6d696e67436f6e746578744578743a312e3000000100000000000000060000000010102000d0000003134
302e37372e31332e34390000f90a0b0000004e616d655365727669636500020000000000000008000000
0100000000545441010000001c0000000100000001000100010000000100010509010100010000000901
0100
Checkpointing Phase 1: Prepare.
Checkpointing Phase 2: Commit.
Checkpointing completed.
```

This sets an omniORB name server which listens for client connections on the default port 2809. If omniNames has already been launched once, *ie* there are already some log files in the log directory, using the `-start` option causes an error. The port is actually read from old log files:

```
~ > omniNames -start

Tue Jun 28 15:57:39 2005:

Error: log file '/tmp/omninames-toto.log' exists.  Can't use -start option.

~ > omniNames

Tue Jun 28 15:58:08 2005:

Read log file successfully.
Root context is IOR:010000002b00000049444c3a6f6d672e6f72672f436f734e616d696e672f4e61
6d696e67436f6e746578744578743a312e3000000100000000000000060000000010102000d0000003134
302e37372e31332e34390000f90a0b0000004e616d655365727669636500020000000000000008000000
0100000000545441010000001c0000000100000001000100010000000100010509010100010000000901
Checkpointing Phase 1: Prepare.
Checkpointing Phase 2: Commit.
Checkpointing completed.
```

CORBA usage for DIET

Every DIET entity must connect to the CORBA name server: it is the way services discover each others. The reference to the omniORB name server is written in a CORBA configuration file, whose path is given to omniORB through the environment variable `OMNIORB_CONFIG` (or, with **omniORB 4**, at compile time, through the configure script option: `--with-omniORB-config`). An example of such a configuration file is given in the directory `src/examples/cfgs` of the DIET source tree and installed in <`install_dir`>`/etc`. The lines concerning the name server in the omniORB configuration file are built as follows:

omniORB 4:

```
InitRef = NameService=corbaname::<name server hostname>:<name server port>
```

The name server port is the port given as an argument to the `-start` option of `omniNames`. You also need to update your `LD_LIBRARY_PATH` to point to <`install_dir`>`/lib`. So your `LD_LIBRARY_PATH` environment variable should now be :
`LD_LIBRARY_PATH`=<`omniORB_home`>`/lib:`<`install_dir`>`/lib`.

NB1: In order to avoid name collision, every agent must be assigned a different name in the name server. *SeD*s do not necessarily need a name, it is optional.

NB2: Each DIET hierarchy can use a different name server, or multiple hierarchies can share one name server (assuming all agents are assigned unique names). In a multi-MA environment, in order for multiple hierarchies to be able to cooperate it is necessary that they all share the same name server.

10.1.2 DIET configuration file

A configuration file is needed to launch a DIET entity. Some fully commented examples of such configuration files are given in the directory `src/examples/cfgs` of the DIET source files and installed in <`install_dir`>`/etc` [1]. Please note that:

- comments start with '#' and finish at the end of the current line,
- meaningful lines have the format: `keyword = value`, following the format of configuration files for omniORB 4,
- for options that accept 0 or 1, 0 means no and 1 means yes, and
- keywords are case sensitive.

[1] if there isn't <`install_dir`>`/etc` directory, please configure DIET with `--enable-examples` and/or run `make install` command in `src/examples` directory.

Tracing API

`traceLevel` *default* `= 1`
This option controls debugging trace output. The following levels are defined:

level = 0	Do not print anything
level = 1	Print only errors
level < 5	Print errors and messages for the main steps (such as "Got a request") - default
level < 10	Print errors and messages for all steps
level = 10	Print errors, all steps, and some important structures (such as the list of offered services)
level > 10	Print all DIET messages AND omniORB messages corresponding to an omniORB traceLevel of (level - 10)

Client parameters

`MAName` *default* `=` *none*
This is a **mandatory** parameter that specifies the name of the Master Agent to connect to. The MA must have registered with this same name to the CORBA name server.

Agent parameters

`agentType` *default* `=` *none*
As DIET offers only one executable for both types of agent, it is **mandatory** to specify which kind of agent must be launched. Two values are available: `DIET_MASTER_AGENT` and `DIET_LOCAL_AGENT`. They have aliases, respectively `MA` and `LA`.

`name` *default* `=` *none*
This is a **mandatory** parameter that specifies the name with which the agent will register to the CORBA name server.

LA and *SeD* parameters

`parentName` *default* `=` *none*
This is a **mandatory** parameter for Local Agents and *SeD*s, but not for the MA. It indicates the name of the parent (an LA or the MA) to register to.

Endpoint Options

`dietPort` *default* `= none`
This option specifies the listening port of an agent or *SeD*. If not specified, the ORB gets a port from the system. This option is very useful when a machine is behind a firewall. By default this option is disabled.

`dietHostname` *default* `= none`
The IP address or hostname at which the entitity can be contacted from other machines. If not specified, let the ORB get the hostname from the system; by default, omniORB takes

the first registered network interface, which is not always accessible from the exterior. This option is very useful in a variety of complicated networking environments such as when multiple interfaces exist or when there is no DNS.

LogService options

`useLogService` *default* = `0`
This activates the connection to LogService. If this option is set to 1 then the LogCentral must be started before any DIET entities. Agents and *SeD*s will connect to LogCentral to deliver their monitoring information and they will refuse to start if they cannot establish this connection. See Section 11.1 to learn more about LogService.

`lsOutbuffersize` *default* = `0`
`lsFlushinterval` *default* = `10000`
DIET's LogService connection can buffer outgoing messages and send them asynchronously. This can decrease the network load when several messages are sent at one time. It can also be used to decouple the generation and the transfer of messages. The buffer is specified by it's size (`lsOutbuffersize`, number of messages) and the time it is regularly flushed (`lsFlushinterval`, nanoseconds). It is recommended not to change the default parameters if you do not encounter problems. The buffer options will be ignored if `useLogService` is set to 0.

Multi-MA options

To federate resources, each MA tries periodically to contact other MAs. These options define how the MA connects to the others.

`neighbours` *default* = `empty list {}`
List of known MAs separated by commas. The MA will try to connect itself to the MAs named in this list. Each MA is described by the name of its host followed by its bind service port number (see `bindServicePort`). For example `host1.domain.com:500`, `host4.domain.com:500`, `host.domainB.net:2001` is a valid three MAs list. By default, an empty list is set into `neighbours`.

`maximumNeighbours` *default* = `10`
This is the maximum number of other MAs that can be connected to the current MA. If another MA wants to connect and the current number of connected MAs is equal to `maximumNeighbours`, the request is rejected.

`minimumNeighbours` *default* = `2`
This is the minimum number of MAs that should be connected to the MA. If the current number of connected MA is lower than `minimumNeighbours`, the MA tries to connect to other MAs.

`updateLinkPeriod` *default* = `300`
The MA checks if the connected MAs are alive every `updateLinkPeriod` seconds.

`bindServicePort` *default* = `none`
The MAs need to use a specific port to be able to federate themselves. This port is only used for initializing connections between MAs. If this parameter is not set, the MA will not accept incoming connection.

You can find the full set of DIET configuration file options in the chapter A.

10.1.3 Example

As shown in Section 1.3, the hierarchy is built from top to bottom: children register to their parent.

Here is an example of a complete platform deployment.

Launching the MA

For such a platform, the MA configuration file could be:

```
# file MA_example.cfg, configuration file for an MA
agentType         =  DIET_MASTER_AGENT
name              =  MA_example
#traceLevel       =  1                 # default
#dietPort         =  <port>            # not needed
#dietHostname     =  <hostname|IP>     # not needed
#useLogService    =  0                 # default
#lsOutbuffersize  =  0                 # default
#lsFlushinterval  =  10000             # default
```

This configuration file is the only argument to the executable `dietAgent`, which is installed in `<install_dir>/bin`. Provided `<install_dir>/bin` is in your PATH environment variable, run

```
~ > dietAgent MA_example.cfg

Master Agent MA_example started.
```

Launching an LA

For such a platform, an LA configuration file could be:

```
# file LA_example.cfg, configuration file for an LA
agentType         =  DIET_LOCAL_AGENT
name              =  LA_example
parentName        =  MA_example
#traceLevel       =  1                 # default
#dietPort         =  <port>            # not needed
#dietHostname     =  <hostname|IP>     # not needed
#useLogService    =  0                 # default
#lsOutbuffersize  =  0                 # default
#lsFlushinterval  =  10000             # default
```

This configuration file is the only argument to the executable `dietAgent`, which is installed in <`install_dir`>`/bin`. This LA will register as a child of MA_example. Run

```
~ > dietAgent LA_example.cfg

Local Agent LA_example started.
```

Launching a server

For such a platform, a *SeD* configuration file could be:

```
# file SeD_example.cfg, configuration file for a SeD
parentName         =  LA_example
#traceLevel        =  1              # default
#dietPort          =  <port>         # not needed
#dietHostname      =  <hostname|IP>  # not needed
#useLogService     =  0              # default
#lsOutbuffersize   =  0              # default
#lsFlushinterval   =  10000          # default
```

The *SeD* will register as a child of LA_example. Run the executable that you linked with the DIET *SeD* library, and do not forget that the first argument of the method call `diet_SeD` must be the path of the configuration file above.

Launching a client

Our client must connect to the MA_example:

```
# file client.cfg, configuration file for a client
MAName        =  MA_example
#traceLevel   =  1           # default
```

Run the executable that you linked with the DIET client library, and do not forget that the first argument of the method call `diet_initialize` must be the path of the configuration file above.

10.2 GoDiet

GoDiet is a Java-based tool for automatic DIET deployment that manages configuration file creation, staging of files, launch of elements, monitoring and reporting on launch success, and process cleanup when the DIET deployment is no longer needed [5]. The user of GoDiet describes the desired deployment in an XML file including all needed external services (*e.g.,* omniNames and LogService); the desired hierarchical organization of agents and servers is expressed directly using the hierarchical organization of XML. The user also defines all machines available for the deployment, disk scratch space available at each site for storage of configuration files, and which machines share the same disk to avoid unecessary copies. GoDiet is extremely useful for large deployments (*e.g.,* more than 5 elements) and for experiments where one needs to deploy and shut-down multiple

deployments to test different configurations. Note that debugging deployment problems when using GoDiet can be difficult, especially if you don't fully understand the role of each element you are launching. If you have trouble identifying the problem, read the rest of this chapter in full and try launching key elements of your deployment by hand. GoDiet is available for download on the web[2].

An example input XML file is shown in Figure 10.1; see [5] for a full explanation of all entries in the XML. You can also have a look at the fully commented XML example file provided in the GoDiet distribution under examples/commented.xml, each option is explained. To launch GoDiet for the simple example XML file provided in the GoDiet distribution under examples/example1.xml, run:

```
~ > java -jar GoDIET-x.x.x.jar example1.xml
XmlScanner constructor
Parsing xml file: example1.xml
GoDIET>
```

GoDiet reads the XML file and then enters an interactive console mode. In this mode you have a number of options:

```
GoDIET> help
The following commands are available:
   launch:       launch entire DIET platform
   launch_check: launch entire DIET platform then check its status
   relaunch:     kill the current platform and launch entire DIET platform once again
   stop:         kill entire DIET platform using kill pid
   status:       print run status of each DIET component
   history:      print history of commands executed
   help:         print this message
   check:        check the platform status
   stop_check:   stop the platform status then check its status before exit
   exit:         exit GoDIET, do not change running platform.
```

We will now launch this example; note that this example is intentionally very simple with all components running locally to provide initial familiarity with the GoDiet run procedure. Deployment with GoDiet is especially useful when launching components on multiple remote machines.

```
GoDIET> launch
* Launching DIET platform at Wed Jul 13 09:57:03 CEST 2005

Local scratch directory ready:
        /home/hdail/tmp/scratch_godiet
```

[2] http://graal.ens-lyon.fr/DIET/godiet.html

```
** Launching element OmniNames on localHost
Writing config file omniORB4.cfg
Staging file omniORB4.cfg to localDisk
Executing element OmniNames on resource localHost
Waiting for 3 seconds after service launch

** Launching element MA_0 on localHost
Writing config file MA_0.cfg
Staging file MA_0.cfg to localDisk
Executing element MA_0 on resource localHost
Waiting for 2 seconds after launch without log service feedback

** Launching element LA_0 on localHost
Writing config file LA_0.cfg
Staging file LA_0.cfg to localDisk
Executing element LA_0 on resource localHost
Waiting for 2 seconds after launch without log service feedback

** Launching element SeD_0 on localHost
Writing config file SeD_0.cfg
Staging file SeD_0.cfg to localDisk
Executing element SeD_0 on resource localHost
Waiting for 2 seconds after launch without log service feedback
* DIET launch done at Wed Jul 13 09:57:14 CEST 2005 [time= 11.0 sec]
```

The `status` command will print out the run-time status of all launched components. The `LaunchState` reports whether GoDiet observed any errors during the launch itself. When the user requests the launch of LogService in the input XML file, GoDiet can connect to the LogService after launching it to obtain the state of launched components; when available, this state is reported in the `LogState` column.

```
GoDIET> status
Status   Element   LaunchState   LogState   Resource     PID
         OmniNames running       none       localHost    1232
         MA_0      running       none       localHost    1262
         LA_0      running       none       localHost    1296
         SeD_0     running       none       localHost    1329
```

Finally, when you are done with your Diet deployment you should always run `stop`. To clean-up each element, GoDiet runs a `kill` operation on the appropriate host using the stored PID of that element.

```
GoDIET> stop

* Stopping DIET platform at Wed Jul 13 10:05:42 CEST 2005
```

```
Trying to stop element SeD_0
Trying to stop element LA_0
Trying to stop element MA_0
Trying to stop element OmniNames

* DIET platform stopped at Wed Jul 13 10:05:43 CEST 2005[time= 0.0 sec]
* Exiting GoDIET. Bye.
```

One of the main problem when writing a GoDiet XML input file is to be compliant with the dtd. A good tool to validate a GoDiet file before using GoDiet is **xmllint**. This tool exist on most platforms and with the following command:

```
$ xmllint your_xml_file --dtdvalid path_to_GoDIET.dtd -noout
```

you will see the different lines where there is problem and a clear description of why your XML file is not compliant.

