# GLADE User's Guide

GLADE, GNAT Library for Ada Distributed Environment
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# GLADE User Guide

GLADE is the GNAT implementation of the Ada95 Distributed Systems Annex.

# About This Guide

## What This Guide Contains

This guide contains the following chapters:

- Chapter 1 [Introduction to Distributed Systems], page 5, describes different ways to develop systems that must run on networks of computers.
- Chapter 2 [The Distributed Systems Annex], page 9, discusses the features presented in Annex E of the Ada 95 language reference. This chapter provides a tutorial for beginners and includes several useful examples for more advanced programmers.
- Chapter 3 [Getting Started With GLADE], page 37, describes how to use the configuration tool `gnatdist`. It also describes in detail the GLADE Partition Communication Subsystem, GARLIC.
- Appendix A [DSA and CORBA], page 61, is a detailed comparison between the capabilities of CORBA and those of the Distributed System Annex.

# 1 Introduction to Distributed Systems

A distributed system architecture comprises a network of computers and the software components that execute on those computers. Such architectures are commonly used to improve the performance, reliability, and reusability of complex applications. Typically, there is no shared address space available to remotely-located components (that is to say, components running on different nodes of the network), and therefore these components must communicate using some form of message-passing.

## 1.1 Using OS Network Services

There are several programming techniques for developing distributed applications. These applications have traditionally been developed using network programming interfaces such as sockets. Programmers explicitly have to perform calls to operating system services, a task that can be tedious and error-prone. This includes initializing socket connection and determining peer location, marshaling and unmarshaling data structures, sending and receiving messages, debugging and testing several programs at the same time, and porting the application to several platforms to uncover subtle differences between various network interfaces.

Of course, this communication code can be encapsulated in wrappers to reduce its complexity, but it is clear that most of it can be automatically generated. Message passing diverts developer's attention from the application domain. The query and reply scenario is a classical scheme in distributed applications; using message passing for such a scheme can be compared to using a "goto" mechanism in a non-distributed application. This is considered unacceptable methodology in modern software engineering. A more robust design is be to use a structured approach based on procedure calls.

In some respects, network programming can be compared to the multi-threading programming issue. The user can decide to split his code into several pieces and to multiplex the thread executions himself, using a table-driven model. The scheduling code ends up embedded into the user code. This solution is error-prone and fragile in regard to any future modification. Relying on an implementation of threads such as provided in POSIX is a better solution. Relying on language primitives that support concurrency, such as Ada tasks, is best.

## 1.2 Using a Middleware Environment

A middleware environment is intended to provide high level abstractions in order to easily develop user applications. Environments like CORBA or Distributed Computing Environment (DCE) provide a framework to develop client/server applications based on the Remote Procedure Call model (RPC). The RPC model is inspired from the query and reply scheme. In rough analogy with a regular procedure call, arguments are pushed onto a stream, along with some data specifying the remote procedure to be executed. The stream is transmitted over the network to the server. The server decodes the stream, performs the regular subprogram call locally, and then puts the output parameters into another stream, along with the exception (if any) raised by the subprogram execution. The server then sends this stream back to the caller. The caller decodes the stream and raises locally the exception if needed.

CORBA provides the same enhancements to the remote procedure model that object-oriented languages provide to classical procedural languages. These enhancements include encapsulation, inheritance, type checking, and exceptions. These features are offered through an Interface Definition Language (IDL).

The middleware communication framework provides all the machinery to perform, somewhat transparently, remote procedure calls or remote object method invocations. For instance, each CORBA interface communicates through an Object Request Broker (ORB). A communication subsystem such as an ORB is intended to allow applications to use objects without being aware of their underlying message-passing implementation. In addition. the user may also require a number of more complex services to develop his distributed application. Some of these services are indispensable, for example a location service that allows clients to reference remote services via higher level names, instead of a traditional scheme for addressing remote services that use Internet host addresses and communication port numbers. Other services provide domain-independent interfaces that are frequently used by distributed applications.

If we return to the multi-thread programming comparison, the middleware solution is close to what a POSIX library or a language like Esterel[1] would provide for developing concurrent applications. A middleware framework like DCE is close to a POSIX library in terms of abstraction levels. Functionalities are very low-level and very complex. CORBA is closer to Esterel in terms of development process. The control part of the application can be specified in a description language. The developer then has to fill-in automatically generated source code templates (stub and skeletons) to build the computational part of the application. The distribution is a pre-compilation process and the distributed boundaries are always explicit. Using CORBA, the distributed part is written in IDL and the core of the application is written in a host language such as C++.

## 1.3 Using a Distributed Language

Rather than defining a new language like the CORBA IDL, an alternative is to extend an existing programming language with the addition of distributed features. The distributed object paradigm provides a more object-oriented approach to programming distributed systems. The notion of a distributed object is an extension to the abstract data type that allows the services provided in the type interface to be called independently of where the actual service is executed. When combined with object-oriented features such as inheritance and polymorphism, distributed objects offer a more dynamic and structured computational environment for distributed applications.

The Distributed Systems Annex (DSA) of Ada95 defines several extensions that allow the user to write a distributed system entirely in Ada. The types of distributed objects, the services they provide, and the bodies of the remote methods to be executed are all defined in conventional Ada packages. The Ada95 model is analogous the Java/RMI model. In both languages, the IDL is replaced by well-defined language constructs. Therefore, the language

[1] `ESTEREL` is an imperative synchronous language designed for the specification and the development of reactive systems.

supports both remote procedure calls and remote object method invocations transparently, and the semantics of distribution are consistent with the rest of the language.