```
<?xml version="1.0" standalone="no"?>
<!DOCTYPE diet_configuration SYSTEM "../GoDIET.dtd">
<diet_configuration>
  <goDiet debug="2" saveStdOut="yes" saveStdErr="yes" useUniqueDirs="no" log="no"/>
  <resources>
    <scratch dir="/tmp/GoDIET_scratch"/>
    <storage label="disk-1">
        <scratch dir="/tmp/run_scratch"/>
        <scp server="res1" login="doe"/>
    </storage>
    <storage label="disk-2">
        <scratch dir="/tmp/run_scratch"/>
        <scp server="res2" login="foo"/>
    </storage>
    <storage label="disk-3">
        <scratch dir="/tmp/run_scratch"/>
        <scp server="res3" login="bar"/>
    </storage>
    <compute label="res1" disk="disk-1">
        <ssh server="res1" login="doe"/>
        <env>
              <var name="PATH" value=""/>
              <var name="LD_LIBRARY_PATH" value=""/>
        </env>
    </compute>
    <compute label="res2" disk="disk-2">
        <ssh server="res2" login="foo"/>
              <env>
                      <var name="PATH" value=""/>
                      <var name="LD_LIBRARY_PATH" value=""/>
              </env>
    </compute>
        <cluster label="res3" disk="disk-3" login="bar">
      <env>
        <var name="PATH" value=""/>
        <var name="LD_LIBRARY_PATH" value=""/>
      </env>
      <node label="res3_host1">
        <ssh server="host1.res3.fr"/>
        <end_point contact="192.5.80.103"/>
      </node>
      <node label="res3_host2">
        <ssh server="host2.res3.fr"/>
      </node>
    </cluster>
  </resources>
  <diet_services>
          <omni_names contact="res1_IP" port="2121">
        <config server="res1" remote_binary="omniNames"/>
    </omni_names>
  </diet_services>
  <diet_hierarchy>
    <master_agent label="MA">
        <config server="res1" remote_binary="dietAgent"/>
           <cfg_options>
             <option name="traceLevel" value="1"/>
           </cfg_options>
            <SeD label="SeD1">
                <config server="res2" remote_binary="server_dyn_add_rem"/>
           <cfg_options>
             <option name="traceLevel" value="1"/>
           </cfg_options>
            </SeD>
        <SeD label="SeD2">
            <config server="res3_host1" remote_binary="server_dyn_add_rem"/>
           <cfg_options>
             <option name="traceLevel" value="30"/>
           </cfg_options>
           <parameters string="T"/>
        </SeD>
        <SeD label="SeD3">
            <config server="res3_host2" remote_binary="server_dyn_add_rem"/>
           <cfg_options>
             <option name="traceLevel" value="1"/>
           </cfg_options>
        </SeD>
    </master_agent>
  </diet_hierarchy>
</diet_configuration>
```

.

Figure 10.1: Example XML input file for GoDiet.

10.3 Shape of the hierarchy

A recurrent question people ask when first using DIET, is *how should my hierarchy look like?* There is unfortunately no universal answer to this. The shape highly depends on the performances you want DIET to attain. The performance metric that we often use to characterize the performance of DIET is the *throughput* the clients get, *i.e.,* the number of serviced requests per time unit.

Several heuristics have been proposed to determine the shape of the hierarchy based on the users' requirements. We can distinguish two main studies. The first one focused on deploying a single service in a DIET hierarchy [3, 4]. The shape of the best hierarchy on a fully homogeneous platform is a *Complete Spanning d-ary tree* (CSD tree). The second study focused on deploying several services alongside in a single hierarchy. Heuristics based on linear programming and genetic algorithm have been proposed for different kinds of platform [6, 7].

Even though the above mentioned studies can provide good, if not the best, deployments, they heavily rely on modelizations and benchmarks of DIET and the services. This process can be quite long. Thus, we propose in this section a simple but somehow efficient way of deploying a hopefully "good" hierarchy. (Note that if you do not care about performances, a simple star graph should be enough, *i.e.,* an MA and all your *SeD*s directly connected to it.) Here are a few general remarks on DIET hierarchies:

- The more computations your service needs, the more powerful server you should choose to put a *SeD* on.
- Scheduling performances of agents depends on the number of children they have, as well as on the number of services each of the child knows. An agent will be more efficient when all its children know one and the same service. Thus it is a good idea to group all *SeD*s having the same characteristics under a common agent.
- The services declared by an agent to its parent is the union of all services present in its underlying hierarchy.
- It is usually a good idea to group all DIET elements having the same services and present on a given cluster under a common agent.
- There is usually no need for too many levels of agents.
- If you suspect that an agent does not schedule the requests fast enough, and that it is overloaded, then add two (or more) agents under this agent, and divide the previous children between these new agents.

Chapter 11

DIET dashboard

This section discussed monitoring tools that can be used with DIET. We are currently working on a tool called DIET Dashboard that will integrate a variety of external tools to provide a single management and monitoring environment for DIET. Currently, however, each of these tools is available separately. See Section 11.1 for a description of LogService, Section 11.2 for a description of VizDIET, and Section 10.2 for a description of GoDIET.

11.1 LogService

The DIET platform can be monitored using a system called LogService. This monitoring service offers the capability to be aware of information that you want to relay from the platform. As shown in Figure 11.1, LogService is composed of three modules: *LogComponent*, *LogCentral* and *LogTool*.

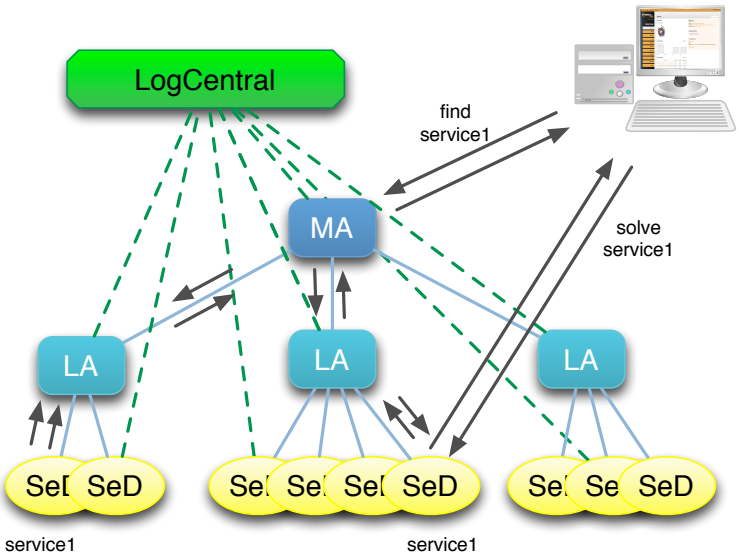


Figure 11.1: DIET and LogService.

- A *LogComponent* is attached to a component and relays information and messages to LogCentral. LogComponents are typically used within components one wants to monitor.

- *LogCentral* collects messages received from *LogComponents*, then *LogCentral* stores or sends these messages to *LogTools*.

- *LogTools* connect themselves to *LogCentral* and wait for messages. LogTools are typically used within monitoring tools.

The main interest in LogService is that information is collected by a central point *LogCentral* that receives *logEvents* from *LogComponents* that are attached to DIET elements (MA, LA and SeD). *LogCentral* offers the possibility to re-send this information to several tools (*LogTools*) that are responsible for analysing these message and offering comprehensive information to the user.

LogService defines and implements several functionalities:

Filtering mechanisms As few messages as possible should be sent to minimize network traffic. With respect to the three-tier model, the communications between applications (*e.g.,* LogComponent) and the collector (*e.g.,* LogCentral), as well as between the collector and the monitoring tools (*e.g.,* LogTools), should be minimized. When a LogTool registers with the LogCentral, it also registers a filter defining which messages are required by the tool.

Message ordering Event ordering is another important feature of a monitoring system. LogService handles this problem by the introduction of a global time line. At generation each message receives a time-stamp. The problem that can occur is that the system time can be different on each host. LogService measures this difference internally and corrects the time-stamps of incoming messages accordingly. The time difference is correcting by using a time difference measurement recorded during the last ping that LogCentral has sent to the LogComponent (pings are sent periodically to verify the "aliveness" of the LogComponent).

However, incoming messages are still unsorted. Thus, the messages are buffered for a short period of time in order to deliver a sorted stream of messages to the tools. Messages that arrive out of order within this time are sorted in the buffer and can thus be properly delivered. Although this induces a delivery-delay for messages, this mechanism guarantees the proper ordering of messages within a certain tolerance. As tools should not rely on true real-time delivery of messages, this short delay is acceptable.

The System State Problem A problem that arises in distributed environments is the state of the application. This state may for example contain information on connected servers, their relationships, the active tasks and many other pieces of information that depend on the application. The system state can be constructed from

all events that occurred in the application. Some tools rely on this state to work properly.

The problem emerges if those specific tools do not receive all messages. This might occur as tools can connect to the monitor after the application has been started. In fact, this is quite probable as the lifetime of the distributed application can be much longer than the lifetime of a tool.

As a consequence, the system state must be maintained and stored. In order to maintain a system state in a general way, LogService does not store the system state itself, but all messages which are required to construct it. Those messages are identified by their tag and stored in a special list. This list is forwarded to each tool that connects. For the tool this process is transparent, since it simply receives a number of messages that represent the state of the application.

In order to further refine this concept, the list of important messages can also be cleaned up by LogService. This is necessary as components may connect and disconnect at runtime. After a disconnection of a component the respective information is no longer relevant for the system state. Therefore, all messages which originated at this component can be removed from the list. They have become obsolete due to the disconnection of the component and can be safely deleted in order to reduce the length of the list of important messages to a minimum.

All DIET components implement the *LogComponent* interface. By using LogCentral, the DIET architecture is able to relay information to LogCentral, and then it is possible to connect to LogCentral by using a *LogTool* to collect, store and analyse this information. LogService is available for download. See the web page `http://graal.ens-lyon.fr/DIET/logservice.html` for more information.

11.2 VizDIET

VizDIET is the monitoring tool written for DIET to be able to vizualize and analyze the status and activities of a running DIET deployment. As described in Section 11.1, all DIET's components integrate a *LogComponent*, and VizDIET implements the *LogTool* interface in order to be able to collect all information sent by DIET's components through their *LogComponent*.

VizDIET provides a graphic representation of the DIET architecture being monitored. There are two ways to use VizDIET.

Real-time monitoring: VizDIET is directly connected to the LogCentral using a Corba connection and receives directly all information about the running DIET platform.

Post-mortem monitoring: VizDIET reads a log file containing all log messages received by *LogCentral*. This post-mortem analysis can also be replayed in real time if the log file is time sorted. The log file is created during the real deployment by a special tool provided with LogService that receives all messages from LogCentral and writes them to a file.

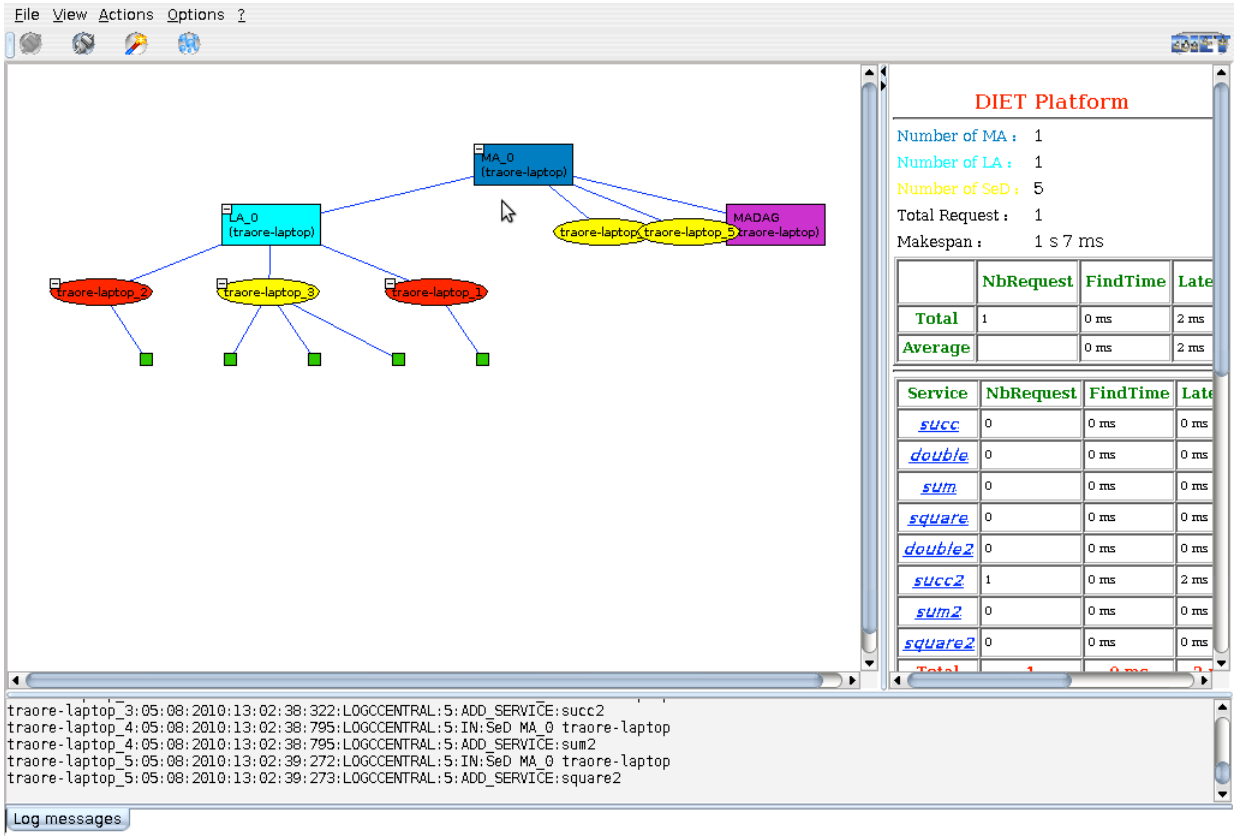


Figure 11.2: Snapshot of VizDIET.

As described in Section 1.4, there are two main steps in the treatment of a request in DIET: one step to find and schedule a service, and one step to solve this service. So two main activities are represented: schedule and compute information

Schedule information :
When an agent takes a scheduling decision for a task (*i.e.*, finding and deciding which SeD can execute a service), it is useful to know how the agent made its decision. This information is represented by *FindRequest* in VizDIET.

Compute information :
When a SeD is computing a job we need to be aware of its state and know when the computation begins and ends. This information is represented by *SolveRequest*. In VizDIET, when a SeD is solving a service, the SeD changes color to red.

FindRequests are only attached to agents and *SolveRequests* are only attached to SeDs. Finally the aggregation of one *FindRequest* and its *SolveRequest* is concatenated in one request: *DIETRequest*. *DIETResquest* can be see as a job execution in a DIET

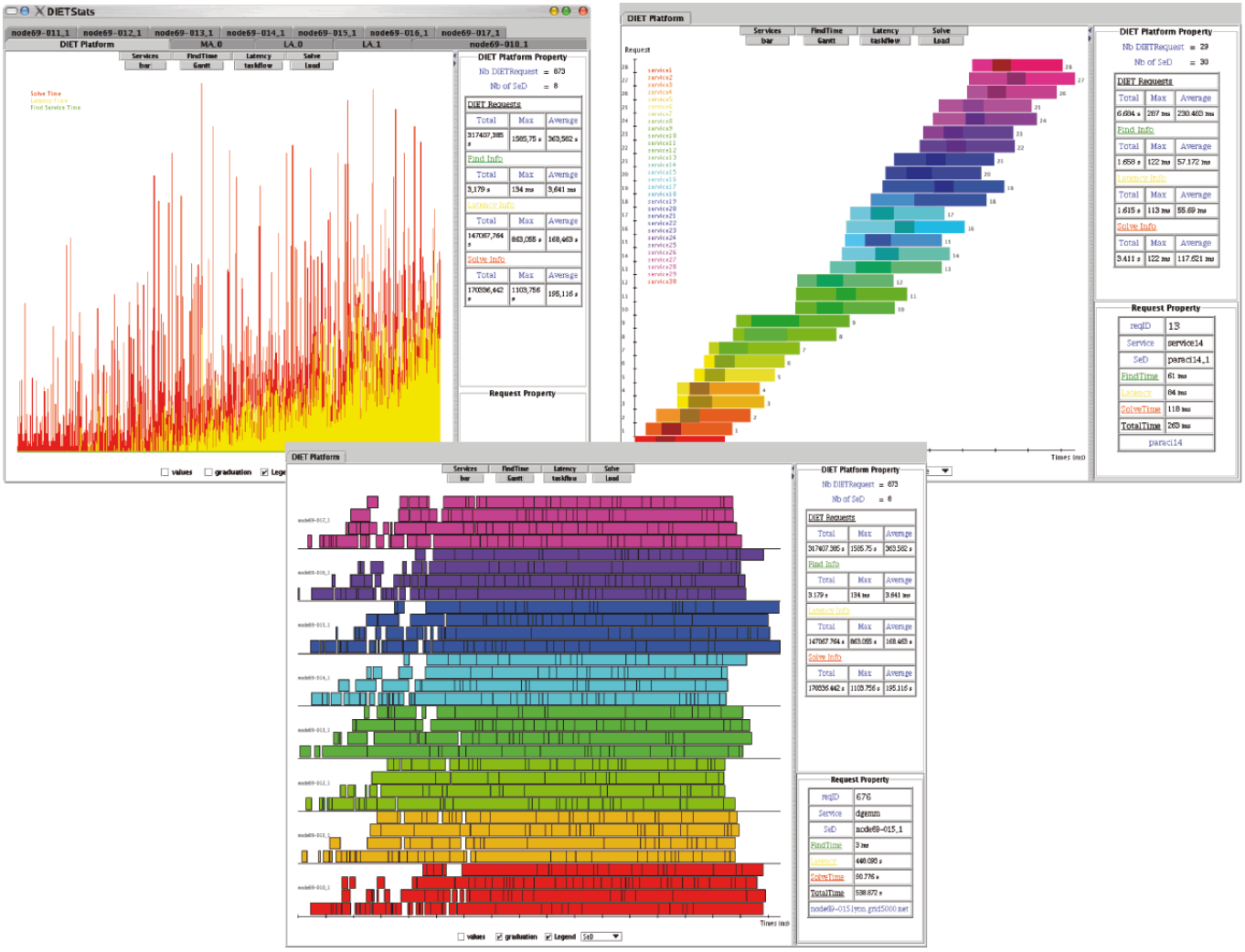


Figure 11.3: Bar, taskflow and gantt graphs in vizDIET.

platform as seen by an end-user. A *DIETRequest* is also associated with a **latency**, which is time between the end of a *FindRequest* and the beginning of a *SolveRequest*.

VizDIET offers the possiblity to visualize all of these requests from either the point of view of the DIET platform, in which case you will see the *DIETRequests*, or in the point of view of the Agents or SeDs, in which case you will see respectively the *FindRequest* and the *SolveRequest*. The different kinds of requests are represented in different types of graphics such as a Gantt chart, taskflow chart, or bar chart.

VizDIET also computes some other statistics for the platform such as average time for scheduling, for solving, or latency. This information can be see for the whole service in the platform or for one specific service. VizDIET has one other interesting feature: the possibility to export all data collected by VizDIET into a file using a format that you specify.

Finally, VizDIET is quite useful for understanding the behavior of the DIET hierarchy

and quite simple to use. You have to keep in mind that VizDIET bases its information upon log information that is forwarded by LogCentral from DIET components. Therefore, the information displayed and computed in VizDIET is limited to the DIET hierarchy (*e.g.,* there is no information about clients).

Future development of VizDIET will depend on new developments in DIET. For example, a new integration between DIET and JuxMem allows DIET to store data in the JuxMem service. Correspondingly, the capability to log and visualize these transfers has been added to VizDIET. VizDIET is available for download. See the web page http://graal.ens-lyon.fr/DIET/vizdiet.html for more information.

Chapter 12

Multi-MA extension

The hierarchical organization of DIET is efficient when the set of resources is shared by few individuals. However, the aim of grid computing is to share resources between several individuals. In that case, the DIET hierarchy become inefficient. The Multi-MA extension has been implemented to resolve this issue. This chapter explains the different scalability issues of grid computing and how to use the multi-MA extension to deal with them.

12.1 Function of the Multi-MA extension

The use of a monolithic architecture become more and more difficult when the number of users and the number of resources grow simultaneously. When a user tries to resolve a problem, without the multi-MA extension, DIET looks for the better *SeD* that can solve it. This search involves the fact that each *SeD* has to be queried to run a performance prediction as described in Section 1.4.

The need to query every *SeD* that can resolve a problem is a serious scalability issue. To avoid it, the multi-MA extension proposes to interconnect several MA together. So, instead of having the whole set of *SeD* available under a hierarchy of a unique MA, there are several MA and each MA manages a subset of *SeD*s. Those MA are interconnected in a way that they can share the access to their *SeD*s.

Each MA works like the usual: when they received a query from a user, they looks for the best *SeD* which can resolve their problem inside their hierarchy. If there is no *SeD* available in its hierarchy, the queried MA forwards the query to another MA to find a *SeD* that can be used by its client. This way, DIET is able to support more clients and more servers because each client request is forwarded to a number of *SeD*s that is independent of the total number of available *SeD*s.

12.2 Deployment example

The instructions about how to compile DIET with the multi-MA extension are available in Section 2.2.5 and the configuration instructions are available in Section 10.1.2.

The example described here is about four organizations which want to share there resources. The first organization, named alpha, have ten *SeD*s which give access to the service **a**. The second organization, named beta, have eight *SeD*s with the service **a** and three with the service **b**. The third one, named gamma, have two *SeD*s with the service **c**. The last one, named delta, have one *SeD* with the service **a**, but the server crash and the *SeD* is unavailable.

Each organization has it's own DIET hierarchy. All MAs (one for each organization) are connected with the multi-MA extension as shown in Figure 12.2

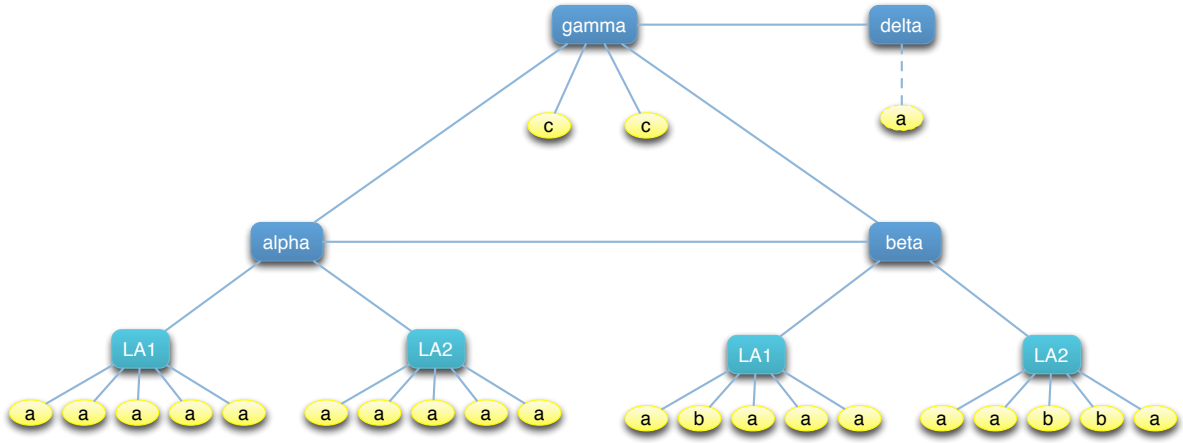


Figure 12.1: Example of a multi-MA deployment

The following lines appear in the MA configuration file of alpha. They tell that the multi-MA extension should listen for incoming connection at port 2001. They also tell that the MA should create a link toward the MA of the organization gamma and toward the MA of the organization beta. (The description of each configuration parameter are available in Section 10.1.2.)

```
agentType = DIET_MASTER_AGENT
dietHostname = diet.alpha.com
bindServicePort = 2001
neighbours = diet.beta.com:2001,ma.gamma.com:6000
```

The following lines appear in the MA configuration file of beta:

```
agentType = DIET_MASTER_AGENT
dietHostname = diet.beta.com
bindServicePort = 2001
neighbours = diet.alpha.com:2001,ma.gamma.com:6000
```

The following lines appear in the MA configuration file of gamma. The `neighbours` value is empty. This means that the gamma's MA will not try to connect itself to other

MA. However, the three others are configured to be connected to gamma. So, after all, the gamma MA is connected to the other three.

```
agentType = DIET_MASTER_AGENT
dietHostname = ma.gamma.com
bindServicePort = 6000
neighbours =
```

Finally the following lines appear in the MA configuration file of delta:

```
agentType = DIET_MASTER_AGENT
dietHostname = ma.delta.com
bindServicePort = 2001
neighbours = ma.gamma.com:6000
```

12.3 Search examples

The following section explains how a `diet_call` is managed when used on the previous architecture.

If a client sends a `diet_call` for the problem **a** to the alpha's MA, the alpha's MA will return a reference of one of it's *SeD*. However, if its scheduler (see Section 8) says that no *SeD* is available, it will forward the request to beta and gamma. If beta has an available *SeD*, it will be used to resolve the problem. If not, the request is forwarded to delta.

Now, if a client performs a `diet_call` for the problem **c** to the delta's MA, the delta MA does not have a *SeD* that can resolve this problem. So, it forwards the request to gamma. If gamma has no available *SeD*, the request is forwarded to alpha and beta.

Chapter 13

Workflow management in DIET

13.1 Overview

Workflow applications consists of multiple components (tasks) related by precedence constraints that usually follow from the data flow between them. Data files generated by one task are needed to start another task. Although this is the most common situation, the precedence constraints may follow from other reasons as well, and may be arbitrarily defined by the user.

This kind of application can be modeled as a DAG (Directed Acyclic Graph) where each vertex is a task with given input data and service name, and each edge can either be a data link between two tasks or a basic precedence constraint. The DIET workflow engine can handle that kind of workflow by assigning each task to a SeD in the DIET hierarchy using a DIET service call. This assignment is made dynamically when the task is ready to be executed (*i.e.,* all predecessors are done) depending on the service performance properties and on available ressources on the grid.

A specific agent called the **Master Agent DAG (**MA_{DAG}**)** provides DAG workflow scheduling. This agent serves as the entry point to the DIET Hierarchy for a client that wants to submit a workflow. The language supported by the MA_{DAG} is based on XML and described in the section 13.4.1.

Because of large amounts of computations and data involved in some workflow applications, the number of tasks in a DAG can grow very fast. The need for a more abstract way of representing a workflow that separates the data instances from the data flow has led to the definition of a "functional workflow language" called the *Gwendia language*. A complex application can be defined using this language that provides data operators and control structures (if/then/else, loops, *etc.*). To execute the application, we need to provide both the workflow description (see 13.4.2) and a file describing the input data set. The DIET workflow engine will instanciate the workflow as one or several tasks' DAGs, sent to the MA_{DAG} agent to be executed in the DIET platform.

13.2 Quick start

Requirements and compilation The workflow supports in DIET needs the following:

- The Xerces library: the XML handling code is written with Xerces-C++ using the provided DOM API.
- The XQilla library: the conditions in conditional or looping workflow structures are written in XQuery language and parsed using the XQilla library.
- Enable the workflow support when compiling DIET. In order to build DIET with workflow support using *cmake*, three configuration parameters need to be set:
  - `DIET_USE_WORKFLOW` as follow: `-DDIET_USE_WORKFLOW:BOOL=ON`
  - `XERCES_DIR`: defines the path to Xerces installation directory. (*e.g.,* `-DXERCES_DIR:PATH=/usr`
  - `XQILLA_DIR`: defines the path to XQilla installation directory. (*e.g.,* `-DXQILLA_DIR:PATH=/usr`

  N.B. 1: By activating the workflow module, the DAGDA module is also activated.

  This is an example of generating command line:

```
cmake .. -DMAINTAINER_MODE:BOOL=ON -DOMNIORB4_DIR=/usr/local/omniORB \
      -DDIET_USE_WORKFLOW:BOOL=ON \
      -DXERCES_DIR=/usr/local/xerces
      -DXQILLA_DIR=/usr/local/xqilla
```

  Workflow support was tested in the following configurations:

  - gcc version 4.0.2 and higher
  - *omniORB* version 4.1.0 and higher
  - *Xerces* 3.0.1
  - *XQilla* 2.2.0

N.B. 2: Workflow support is not available on Windows/Cygwin platforms (Windows XP and Cygwin <= 1.5.25) for *Xerces* 3.0.1 and *XQilla* 2.2.0.

Executing the examples The directory `examples/workflow` includes some examples of workflows. You can find a simple DAG workflow (see Figure 13.1) in the file `xml/scalar.xml` and you can test it with the following command, where `local_client.cfg` is the DIET configuration file (example provided in the `etc/client_wf.cfg` file).

```
./generic_client local_client.cfg -dag scalar.xml
```

You need to have a running DIET platform with the MA_{DAG} agent and the needed services. You can launch a single *SeD* (`scalar_server`) that includes all the needed services. (read Chapter 5 for more details).

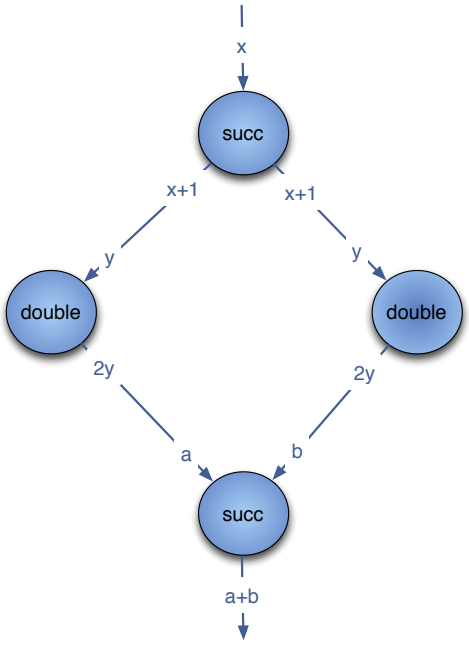


Figure 13.1: DAG example

You can also find some examples of functional workflows written in the Gwendia language (see file `xml/func_string.xml`) and you can test it with the following command:

```
./generic_client local_client.cfg -wf func_string.xml data.xml
```

You need to have a running DIET platform with the needed services (the commands to launch the services are included as comments within the workflow XML).

13.3 Software architecture

A new agent called the MA_{DAG} is used to manage workflows in the DIET architecture. This agent receives requests from clients containing the description of a workflow in a specific language (the MA_{DAG} XML workflow language for DAGs). The role of the MA_{DAG} is to determine how to schedule the tasks contained in the workflow in order to follow the precedence constraints between tasks, and how to map the tasks to appropriate ressources in the DIET hierarchy.

The execution of the individual tasks is actually delegated by the MA_{DAG} to the client that submitted the workflow. After submitting the workflow, the client is put in a waiting mode and it will receive individual requests from the MA_{DAG} to execute each task of the workflow. Therefore all the data transfers are done only from the client to the *SeD*s and do not transit through the MA_{DAG}.

When all tasks are completed, the MA_{DAG} will send a release signal to the client which will then retrieve the results if the execution was successful.

To use the MA_{DAG}, the client configuration file must include the parameter `MADAGNAME` with the appropriate name.

When the client uses a functional workflow (in Gwendia language) the DIET client library provides the logic for instanciating the workflow, generating the DAGs and sending them to the MA_{DAG} agent. Note that when several DAGs are generated they are usually not independent as some data generated by one DAG may be used by another one.

13.4 Workflow description languages

13.4.1 MA_{DAG} language

A DAG is described with an XML representation which is close to DIET profile representation. In addition to profile description (problem path and arguments), this description represents also the data dependencies between ports (source/sink), the node identifier (unique) and the precedences between nodes. This last information can be removed since it can be retrieved from the dependencies between ports, however it can be useful to define a temporal dependency without port linking.

The general structure of this description is:

```
<dag>
  <node id="..." path="...">
    <arg name="..." type="........" value=".."/>
    <in name="..." type="........" source="......."/>
    <out name="...." type="........" sink="......"/>
    <out name="...." type="........" sink="......"/>
  </node>
  ....
```

The name argument represents the identifier of the port. To use it to define a *source* or a *sink* value, it must be prefixed with the node id. For example if the source of the input port *in3* is the port *out2* of the node *n1*, than the element must be described as follow:

```
    <in name="in3" type="DIET_INT" source="n1#out2"/>
```

The link between input and output ports must be described either by a *source* value in the <*in*> element, or by a *sink* value in the <*out*> element. Specifying both does not cause an error but duplicates the information.

The example shown in Figure 13.1 can be represented by this XML description:

```
<dag>
  <node id="n1" path="succ">
    <arg name="in1" type="DIET_INT" value="56"/>
    <out name="out1" type="DIET_INT"/>
    <out name="out2" type="DIET_INT"/>
  </node>
```

```
  <node id="n2" path="double">
    <in name="in2" type="DIET_INT" source="n1#out1"/>
    <out name="out3" type="DIET_INT"/>
  </node>
  <node id="n3" path="double">
    <in name="in3" type="DIET_INT" source="n1#out2"/>
    <out name="out4" type="DIET_INT"/>
  </node>
  <node id="n4" path="sum">
    <in name="in4" type="DIET_INT" source="n2#out3"/>
    <in name="in5" type="DIET_INT" source="n3#out4"/>
    <out name="out4" type="DIET_INT"/>
  </node>
</dag>
```

13.4.2 Gwendia language

The Gwendia language is written in XML and validated by the workflow parser if the path to the DTD is provided (using a !DOCTYPE XML entity in the workflow XML file). The Gwendia DTD is included in the DIET distribution in the `/usr/share/diet/FWorkflow.dtd` file.

Types Values flowing through the workflow are typed. Basic types are `integer`, `short`, `double`, `longint`, `float`, `string` and `file`. Homogeneous arrays of values can be also used as inputs/outputs and can have any *depth*: an array can contain arrays of values (depth = 2). Arrays are ordered and can eventually contain *NULL* elements.

Processors A `processor` is a data production unit. A regular processor invokes a service through a known interface. Defined processor types are `webservice`, `diet` and `beanshell`. Special processors are workflow `source` (a processor with no inbound connectivity, delivering a list of externally defined data values), `sink` (a processor with no outbound connectivity, receiving some workflow output) and `constant` (a processor delivering a single, constant value). To improve readability, the `source`, `sink` and `constant` processors are grouped in an `<interface>` tag within the document. Other example of processors are grouped in a `<processors>` tag. Web services define a `<wsdl>` tag pointing to their WSDL description and the operation to invoke. Beanshells define a `<script>` tag containing the java code to interpret. DIET services define a `<diet>` tag describing the path to service to invoke. (When executing the workflow using the DIET workflow engine, only processors containing a `<diet>` tag can be used). The `<diet>` tag contains the `path` attribute that matches exactly the DIET service name, and optionnally contains the 'estimation' attribute (with value keyword 'constant') whenever the computation time estimation for this service does not depend on input data (using this option may reduce considerably the load on the DIET platform because the request for

performance estimation is done only once by the MaDag instead of being done for each task).

Processor ports Processor input and output ports are named and declared. A port may be an input (`<in>` tag) or an output (`<out>` tag). For each input/output, the following attributes can be defined:

- `type` (mandatory): contains the base type of data *i.e.,* a basic type identifier that describes the type of the data received/generated by the port. When data is scalar this is the actual data type, when data is an array this is the type of the data leaves of the array.
- `depth` (optional, default is 0): contains the depth of the array if applicable
- `cardinality` (optional, only for out ports with depth > 0): contains the number of elements of the generated array. This value can be provided only if it is a constant *i.e.,* the number of elements does not vary for each instance of data. When the data depth is greater than 1, the format for the cardinality attribute is a column-separated list of integers (for example, "2:3" for an array containing 2 arrays of 3 elements).

Iteration strategies Iteration strategies must be defined when the processor has two or more input ports. By default the workflow parser will use a *dot* iteration strategy for all inputs. These operators use the `index` of data items received or produced by workflow processors to combine them. The index of a data item corresponds, for data items produced by a `source` to the order number in the source data file, and for data items produced by a standard processor to the index of input data items eventually combined by the operators. There are 4 data manipulation operators:

- `dot` (groups 2 or more ports): data from the different ports are processed together when their index match exactly (data with index 0 of one port is matched with data with index 0 of the other ports). The output index is the same as the index of the input data.
- `cross` (groups 2 ports): processes each data instance of the first port with each data instance of the second port. This processor will increase by one the index depth of the output (for example: if data inputs have indexes 0 and 1 then the outputs have the index 0_1).
- `flatcross` (groups 2 ports): same as cross but with a different output indexation scheme. This operator does not increase the depth of the output index but creates new indexes (*e.g.,* if data inputs have indexes 1 and 2 with a maximum index of 3 for the right input, then the output has the index $6 = 4 * 1 + 2$). Note that this operator creates a synchronization constraint among all instances as the maximum index of the right input must be known by the workflow engine before being able to create new indexes.

- `match` (groups 2 ports): processes each data instance of the first port with all the data instances of the second port that have an index prefix that matches the first port's index (for example: if left data has index 1_1, it will be processed with all right data which have an index beginning with 1_1). The output index is the second port's index.

Add figures explaining the different iteration strategies

Here is an example of a Gwendia workflow (to be continued with the links part below):

```
<workflow>
  <interface>
    <constant name="parameter" type="integer" value="50"/>
    <source name="key" type="double" />
    <sink name="results" type="file" />
  </interface>

  </processors>
    <processor name="genParam">
      <in name="paramKey" type="double"/>
      <out name="paramFiles" type="file" depth="1"/>
      <diet path="gen" estimation="constant"/>
    </processor>

    <processor name="docking">
      <in name="param" type="integer" />
      <in name="input" type="file" />
      <out name="result" type="double" />
      <iterationstrategy>
        <cross>
          <port name="param" />
          <port name="input" />
        </cross>
      </iterationstrategy>
      <diet path="dock" estimation="constant"/>
    </processor>

    <processor name="statisticaltest">
      <in name="values" type="double" depth="1"/>
      <out name="result" type="file"/>
      <iterationstrategy>
        <cross>
          <port name="coefficient" />
          <match>
            <port name="values" />
            <port name="weights" />
```

```
          </match>
        </cross>
      </iterationstrategy>
      <diet path="weightedaverage" />
    </processor>
</processors>
<links>
  <!-- LINKS (see below) -->
</links>
</workflow>
```

Data links A data link is a connection between a processor output port and a processor input port as exampled below:

```
<links>
    <link from="key" to="genParam:paramKey"/>
    <link from="genParam:paramFiles" to="docking:input"/>
    <link from="parameter" to="docking:param"/>
    <link from="docking:result" to="statisticaltest:values" />
    <link from="statisticaltest:result" to="results" />
</links>
```

When a processor A (port A.out) is connected to a processor B (port B.in) through a data link, an instance of A (one task) may trigger a number of B instances that depends on first, the data depth at both ends of the link and second, the iteration strategy chosen for the B.in port within the B processor.

The data depths on both ends of the link determine the number of data items received by the B.in port. Three cases are possible:

- `1 to 1` : when depth(A.out) = depth(B.in), a data item produced by A.out is sent as-is to B.in

- `1 to N` : when depth(A.out) < depth(B.in), a data item produced by A.out is an array that will be split into its elements when sent to B. This will produce several parallel instances (tasks) of the B processor. This is equivalent to a *foreach* structure in usual programming languages, but is here transparent for the user as this is the workflow engines that manages it.

- `N to 1` : when depth(A.out) > depth(B.in), several data items produced by A.out (by *different* tasks) will be grouped in an array before being sent to B.in. This is the opposite behaviour from the previous point. Note that this structure creates a synchronization barrier among the A tasks as they must all be completed before the B tasks can be launched.

Conditionals (if/then/else) Specific out ports tags (<outThen> and <outElse>) are used in that kind of node. An outThen port will receive data assigned according to the assignment list in the <then> tag only when the condition is evaluated to true. If the condition is false, this port will not receive data but the <outElse> port will receive data according to the assignment list in the <else> tag (assignment lists are semi-column separated lists of assignments of an outThen or outElse port to an input port).

```
<condition name="IF_Example">
  <in name="i" type="integer" />
  <in name="j" type="integer" />
  <outThen name="out1" type="integer" />
  <outElse name="out2" type="integer" />
  <!-- IF Condition must be written in XQuery language -->
  <if>$i lt $j</if>
  <then>out1=i;</then>
  <else>out2=j;</else>
</condition>
```

Note that all the operators and functions defined in the XQuery standard (see http://www.w3.org/TR/xquery-operators/) can be used to make the boolean expression of the <if> tag. These can process both numerical and string variables, and can also contain XPath expressions to access elements of an array when the input port type is an array (*e.g.,* the expression " `contains($inlistitem[1]text(), 'a')` " tests if the 1st element of the array provided by the 'in' port contains the letter 'a').

While loops This structure uses specific port tags (<inLoop> and <outLoop>) in addition to standard port tags. They are used to connect this processor to other processors that will be iterated as long as the while condition is true (condition is evaluated *before* the first iteration). The standard <in> and <out> ports are used to connect this processor to the rest of the workflow.

The loop initialization is done by mapping data from in ports to inLoop ports using the 'init' attribute. Each iteration produces data on outLoop ports according to the assignments of the <do> tag (semi-column separated list of assignments). The outputs of the processors that are iterated can be connected to the inLoop ports when the results of one iteration are used by the next one (but this is not mandatory). When the while condition is evaluated to false, the outLoop data items are handed over to the corresponding out ports according to the 'final' attribute of these. They are then sent to the connected processors.

Finally for one instance of this *while* processor, $N \geq 0$ iterations are done for processors connected to the outLoop ports and one data item is produced by the out port(s).

```
<loop name="WHILE_Example">
  <!-- REQUIRED nb of IN ports EQUALS nb of OUT ports -->
  <in name="v" type="double" />
  <out name="out" type="double" />
```

```
    <inLoop name="v_l" type="double" init="v"/>
    <outLoop name="l" type="double" final="out"/>

    <!-- WHILE Condition must be written in XQuery language -->
    <!-- it can contain ONLY LOOP IN ports -->
    <while>$v lt 100</while>

    <!-- DO maps the inLoop ports to the outLoop ports - straightforward -->
    <do>l=v_l;</do>

  </loop>
```

13.5 Client API

13.5.1 Structure of client program

The structure of a client program is very close to the structure of usual DIET client. The general algorithm is as follow:

```
diet_initialize

create the workflow profile

call the method diet_wf_call

if success retrieve the results

free the workflow profile

diet_finalize
```

The following tables show a description of methods provided by the DIET workflow API. The table 13.1 contains the main methods that are common to the DAG workflows API and to the functional workflows API. The table 13.2 contains the methods that are specific to the DAG API. The table 13.3 contains the methods that are specific to the functional workflows API.

13.5.2 The simplest example

This example represents the basic client code to execute a DAG. Line 26 indicates that the workflow output is a double value named `n4#out4`. The example shown in Figure 13.1 can be fully (execution and result retrieving) executed with this client.

Workflow function	Description
`diet_wf_desc_t* diet_wf_profile_alloc(const char* wf_file_name, const char* wf_name, wf_level_t wf_level);`	allocate a workflow profile to be used for a workflow submission. *wf_file_name* : the file name containing the workflow XML description. *wf_name* : the name of the workflow (used for logs) *wf_level* : specifier for workflow type (DAG or FUNCTIONAL)
`void diet_wf_profile_free(diet_wf_desc_t * profile);`	free the workflow profile.
`diet_error_t diet_wf_call(diet_wf_desc_t* wf_profile);`	execute the workflow associated to profile *wf_profile*.
`int diet_wf_print_results(diet_wf_desc_t * profile);`	print on standard output all the results of the current executed workflow or dag.

Table 13.1: DIET workflow common API

Workflow function	Description
`int diet_wf_scalar_get(const char * id, void** value);`	retrieves a workflow scalar result. *id* : the output port identifier.
`int diet_wf_string_get(const char * id, char** value);`	retrieves a workflow string result. *id* : the output port identifier.
`int diet_wf_file_get(const char * id, size_t* size, char** path);`	retrieves a workflow file result. *id* : the output port identifier.
`int diet_wf_matrix_get(id, (void**)value, nb_rows, nb_cols, order);`	retrieves a workflow matrix result. *id* : the output port identifier.

Table 13.2: DIET workflow DAG-specific API

Workflow function	Description
`void diet_wf_set_data_file( diet_wf_desc_t * profile, const char * data_file_name);`	specifies the file containing the data description used to generate the workflow
`void diet_wf_set_transcript_file( diet_wf_desc_t * profile, const char * transcript_file_name);`	specifies the file containing the tasks status and data (used to restart a dag or workflow)
`int diet_wf_save_data_file( diet_wf_desc_t * profile, const char * data_file_name);`	saves the input and output data description ('source' and 'sink' nodes) in XML format. The file can be used as input data file for another workflow execution.
`int diet_wf_save_transcript_file( diet_wf_desc_t * profile, const char * transcript_file_name);`	saves the transcript of the current workflow (list of tasks with their status and data). This file can be used as input transcript file for another workflow execution (tasks already done with output data still available on the platform will not be executed again)
`int diet_wf_sink_get( diet_wf_desc_t* wf_profile, const char * id, char** dataID;`	gets a container (DAGDA data) containing all the data received by a 'sink' node

Table 13.3: DIET workflow Functional-specific API

```
#include <string.h>
#include <unistd.h>
#include <stdlib.h>
#include <stdio.h>
#include <sys/stat.h>

#include "DIET_client.h"

int main(int argc, char* argv[])
{
  diet_wf_desc_t * profile;
  char * fileName;
  long * l;
  if (argc != 3) {
    fprintf(stderr, "Usage: %s <file.cfg> <wf_file> \n", argv[0]);
    return 1;
  }

  if (diet_initialize(argv[1], argc, argv)) {
    fprintf(stderr, "DIET initialization failed !\n");
    return 1;
  }
  fileName = argv[2];
  profile = diet_wf_profile_alloc(fileName,"test",DIET_WF_DAG);
  if (!diet_wf_call(profile)) {
    printf("get result = %d ", diet_wf_scalar_get("n4#out4", &l));
    printf("%ld\n", (long)(*l));
  }
  diet_wf_free(profile);
  return 0;
}
```

13.6 Scheduling

The MA_{DAG} agent may receive many requests to execute workflows from one or several clients, and the number of ressources to execute all tasks in parallel may not be sufficient on the grid. In this case the choice of a particular workflow scheduler is critical to determine the order of execution of all tasks that are ready to be executed.

Schedulers provide different online scheduling heuristics that apply different prioritization algorithms to choose the order of execution between tasks of the same DAG (intra-DAG priority) and between tasks of different DAGs (inter-DAG priority). All heuristics are based on the well-known HEFT heuristic that is extended to this case of online multi-workflow scheduling.

13.6.1 Available schedulers

The available MA$_{DAG}$ workflow schedulers are:

- A basic scheduler (option -basic or default choice): this scheduler manages the precedence constraints between the tasks. The priority between tasks within a dag is set according (Heterogeneous Earliest Finish Time) HEFT [24] heuristic. When a task is ready to be executed (*i.e.*, the preceding tasks are completed) the ready task with the higher HEFT rank is sent to the client for execution without specifying a ressource. Then the client performs a standard DIET request that will use the scheduler configured by the *SeD*.

- A Multi-HEFT scheduler (option -heft): this scheduler applies the HEFT heuristic to all workflows submitted by different clients to the MA$_{DAG}$. This means that the priorities assigned by the HEFT heuristic are used to order the tasks of all dags processed by the MA$_{DAG}$ and following this order the tasks are mapped to the first available ressource.

- A Multi-AgingHEFT scheduler (option -aging_heft): this scheduler is similar to Multi-HEFT but it applies a correction factor to the priorities calculated by the HEFT algorithm. This factor is based on the age of the dag ie the time since it was submitted to the scheduler. Compared to Multi-HEFT this scheduler will increase the priority of the tasks of a workflow that has been submitted earlier than other dags.

- A FOFT (Fairness on Finish Time) scheduler (option -fairness): this scheduler uses another heuristic to apply a correction factor to the priorities calculated by the HEFT algorithm. This factor is based on the slowdown of the dag that is calculated by comparing the earliest finish time of the tasks in the same environment without any other concurrent workflow and the actual estimated finish time.

13.6.2 *SeD* requirements for workflow scheduling

The workflow schedulers (Basic, Multi-HEFT, Multi-AgingHEFT and FOFT) use information provided by the *SeD*s to be able to run the HEFT heuristic. So the *SeD* programmer must provide the required data in the estimation vector by implementing a plugin scheduler (see chapter 8).

The following fields in the estimation vector must be filled in:

1. The `TCOMP` field must contain the estimation of the computation time for the job (in milliseconds). This can be done using the `diet_estimate_comptime(estVector_tev, double value)` method within the performance evaluation function.

2. The `EFT` field must contain the estimation of the earliest finish time (in milliseconds from the time of the current submit request) for the job. To compute this value, the *SeD* programmer can use the API method

`diet_estimate_eft(...)` to retrieve the estimated value of earliest finish time for a new job.

Chapter 14

DAGDA: Data Manager

DAGDA (**D**ata **A**rrangement for **G**rid and **D**istributed **A**pplications) is a new data manager for DIET. DAGDA offers to the DIET application developers a simple and efficient way to manage the data. It was not designed to replace the JuxMem extension but to be possibly coupled with it. In a future work, DAGDA will be divided in two parts: The DAGDA data manager and the DAGDA data interface. The data interface will make interactions between DAGDA, JuxMem, FTP etc. and other data transfer/management protocols. In this chapter, we will present the current version of DAGDA which is an alternative data manager for DIET with several advanced data management features.

14.1 Overview

DAGDA allows data explicit or implicit replications and advanced data management on the grid. It was designed to be backward compatible with previously developed applications for DIET which benefit transparently of the data replications. Moreover, DAGDA limits the data size loaded in memory to a user-fixed value and avoids CORBA errors when transmitting too large data regarding to the ORB configuration.

DAGDA offers a new way to manage the data on DIET. The API allows the application developer to replicate, move, add or delete a data to be reused later or by another application. Each component of DIET can interact with DAGDA and the data manipulation can be done from a client application, a server or an agent through a plug-in scheduler.

A DAGDA component is associated to each element in a DIET platform (client, Master Agent, Local Agent, SeD). These components are connected following the DIET deployment topology. Figure 14.1 shows how the DAGDA and DIET classical components are connected. Contrary to a DIET architecture, each DAGDA component has the same role. It can store, transfer or move a data. The client's DAGDA component is isolated of the architecture and communicates only with the chosen SeDs DAGDA components when necessary. When searching for a data, DAGDA uses its hierarchical topology to contact the data managers. Among the data managers having one replicate of the data, DAGDA chooses the *"best"* source to transfer it. To make this choice DAGDA uses some statistics collected from previous data transfers between the nodes. By not using dynamic infor-

mation, it is unsure that DAGDA really chose the "best" nodes for the transfers. In a future version, we will introduce some facilities to estimate the time needed to transfer a data and to improve the choice of a data stored on the grid. To do the data transfers, DAGDA uses the pull model: it is the destination node that ask for the data transfer.

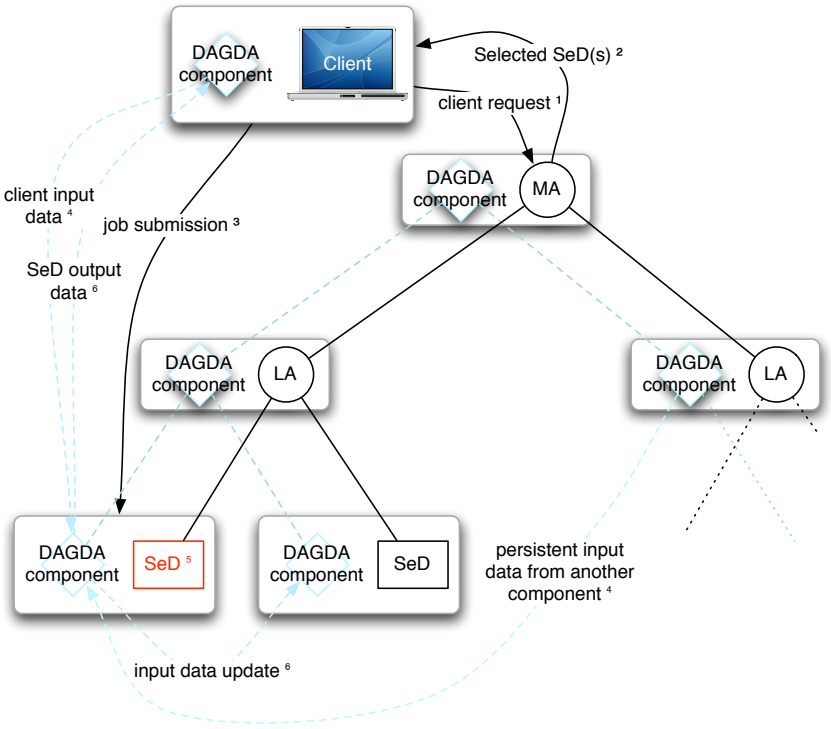


Figure 14.1: DAGDA architecture in DIET.

Figure 14.1 presents how DAGDA manages the data when a client submit a job. In this example, the client wants to use some data stored on the grid and some personal data. He wants to obtain some results and to store some others on the grid. Some of these output data are already stored on the platform and they should be updated after the job execution.

1. The client sends a request to the Master Agent.

2. The Master agent returns one or more *SeD* references.

3. The client sends its request to the chosen node. The parameters data are identified by a unique ID and the problem profile contains a reference to the client's data manager.

4. Receiving the request the *SeD* asks the client to transfer the data of the user and it asks to the DAGDA architecture to obtain the persistent data already stored on the platform.

5. The *SeD* executes the job. After the execution, the *SeD* stores the output data and it informs the client that the data are ready to be downloaded. It also asks the architecture to update the modified output data.

6. The client upload its results and the data are updated on the nodes.

14.2 The DAGDA configuration options

DAGDA introduces new configuration options that can be defined for all the DAGDA components. None of these options are mandatory to use DAGDA. Figure 14.2 presents all the DAGDA available options, their meaning and default values.

Option	Description	Default value	Client	Agent	SeD
storageDirectory	The directory on which DAGDA will store the data files	The */tmp* directory.	✔	✔	✔
maxMsgSize	The maximum size of a CORBA message sent by DAGDA.	The omniORB *giopMaxMsgSize* size.	✔	✔	✔
maxDiskSpace	The maximum disk space used by DAGDA to store the data. If set to 0, DAGDA will not take care of the disk usage.	The available disk space on the disk partition chosen by the *storageDirectory* option.	✔	✔	✔
maxMemSpace	The maximum memory space used by DAGDA to store the data. If set to 0, DAGDA will not take care of the memory usage.	No maximum memory usage is set. Same effect than to choose 0.	✔	✔	✔
cacheAlgorithm	The cache replacement algorithm used when DAGDA needs more space to store a data. Possible values are: *LRU, LFU, FIFO*	No cache replacement algorithm. DAGDA never replace a data by another one.	✔	✔	✔
shareFiles	The DAGDA component shares its file data with all its children (when the path is accessible by them, for example, if the storage directory is on a NFS partition). Value can be 0 or 1.	No file sharing - 0	✘	✔	✘
dataBackupFile	The path to the file that will be used when DAGDA save all its stored data/-data path when asked by the user (Checkpointing).	No checkpointing is possible.	✘	✔	✔
restoreOnStart	DAGDA will load the *dataBackupFile* file at start and restore all the data recorded at the last checkpointing event. Possible values are 0 or 1.	No file loading on start - 0	✘	✔	✔

Figure 14.2: DAGDA configuration options

14.3 Cache replacement algorithm

When a data is replicated on a site, it is possible that not enough disk/memory space is available. In that case, DAGDA allows to choose a strategy to delete a persistent data. Only a simple persistent data can be deleted, the sticky ones are never deleted by the chosen algorithm. DAGDA offers three algorithms to manage the cache replacement:

- LRU: The least recently used persistent data of sufficient size is deleted.
- LFU: The least frequently used persistent data of sufficient size is deleted.
- FIFO: Among the persistent data of sufficient size, the *oldest* is deleted.

14.4 The DAGDA API

By compiling DIET with the DAGDA extension activated, the *DIET_Dagda.h* file is installed on the DIET include directory. This file contains some data management functions and macros.

14.4.1 Note on the memory management

On the *SeD* side, DAGDA and the *SeD* share the same data pointers, that means that if the pointer is a local variable reference, when DAGDA will use the data, it will read an unallocated variable. The users should allways allocate the data with a *"malloc"/"calloc"* or *"new"* call on the *SeD* and agent sides. Because DAGDA takes the control of the data pointer, there is no risk of memory leak even if the service allocate a new pointer at each call. The data lifetime is managed by DAGDA and the data will be freed according to its persistence mode.

On the *SeD* and agent sides, DAGDA takes the control of the data pointers. To free a data may cause major bugs which could be very hard to find. The users could only free a DIET data on the client side after the end of a transfer.

14.4.2 Synchronous data transfers

All of the following functions return at the end of the transfer or if an error occured. They all return an integer value: 0 if the operation succeeds, another value if it fails.

DAGDA *put* data macros/functions

The following functions put a data on the DAGDA hierarchy to be used later. The last parameter is always a pointer to a C-string which will be initialized with a pointer to the ID string of the data. This string is allocated by DAGDA and can be freed when the user does not need it anymore. The first parameter is always a pointer to the data: for a scalar value a pointer on the data, for a vector, matrix or string, a pointer on the

first element of the data. The *"value"* argument for a file is a C-string containing the path of this file. The persistence mode for a data managed by DAGDA should allways be DIET_PERSISTENT or DIET_STICKY. The VOLATILE and *_RETURN modes do not make sense in this data management context.

- `dagda_put_scalar(void* value, diet_base_type_t base_type, diet_persistence_mode_t mode, char** ID)`:
  This macro adds to the platform the scalar data of type *"base_type"* pointed by *"value"* with the persistence mode *"mode"* (DIET_PERSISTENT or DIET_STICKY) and initializes *"*ID"* with the ID of the data.

- `dagda_put_vector(void* value, diet_base_type_t base_type, diet_persistent_mode_t mode, size_t size, char** ID)`:
  This macro adds to the platform the vector of *"size"* *"base_type"* elements pointed by *"value"* with the persistence mode *"mode"* and stores the data ID in *"ID"*.

- `dagda_put_matrix(void* value, diet_base_type_t base_type, diet_persistence_mode_t mode, size_t nb_rows, size_t nb_cols, diet_matrix_order_t order, char** ID)`:
  This macro adds to the platform the *"base_type"* matrix of dimension *"nb_rows"* × *"nb_cols"* stored in *"order"* order. The data ID is stored on *"ID"*.

- `dagda_put_string(char* value, diet_persistence_mode_t mode, char** ID)`:
  This macro adds to the platform the string pointed by *"value"* with the persistence mode *"mode"* and stores the data ID into *"ID"*.

- `dagda_put_file(char* path, diet_persistence_mode_t mode, char**ID)`:
  This macro adds the file of path *"path"* with the persistence mode *"mode"* to the platform and stores the data ID into *"ID"*

DAGDA *get* data macros/functions

The following API functions are defined to obtain a data from DAGDA using its ID:

- `dagda_get_scalar(char* ID, void** value, diet_base_type_t* base_type)`:
  The scalar value using the ID *"ID"* is obtained from DAGDA and the *"value"* argument is initialized with a pointer to the data. The *"base_type"* pointer content is set to the data base type. This last parameter is optional and can be set to NULL if the user does not want to get the *"base_type"* value.

- `dagda_get_vector(char* ID, void** value, diet_base_type_t* base_type, size_t* size)`:
  The vector using the ID *"ID"* is obtained from DAGDA. The *"value"* argument is initialized with a pointer to the first vector element. The *"base_type"* content are initialized with the base type and size of the vector. These two parameters can be set to NULL if the user does not take care about it.

- `dagda_get_matrix(char* ID, void** value, diet_base_type_t* base_type, size_t* nb_r, size_t* nb_c, diet_matrix_order_t* order)`:
  The matrix using the ID *"ID"* is obtained from DAGDA. The *"value"* argument is initialized with a pointer to the first matrix element. The *"base_type"*, *"nb_r"*, *"nb_c"* and *"order"* arguments contents are repectively set to the base type of the matrix, the number of rows, the number of columns and the matrix order. All of these parameters can be set to NULL if the user does not take care about it.

- `dagda_get_string(char* ID, char** value)`:
  The string of ID *"ID"* is obtained from DAGDA and the *value* content is set to a pointer on the first string character.

- `dagda_get_file(char* ID, char** path)`:
  The file of ID *"ID"* is obtained from DAGDA and the *"path"* content is set to a pointer on the first path string character.

14.4.3 Asynchronous data transfers

With DAGDA, there are two ways to manage the asynchronous data transfers, depending of the data usage:

- With end-of-transfer control: DAGDA maintains a reference to the transfer thread. It only releases this reference after a call to the corresponding waiting function. The client developer should always use these functions, that's why a data ID is only returned by the *"dagda_wait_*"* and *"dagda_wait_data_ID"* functions.

- Without end-of-transfer control: The data is loaded from/to the DAGDA hierarchy without the possibility to wait for the end of the transfer. These functions should only be called from an agent plugin scheduler, a *SeD* plugin scheduler or a *SeD* if the data transfer without usage of the data is one of the objectives of the called service. The data adding functions without control should be used very carefully because there is no way to be sure the data transfer is achieved or even started.

With asynchronous transfers, the user should take care of the data lifetime because DAGDA does not duplicate the data pointed by the passed pointer. For example, if the program uses a local variable reference to add a data to the DAGDA hierarchy and goes out of the variable scope, a crash could occured because the data pointer could be freed by the system before DAGDA has finished to read it.

DAGDA asynchronous *put* macros/functions

The arguments to these functions are the same than for the synchronous ones. See Section 14.4.2 for more details. All of these functions return a reference to the data transfer which is an unsigned int. This value will be passed to the *"dagda_wait_data_ID"* function.

- `dagda_put_scalar_async(void* value, diet_base_type_t base_type, diet_persistence_mode_t mode)`

- `dagda_put_vector_async(void* value, diet_base_type_t base_type, diet_persistence_mode_t mode, size_t size)`

- `dagda_put_matrix_async(void* value, diet_base_type_t base_type, diet_persistence_mode_t mode, size_t nb_rows, size_t nb_cols, diet_matrix_order_t order)`

- `dagda_put_string_async(char* value, diet_persistence_mode_t mode)`

- `dagda_put_file_async(char* path, diet_persistence_mode_t mode)`

After a call to one of these functions, the user can obtain the data ID by calling the *"dagda_wait_data_ID"* function with a transfer reference.

- `dagda_wait_data_ID(unsigned int transferRef, char** ID)`:
  The *"transferRef"* argument is the value returned by a *"dagda_put_*_async"* function. The *"ID"* content will be initialized to a pointer on the data ID.

DAGDA asynchronous *get* macros/functions

The only argument needed for one of these functions is the data ID. All of these functions return a reference to the data transfer which is an unsigned int. This value will be passed to the corresponding *"dagda_wait_*"* functions described later.

- `dagda_get_scalar_async(char* ID)`

- `dagda_get_vector_async(char* ID)`

- `dagda_get_matrix_async(char* ID)`

- `dagda_get_string_async(char* ID)`

- `dagda_get_file_async(char* ID)`

After asking for an asynchronous transfer, the user has to wait the end by calling the corresponding *"dagda_wait_*"* function. The arguments of these functions are the same than for the synchronous *"dagda_get_*"* functions. See Section 14.4.2 for more details.

- `dagda_wait_scalar(unsigned int transferRef, void** value, diet_base_type_t* base_type)`

- `dagda_wait_vector(unsigned int transferRef, void** value, diet_base_type_t* base_type, size_t* size)`

- `dagda_wait_matrix(unsigned int transferRef, void** value, diet_base_type_t* base_type, size_t* nb_r, size_t* nb_c, diet_matrix_order_t* order)`

- `dagda_wait_string(unsigned int transferRef, char** value)`

- `dagda_wait_file(unsigned int transferRef, char** path)`

A plugin scheduler developer often wants to make an asynchronous data transfer to the local DIET node. Problems can arise if you want to wait the completion of the tranfer before returning. But with the previously defined functions, DAGDA maintains a reference to the transfer thread which will be released after a call to the waiting function. To avoid DAGDA to keep infinitely these references, the user should call the *"dagda_load_*"* functions instead of the *"dagda_get_*_async"* ones.

- `dagda_load_scalar(char* ID)`

- `dagda_load_vector(char* ID)`

- `dagda_load_matrix(char* ID)`

- `dagda_load_string(char* ID)`

- `dagda_load_file(char* ID)`

14.4.4 Data checkpointing with DAGDA

DAGDA allows the *SeD* administrator to choose a file where DAGDA will store all the data it's managing. When a *SeD* has a configured and valid path name to a backup file (*"dataBackupFile"* option in the configuration file), a client can ask to the agents or *SeD*s DAGDA components to save the data.

The `dagda_save_platform()` function, which can only be called from a client, records all the data managed by the agents' or *SeD*s' DAGDA components that allow it.
Then, the *"restoreOnStart"* configuration file option asks to the DAGDA component to restore the data stored on the *"dataBackupFile"* file when the component starts. This mechanism allows to stop the DIET platform for a while and restart it conserving the same data distribution.

14.4.5 Create data ID aliases

For many applications using large sets of data shared by several users, to use an automatically generated ID to retrieve a data is difficult or even impossible. DAGDA allows the user to define data aliases, using human readable and expressive strings to retrieve a data ID. Two functions are defined to do it:

- `dagda_data_alias(const char* id, const char* alias)`:
  Tries to associate *"alias"* to *"id"*. If the alias is already defined, returns a non zero value. A data can have several aliases but an alias is always associated to only one data.

- `dagda_id_from_alias(const char* alias, char** id)`:
  This function tries to retrieve the data id associated to the alias.

14.4.6 Data replication

After a data has been added to the DAGDA hierarchy, the users can choose to replicate it explicitely on one or several DIET nodes. With the current DAGDA version, we allow to choose the nodes where the data will be replicated by hostname or DAGDA component ID. In future developments, it will be possible to select the nodes differently. To maintain backward compatibility, the replication function uses a C-string to define the replication rule.

```
- dagda_replicate_data(const char* id, const char* rule)
```

The replication rule is defined as follows:
"<Pattern target>:<identification pattern>:<Capacity overflow behavior>"

- The *pattern target* can be "ID" or "host".
- The *identification pattern* can contain some *wildcards* characters. (for example *"*.lyon.grid5000.fr"* is a valid pattern.
- The *capacity overflow behavior* can be "replace" or "noreplace". "replace" means the cache replacement algorithm will be used if available on the target node (a data could be deleted from the node to leave space to store the new one). "noreplace" means that the data will be replicated on the node if and only if there is enough storage capacity on it.

For example, *"host:capricorne-*.lyon.*:replace"* is a valid replication rule.

14.5 On the correct usage of DAGDA

Some things to keep in mind when using DAGDA as data manager for DIET:

- All the data managed by DAGDA are entirely managed by DAGDA: The user don't have to free them. DAGDA avoids memory leaks, so the user does not have to worry about the memory management for the data managed by DAGDA.
- When using more than one DAGDA component on a node, the user should define a different storage directory for each component. For example, the Master Agent and one *SeD* are launched on the same computer: the user can define the storage directory of the Master Agent as "/tmp/MA" and the one for the *SeD* as "/tmp/SeD1". Do not forget to create the directories before to use DAGDA. This tip avoids many bugs which are really hard to find.
- The DAGDA API can be used to transfer the parameters of a service, but it should not be used as this. If an application needs a data which is only on the client, the user should transmit it through the profile. The DAGDA API should be used to share, replicate or retrieve an existing data. Using the API allows the user

to optimize their applications, not to proceed to a diet_call even if it works fine. Indeed, the DAGDA client component is not linked to the DIET hierarchy, so using the API to add a data and then to use it as a profile parameter makes DAGDA to do additional and useless transfers.

- DAGDA can be used without any configuration, but it is always a good idea to define all the DAGDA parameters in the configuration files.

For any comment or bug report on DAGDA, please contact G. Le Mahec at the following e-mail address: gael.le.mahec@u-picardie.fr.

14.6 Future works

The next version of DAGDA will allow the users to develop their own cache replacement algorithms and network capacity measurements methods. DAGDA will be separated in two parts: A data management interface and the DAGDA data manager itself. DAGDA will implement the GridRPC data management API extension.

Chapter 15

Dynamic management

15.1 Dynamically modifying the hierarchy

15.1.1 Motivations

So far we saw that DIET's hierarchy was mainly static: once the shape of the hierarchy chosen, and the hierarchy deployed, the only thing you can do is kill part of the hierarchy, or add new subtrees to the existing hierarchy. But whenever an agent is killed, the whole underlying hierarchy is lost. This has several drawbacks: some *SeD* will become unavailable, and if you want to reuse the machines on which those *SeD* (or agents) are, you need to kill the existing DIET element, and redeploy a new subtree. Another problem due to this static asignement of the parent/children links is that if you have an agent that is overloaded, you cannot move part of its children to an underloaded agent somewhere else in the hierarchy without once again killing part of the hierarchy, and deploying once again.

15.1.2 "And thus it began to evolve"

Hence, DIET also has a built-in mode in which you can dynamically modify its shape using CORBA calls. In this mode, if a DIET element cannot reach its parent, when initializing, it won't exit, but will wait for an order to connect itself to a new parent. Hence, you do not need to deploy DIET starting from the MA down to the *SeD*, you can launch all the elements at once, and then, send the orders for each element to connect to its correct parent (you do not even need to follow the shape of the tree, you can start from the bottom to the tree up to the root, or use a random order, the service tables will be correctly initialized.)

You now have access to the following CORBA methods:

- `long bindParent(in string parentName)`: sends an order to a *SeD* or agent to bind to a new parent having the name "`parentName`" if this parent can be contacted, otherwise the element keeps its old parent. If the element already has a parent, it unsubscribes itself from the parent, so that this latter is able to update its service

table and list of children. A `null` value is returned if the change occurred, otherwise a value different from 0 is returned if a problem occurred.

- `long disconnect()`: sends an order to disconnect an element from its parent. This does not kill the element, but merely removes the link between the element and its parent. Thus, the underlying hierarchy will be unreachable until the element is connected to a new parent.

- `long removeElement()`: sends an order to a *SeD* to kill itself. The *SeD* first unsubscribe from its parent before ending itself properly.

- `long removeElement(in boolean recursive)`: same as above but for agents. The parameter "`recursive`" if true also destroys the underlying hierarchy, otherwise only the agent is killed.

Now, what happens if during a request submission an element receives an order to change its parent? Actually, nothing will change, as whenever a request is received a reference to the parent from which the request originates is locally kept. So if the parent changes before the request is sent back to the parent, as we keep a local reference on the parent, the request will be sent back to the correct "parent". Hence, for a short period of time, an element can have multiple parents.

WARNING: currently no control is done on whether or not you are creating loops in the hierarchy when changing a parent.

15.1.3 Example

Two examples on how to call those CORBA methods are present in `src/examples/dynamic_hierarchy`:

- `connect.cc` sends orders to change the parent of an element.
  `Usage: ./connect <SED|LA> <element name> <parent name>`.

- `disconnect.cc` sends orders to disconnect an element from its parent. It does not kill the element, but only disconnects it from the DIET hierarchy (useful when your platform is not heavily loaded and you want to use only part of the hierarchy)
  `Usage: ./disconnect <SED|LA> <element name>`.

- `remove.cc` sends orders to remove an element.
  `Usage: ./remove <SED|AGENT> <element name> [recursive: 0|1]`

15.2 Changing offered services

15.2.1 Presentation

A *SeD* does not necessarily need to declare all its services initially, *i.e.,* as presented in Chapter 5 before launching the *SeD* via `diet_SeD(...)`. One could want to initially

declare a given set of services, and then, depending on parameters, or external events, one could want to modify this set of services. An example of such usage is to spawn a service that is in charge of cleaning temporary files when they won't be needed nor by this *SeD*, nor by any other *SeD* or clients, and when this service is called, it cleans whatever needs to be cleaned, and then this service is removed from the service table.

Adding a service has already been introduced in Chapter 5: using `diet_service_table_add(...)` you can easily add a new service (be it before running the *SeD* or within a service). Well, removing a service is as easy, you only need to call one of these methods:

```
int diet_service_table_remove(const diet_profile_t* const profile);
int diet_service_table_remove_desc(const diet_profile_desc_t* const profile);
```

So basically, when you want to remove the service that is called, you only need to pass the `diet_profile_t` you receive in the solve function to `diet_service_table_remove`. If you want to remove another service, you need to build its profile description (just as if you wanted to create a new service), and pass it to `diet_service_table_remove_desc`.

15.2.2 Example

The following example (present in `src/examples/dyn_add_rem`) initially declares one service. This service receives an integer n as parameter. It creates n services, and removes the service that has just been called. Hence a service can only be called once, but it spawns n new services.

```
#include <iostream>
#include <sstream>
#include <cstring>

#include "DIET_server.h"
#include "DIET_Dagda.h"

/* begin function prototypes*/
int service(diet_profile_t *pb);
int add_service(const char* service_name);
/* end function prototypes*/

static unsigned int NB = 1;

template <typename T>
std::string toString( T t ) {
    std::ostringstream oss;
    oss << t;
    return oss.str();
}

/* Solve Function */
int
service(diet_profile_t* pb) {
  int *nb;
```

```
  if (pb->pb_name)
    std::cout << "## Executing " << pb->pb_name << std::endl;
  else {
    std::cout << "## ERROR: No name for the service" << std::endl;
    return -1;
  }

  diet_scalar_get(diet_parameter(pb,0), &nb, NULL);
  std::cout << "## Will create " << *nb << " services." << std::endl;

  for (int i = 0; i < *nb; i++) {
    add_service(std::string("dyn_add_rem_" + toString(NB++)).c_str());
  }

  std::cout << "## Services added" << std::endl;
  diet_print_service_table();

  /* Removing */
  std::cout << "## Removing service " << pb->pb_name << std::endl;
#ifdef HAVE_ALT_BATCH
  pb->parallel_flag = 1;
#endif
  diet_service_table_remove(pb);
  std::cout << "## Service removed" << std::endl;

  /* Print service table */
  diet_print_service_table();

  return 0;
}

/* usage function */
int
usage(char* cmd) {
  std::cerr << "Usage: " << cmd << " <SeD.cfg>" << std::endl;
  return -1;
}

/* add_service function: declares SeD's service */
int
add_service(const char* service_name) {
  diet_profile_desc_t* profile = NULL;
  unsigned int pos = 0;

  /* Set profile parameters: */
  profile = diet_profile_desc_alloc(strdup(service_name),0,0,0);

  diet_generic_desc_set(diet_param_desc(profile,pos++),DIET_SCALAR, DIET_INT);

  /* Add service to the service table */
  if (diet_service_table_add(profile, NULL, service )) return 1;

  /* Free the profile, since it was deep copied */
```

```
  diet_profile_desc_free(profile);

  std::cout << "Service '" << service_name << "' added!" << std::endl;

  return 0;
}

int checkUsage(int argc, char ** argv) {
  if (argc != 2) {
    usage(argv[0]);
    exit(1);
  }
  return 0;
}

/* MAIN */
int
main( int argc, char* argv[]) {
  int res;
  std::string service_name = "dyn_add_rem_0";

  checkUsage(argc, argv);

  /* Add service */
  diet_service_table_init(1);
  add_service(service_name.c_str());

  /* Print service table and launch daemon */
  diet_print_service_table();
  res = diet_SeD(argv[1],argc,argv);
  return res;
}
```

15.2.3 Going further

Finally, another example is provided in `src/examples/dynamicServiceMgr` showing how to dynamically load and unload libraries containing services. Hence, a client can send a library to as server, and for as long as the library is compiled for the right architecture, the server will be able to load it, and instanciate the service present in the library. The service can further be called by other clients, and whenever it is not required anymore, it can be easily removed.

Chapter 16

DIET forwarders

The DIET middleware uses CORBA as its communication layer. It is an easy and flexible way for the different platform components to communicate. However, deploying DIET on heterogeneous networks that are not reachable from each other except through ssh connection is a complicated task needing complex configuration. Moreover, to ensure that all objects can contact each others, we need to set-up and launch ssh tunnels between each of them, reducing significantly the DIET scalability in that network configuration context.

The DIET *forwarders* are the solution for such a situation, by reducing the number of ssh tunnels to the minimum and making their launch totally transparent for the final users. The DIET forwarders configuration is very simple even for very complex network topologies.

The next section presents the global operation of DIET forwarders. Section 16.2 presents the DIETForwarder executable, its command-line options and configuration file. Then, section 16.3 gives two examples of forwarder configurations.

16.1 Easy CORBA objects connections through ssh

Each CORBA object in DIET is reachable through omniORB using a TCP port and the hostname of the machine on which it is executed. By default these parameters are fixed automatically by omniORB but it is also possible to choose them statically using the DIET configuration file. When two objects are located on different networks that are reachable only through ssh, it is easy to open an ssh tunnel to redirect the communications between them on the good port and host. Then, correcting the objects bindings into the omniNames servers is sufficient to ensure the communications between the different objects. To allow two CORBA objects to communicate through an ssh tunnel, users must:

- Start the process which declares the objects and register them into the omniNames server(s).
- Open ssh tunnels that redirect the local objects ports to remote ports.

- Modify the objects bindings in the omniNames server(s) to make them point to the forwarded ports.

When using few objects that do not need much interaction, these steps can easily be done "manually". But DIET uses several different objects for each element and is designed to manage thousands of nodes. Moreover, creating an ssh tunnel between all the nodes of a Grid cannot even be considered.

The DIET forwarders deal with this problem by creating *proxy objects* that forward the communications to a peer forwarder through a unique ssh tunnel. Then, only one ssh tunnel is created to connect two different networks. This system also allows users to define complex communications routing. Figure 16.1 shows how the DIET forwarders work to route communications through ssh tunnels. Moreover most of the configuration of the forwarders automatically can be set by DIET itself.

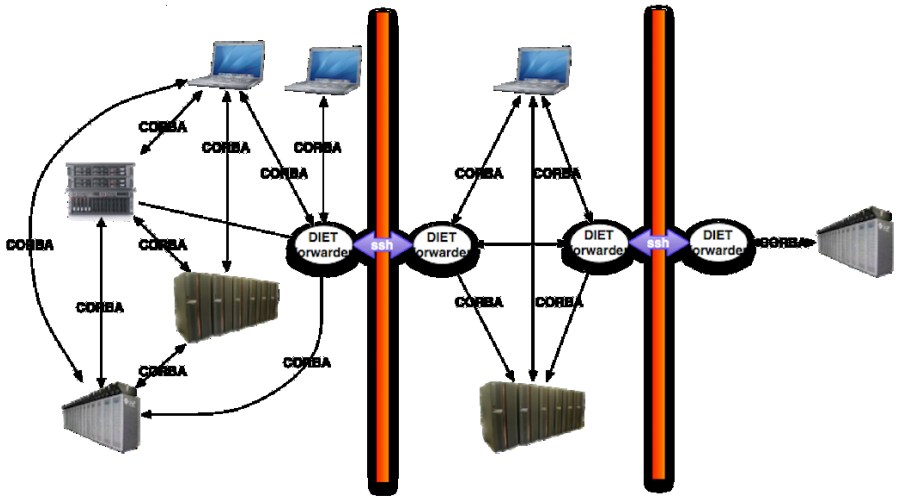


Figure 16.1: Forwarders routing DIET communication through ssh tunnels

16.2 The DIETForwarder executable

Since DIET 2.5, when installing DIET, an executable called *DIETForwarder* is installed on the *bin* directory. It allows to launch a forwarder object following the configuration passed on the command line.

16.2.1 Command line options

The DIET forwarder executable takes several options to be launched:

- `--name`: to define the name of the forwarder.
- `--peer-name`: the name of its peer on the other network.

- `--ssh-host`: the ssh host for the tunnel creation.
- `--ssh-port`: the port to use to establish the ssh connection (by default: 22).
- `--ssh-login`: the login to use to establish the ssh connection (by default: current user login).
- `--ssh-key`: the private key to use to establish the ssh connection (by default: `$HOME/.ssh/id_rsa`).
- `--remote-port`: the port to listen on the ssh host (by default: the remote forwarder tries to dermine an available port automatically, note that if the connection fails when you do not use this option, then you have to specify the remote port).
- `--remote-host`: the host to which the connection is made by the tunnel (corresponds to `host` in the ssh options `-L` and `-R`).
- `--nb-retry`: the number of times the local forwarder tries to bind itself to the distant forwarder (default is 3).
- `--peer-ior`: if you already know the IOR of the distant forwarder, then you can pass it to your local forwarder. By default, the local forwarder retrieves the IOR of its peer.
- `--tunnel-wait`: the time is seconds that the forwarder will wait while opening the ssh tunnel.

The remote port can be chosen randomly among the available TCP ports on the remote host. Sometimes, depending on the configuration of sshd, you will need to set `--remote-host` to `localhost` or `127.0.0.1` (or the address of the local loopback if it is not `127.0.0.1`) for the tunnel to work correctly (in fact, most problems come from a badly configured tunnel).

In order, to activate a DIET forwarder, users must:

- Launch omniNames on the remote and local hosts.
- Launch the first peer on the remote host, only defining its name and its network configuration.
- Launch the second peer, passing it it the first peer name, the ssh connection informations, the remote port to use and its network configuration.

Rem: The forwarders must be launched before the DIET *hierarchy.*

16.3 Configuration examples

The first example presents the configurations of DIET forwarders to connect a *SeD* located on a network only reachable through ssh to a DIET hierarchy located on another network.

The second example presents the configurations of DIET forwarders to connect three networks: the first one can only reach the second one through ssh and the third one can also only reach the second one through ssh. We want to connect DIET elements distributed over the three networks.

16.3.1 Simple configuration

- The two different domains are *net1* and *net2*. The forwarders will be launched on the hosts *fwd.net1* and *fwd.net2*.
- There is no possibility to access *fwd.net1* from *fwd.net2* but users can access *fwd.net2* from *fwd.net1* using an ssh connection.
- The forwarder on *fwd.net1* is named *Fwd1*, the forwarder on *fwd.net2* is named *Fwd2*.
- One *SeD* is launched on *fwd.net2*, the rest of the DIET hierarchy is launched on the *net1* domain.

Command line to launch *Fwd1*:

```
fwd.net1$ dietForwarder --name Fwd1 --peer-name Fwd2 \
                        --ssh-host fwd.net2 --ssh-login dietUser \
                        --ssh-key id_rsa_net2 --remote-port 50000
```

Command line to launch *Fwd2*:

```
fwd.net2$ dietForwarder --name Fwd2
```

Note that *Fwd2* has to be launched before *Fwd1*. When the two forwarders are launched, the user can deploy his DIET hierarchy. All the communications through DIET forwarders are transparent.

16.3.2 Complex network topology

To connect the three domains, we need 4 forwarders (2 pairs): one on *net1*, two on *net2* and one on *net3*.

- The three domains are: *net1*, *net2* and *net3*.
- The machines located on *net1* and *net3* are only reachable from *fwd.net2* through ssh.

- The four forwarders are named *Fwd1*, *Fwd2-1*, *Fwd2-3* and *Fwd3*.
- The DIET hierarchy is distributed on the three networks.

Command line to launch *Fwd1*:
fwd.net1$ dietForwarder --name Fwd1

Command line to launch *Fwd2-1*:
```
fwd.net2$ dietForwarder --name Fwd2-1 --peer-name Fwd1 \
                        --ssh-host fwd.net1 --ssh-login dietUser \
                        --ssh-key id_rsa_net1 --remote-port 50000
```

Command line to launch *Fwd2-3*:
```
fwd.net2$ dietForwarder --name Fwd2-3 --peer-name Fwd3 \
                        --ssh-host fwd.net3 --ssh-login dietUser \
                        --ssh-key id_rsa_net3 --remote-port 50000
```

Command line to launch *Fwd3*:
fwd.net3$ dietForwarder --name Fwd3

Using this configuration, a communication from a host on *net1* to a host on *net3* is first routed from *Fwd1* to *Fwd2-1* and then from *Fwd2-3* to *Fwd3*. Note that *Fwd1* has to be launched before *Fwd2-1*, and *Fwd3* has to be launched before *Fwd2-3*.

Appendix A

Appendix

A.1 Configuration files

agentType

- Component: Agent (MA and LA)
- Mode: All
- Type: Agent type
- Description: Master Agent or Local Agent? As there is only one executable for both agent types, it is COMPULSORY to specify the type of this agent: DIET_MASTER_AGENT (or MA) or DIET_LOCAL_AGENT (or LA).

batchName

- Component: *SeD*
- Mode: Batch
- Type: String
- Description: The reservation batch system's name.

batchQueue

- Component: *SeD*
- Mode: Batch
- Type: String
- Description: The name of the queue where the job will be submitted.

bindServicePort

- Component: MA
- Mode: All
- Type: Integer

- Description: port used by the Master Agent to share its IOR.

cacheAlgorithm

- Component: All
- Mode: DAGDA
- Type: String
- Description: The cache replacement algorithm used when DAGDA needs more space to store a data. Possible values are: *LRU, LFU, FIFO*. By default, no cache replacement algorithm. DAGDA never replace a data by another one.

clientMaxNbSeD

- Component: Client
- Mode: All
- Type: Integer
- Description: The maximum number of *SeD* the client should receive.

dataBackupFile

- Component: Agent and SeD
- Mode: DAGDA
- Type: String
- Description: The path to the file that will be used when DAGDA save all its stored data/data path when asked by the user (Checkpointing). By default, no checkpointing is possible.

dietHostName

- Component: All
- Mode: All
- Type: String
- Description: the listening interface of the agent. If not specified, let the ORB get the hostname from the system (the first one if several one are available).

dietPort

- Component: All
- Mode: All
- Type: Integer
- Description: the listening port of the agent. If not specified, let the ORB get a port from the system (if the default 2809 was busy).

forceRebind

- Component: Client
- Mode: All
- Type: Boolean
- Description: force clients rebinding into CORBA Naming Service (default : true).

initRequestID

- Component: MA
- Mode: All
- Type: Integer
- Description: When a request is sent to the Master Agent, a request ID is associated and by default it begins at 1. If this parameter is provided, it will begins at initRequestID.

internOARbatchQueueName

- Component: *SeD*
- Mode: Batch
- Type: String
- Description: only useful when using CORI batch features with OAR 1.6

locationID

- Component: *SeD*
- Mode: DAGDA
- Type: String
- Description: This parameter is used for alternative transfer cost prediction.

lsOutbuffersize

- Component: Agent and *SeD*
- Mode: All
- Type: Integer
- Description: the size of the buffer for outgoing messages.

lsFlushinterval

- Component: Agent and *SeD*
- Mode: All

- Type: Integer
- Description: the flush interval for the outgoing message buffer.

MADAGNAME

- Component: Client
- Mode: Workflow
- Type: String
- Description: the name of the MA_{DAG} agent to wich the client will connect.

MAName

- Component: Client
- Mode: All
- Type: String
- Description: Master Agent name. The ORB configuration files of the clients and the children of this MA (LAs and SeDs) must point at the same CORBA Naming Service as the one pointed at by the ORB configuration file of this agent.

maxConcJobs

- Component: *SeD*
- Mode: All
- Type: Integer
- Description: If useConcJobLimit == true, how many jobs can run at once? This shoudl be used in conjunction with *maxConcJobs*.

maxDiskSpace

- Component: All
- Mode: DAGDA
- Type: Integer
- Description: The maximum disk space used by DAGDA to store the data. If set to 0, DAGDA will not take care of the disk usage. By default this value is equal to the available disk space on the disk partition chosen by the *storageDirectory* option.

maximumNeighbours

- Component: MA
- Mode: Integer

- Type: Multi MA
- Description: maximum number of connected neighbours. The agent does not accept a greater number of connection to build the federation than maximumNeighbours.

maxMemSpace

- Component: All
- Mode: DAGDA
- Type: Integer
- Description: The maximum memory space used by DAGDA to store the data. If set to 0, DAGDA will not take care of the memory usage. By default no maximum memory usage is set. Same effect than to choose 0.

maxMsgSize

- Component: All
- Mode: DAGDA
- Type: Integer
- Description: The maximum size of a CORBA message sent by DAGDA. By default this value is equal to the omniORB *giopMaxMsgSize* size.

minimumNeighbours

- Component: MA
- Mode: Multi MA
- Type: Integer
- Description: Minimum number of connected neighbours. If the agent has less that this number of connected neighbours, is going to find some new connections.

moduleConfigFile

- Component: Agent
- Mode: User scheduling
- Type: String
- Description: Optional configuration file for the module.

name

- Component: Agent and *SeD*
- Mode: All

- Type: String
- Description: The name of the element. This parameter is not mandatory for a *SeD* as it can generate a name during launch time.

neighbours

- Component: MA
- Mode: Multi MA
- Type: String
- Description: A list of Master Agent that must be contacted to build a federation. The format is a list of host:port.

parentName

- Component: LA and *SeD*
- Mode: All
- Type: String
- Description: the name of the agent to which the element will register. This agent must have registered at the same CORBA Naming Service that is pointed to by your ORB configuration.

pathToNFS

- Component: *SeD*
- Mode: Batch
- Type: String
- Description: Path to an NFS directory where you have read/write rights.

pathToTmp

- Component: *SeD*
- Mode: Batch
- Type: String
- Description: Path to a temporary directory where you have read/write rights.

restoreOnStart

- Component: Agent and SeD
- Mode: DAGDA
- Type: Boolean
- Description: DAGDA will load the *dataBackupFile* file at start and restore all the data recorded at the last checkpointing event. Possible values are 0 or 1. By default, no file loading on start - 0.

schedulerModule

- Component: Agent
- Mode: User scheduling
- Type: String
- Description: The path to the scheduler library file containing the implementation of the plugin scheduler class.

shareFiles

- Component: Agent
- Mode: DAGDA
- Type: Boolean
- Description: The DAGDA component shares its file data with all its children (when the path is accessible by them, for example, if the storage directory is on a NFS partition). Value can be 0 or 1. By default no file sharing - 0.

storageDirectory

- Component: All
- Mode: DAGDA or Batch
- Type: String
- Description: The directory on which DAGDA will store the data files. By default `/tmp` is used.

traceLevel

- Component: All
- Mode: All
- Type: Integer
- Description: traceLevel for the DIET agent:
  - 0 DIET do not print anything,
  - 1 DIET prints only warnings and errors on the standard error output,
  - 2 [default] DIET prints information on the main steps of a call,
  - 5 DIET prints information on all internal steps too,
  - 10 DIET prints all the communication structures too,
  - > 10 (traceLevel - 10) is given to the ORB to print CORBA messages too.

updateLinkPeriod

- Component: MA

- Mode: Multi MA
- Type: Integer
- Description: The agent check at a regular time basis that all it's neighbours are still alive and try to connect to a new one if the number of connections is less than *minimumNeighbours*. *updateLinkPeriod* indicate the period in second between two checks.

useConcJobLimit

- Component: *SeD*
- Mode: All
- Type: Boolean
- Description: should SeD restrict the number of concurrent solves? This should be used in conjunction with *maxConcJobs*.

useLogService

- Component: Agent and *SeD*
- Mode: All
- Type: Boolean
- Description: 1 to use the LogService for monitoring.

USE_SPECIFIC_SCHEDULING

- Component: Client
- Mode: Custom Client Scheduling (CCS)
- Type: String
- Description: This option specifies the scheduler the client will use whenever it submits a request:
  - BURST_REQUEST: round robin on the available *SeD*
  - BURST_LIMIT: only allow a certain number of request per *SeD* in parallel the limit can be set with "void setAllowedReqPerSeD(unsigned ix)"

Bibliography

[1] D. Arnold, S. Agrawal, S. Blackford, J. Dongarra, M. Miller, K. Sagi, Z. Shi, and S. Vadhiyar. Users' Guide to NetSolve V1.4. Computer Science Dept. Technical Report CS-01-467, University of Tennessee, Knoxville, TN, July 2001. http://www.cs.utk.edu/netsolve/.

[2] F. Cappello, F. Desprez, M. Dayde, E. Jeannot, Y. Jegou, S. Lanteri, N. Melab, R. Namyst, P. Primet, O. Richard, E. Caron, J. Leduc, and G. Mornet. Grid'5000: A large scale, reconfigurable, controlable and monitorable grid platform. In *Proceedings of the 6th IEEE/ACM International Workshop on Grid Computing, Grid'2005*, Seattle, Washington, USA, November 2005.

[3] Eddy Caron, Pushpinder Kaur Chouhan, and Frédéric Desprez. Automatic middleware deployment planning on heterogeneous platfoms. In *The 17th Heterogeneous Computing Workshop (HCW'08)*, Miami, Florida, April 2008. In conjunction with IPDPS 2008.

[4] Eddy Caron, Pushpinder Kaur Chouhan, and Arnaud Legrand. Automatic deployment for hierarchical network enabled server. In *The 13th Heterogeneous Computing Workshop (HCW 2004)*, page 109b (10 pages), Santa Fe. New Mexico, April 2004.

[5] Eddy Caron and Holly Dail. Godiet: a tool for managing distributed hierarchies of diet agents and servers. Research report 2005-06, Laboratoire de l'Informatique du Paralllisme (LIP), February 2005. Also available as INRIA Research Report RR-5520.

[6] Eddy Caron, Benjamin Depardon, and Frédéric Desprez. Modelization for the Deployment of a Hierarchical Middleware on a Heterogeneous Platform. Research Report RR-7309, INRIA, 06 2010. Also available as LIP Research Report RRLIP2010-19.

[7] Eddy Caron, Benjamin Depardon, and Frédéric Desprez. Modelization for the Deployment of a Hierarchical Middleware on a Homogeneous Platform. Research Report RR-7201, INRIA, 02 2010. Also available as LIP Research Report RRLIP2010-10.

[8] Eddy Caron and Frédéric Desprez. DIET: A scalable toolbox to build network enabled servers on the grid. *International Journal of High Performance Computing Applications*, 20(3):335–352, 2006.

[9] Condor-G. http://www.cs.wisc.edu/condor/condorg/.

[10] M.C. Ferris, M.P. Mesnier, and J.J. Mori. NEOS and Condor: Solving Optimization Problems Over the Internet. *ACM Transaction on Mathematical Sofware*, 26(1):1–18, 2000. http://www-unix.mcs.anl.gov/metaneos/publications/index.html.

[11] C. Germain, G. Fedak, V. Néri, and F. Cappello. Global computing systems. *Lecture Notes in Computer Science*, 2179:218–227, 2001.

[12] Globus. http://www.globus.org/.

[13] Sun GridEngine. http://wwws.sun.com/software/gridware/.

[14] GridRPC Working Group. https://forge.gridforum.org/projects/gridrpc-wg/.

[15] S. Matsuoka, H. Nakada, M. Sato, and S. Sekiguchi. Design Issues of Network Enabled Server Systems for the Grid. http://www.eece.unm.edu/~dbader/grid/WhitePapers/satoshi.pdf, 2000. Grid Forum, Advanced Programming Models Working Group whitepaper.

[16] Nagios. http://www.nagios.org.

[17] H. Nakada, S. Matsuoka, K. Seymour, J. Dongarra, C. Lee, and H. Casanova. GridRPC: A Remote Procedure Call API for Grid Computing. In *Grid 2002, Workshop on Grid Computing*, number 2536 in Lecture Notes in Computer Science, pages 274–278, Baltimore, MD, USA, November 2002.

[18] H. Nakada, M. Sato, and S. Sekiguchi. Design and Implementations of Ninf: towards a Global Computing Infrastructure. *Future Generation Computing Systems, Metacomputing Issue*, 15(5-6):649–658, 1999. http://ninf.apgrid.org/papers/papers.shtml.

[19] OMNIORB. http://www.uk.research.att.com/omniORB/.

[20] Andy Oram, editor. *Peer-to-Peer: Harnessing the Benefits of a Disruptive Technology*. O'Reilly, 2001.

[21] Federico D. Sacerdoti, Mason J. Katz, Matthew L. Massie, and David E Culler. Wide area cluster monitoring with ganglia, 2003.

[22] M. Sato, M. Hirano, Y. Tanaka, and S. Sekiguchi. OmniRPC: A Grid RPC Facility for Cluster and Global Computing in OpenMP. *Lecture Notes in Computer Science*, 2104:130–136, 2001.

[23] Keith Seymour, Hidemoto Nakada, Satoshi Matsuoka, Jack Dongarra, Craig Lee, and Henri Casanova. Overview of GridRPC: A Remote Procedure Call API for Grid Computing. In Manish Parashar, editor, *Grid Computing - GRID 2002, Third International Workshop, Baltimore, MD, USA, November 18, 2002, Proceedings*, volume 2536 of *LNCS*, pages 274–278. Springer, 2002.

[24] Haluk Topcuouglu, Salim Hariri, and Min you Wu. Performance-effective and low-complexity task scheduling for heterogeneous computing. *IEEE Trans. Parallel Distrib. Syst.*, 13(3):260–274, 2002.