A program written in such a language is intended to communicate with a program written in the same language, but this apparent restriction has several useful consequences. The language can provide more powerful features because it is not constrained by the common features available in all host languages. In Ada95, the user will define a specification of remote services and implement them exactly as he would for ordinary, non-distributed services. His Ada95 environment will compile them to produce a stub file (on the caller side) and a skeleton file that automatically includes the body of the services (on the receiver side). Creating objects, obtaining or registering object references or adapting the object skeleton to the user object implementation are made transparent because the language environment has a full control on the development process.

Comparing with multi-thread programming once again, the language extension solution is equivalent to the solution adopted for tasking facilities in Ada. Writing a distributed application is as simple as writing a concurrent application: there is no binding consideration and no code to wrap. The language and its run-time system take care of most issues that would divert the programmer's attention from the application domain.

# 2 The Distributed Systems Annex

A critical feature of the Distributed Systems Annex (DSA) is that it allows the user to develop his application the same way whether this application is going to be executed as several programs on a distributed system, or as a single program on a non-distributed system. The DSA has been designed to minimize the source changes needed to convert an ordinary non-distributed program into a distributed program.

The simplest way to start with DSA is to develop the application on a non-distributed system. Of course, the design of the application should take into account the fact that some units are going to be accessed remotely. In order to write an Ada95 distributed program, it is necessary for the user to label by means of categorization pragmas some of library level compilation units of the application program. The units which require categorization are typically those that are called remotely, and those that provide the types used in remote invocations.

In order to insure that distributed execution is possible, these units are restricted to contain only a limited set of Ada constructs. For instance, if the distributed system has no shared memory, shared variables must be forbidden. To specify the nature of these restrictions, the DSA provides different categorization pragmas, each of which excludes some language constructs from the categorized package.

Of course, the user can develop the non-distributed application with his usual software engineering environment. It is critical to note that the user needs no specialized tools to develop his/her distributed application. For instance, he can debug his application with the usual debugger. Note that a non-distributed program is not to be confused with a distributed application composed of only one program. The later is built with the help of the configuration tool and includes the communication library.

Once the non-distributed version of the program is complete, it has to be configured into separate partitions, This step is surprisingly simple, compared to that of developing the application itself. The configuration step consists in mapping sets of compilation units into individual partitions, and specifying the mapping between partitions and nodes in the computer network. This mapping is specified and managed by means of GLADE.

The distributed version of the user application should work as is, but even when a program can be built both as a non-distributed or a distributed program using the same source code, there may still be differences in program execution between the distributed and non-distributed versions. These differences are discussed in subsequent sections (see Section 2.7.4 [Pragma Asynchronous], page 23 and Section 2.7.5 [Pragma All_Calls_Remote], page 26).

Developping a non-distributed application in order to distribute it later is the natural approach for a novice. Of course, it is not always possible to write a distributed application as a non-distributed application. For instance, a client/server application does not belong to this category because several instances of the client can be active at the same time. It is very easy to develop such an application using GLADE; we shall describe how to do this in the following sections.

## 2.1 Architecture of a Distributed Ada95 Application

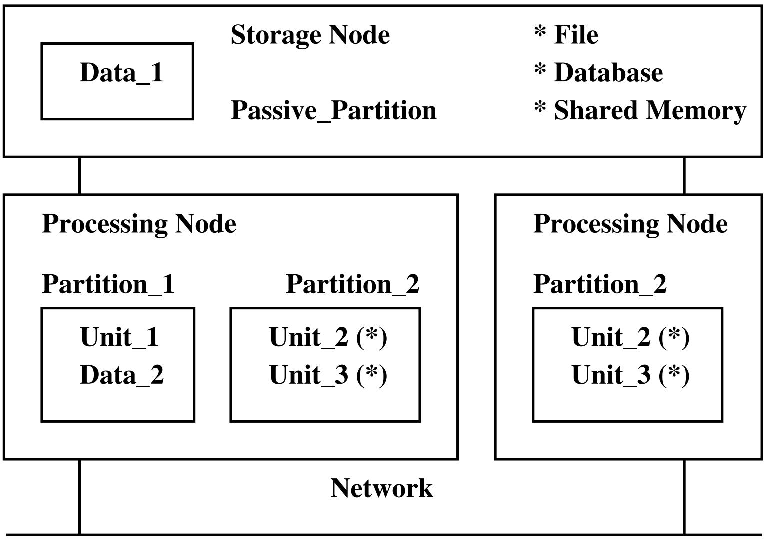
A distributed system is an interconnection of one or more processing nodes and zero or more storage nodes. A distributed program comprises one or more partitions. A partition is an aggregate of library units. Partitions communicate through shared data or RPCs. A passive partition has no thread of control. Only a passive partition can be configured on a storage node. An active partition has zero or more threads of control and has to be configured on a processing node.

The library unit is the core component of an Ada95 distributed application. The user can explicitly assign library units to a partition. Partitioning is a post-compilation process. The user identifies interface packages at compile-time. These packages are categorized using pragmas. Each of these pragmas supports the use of one of the following classical paradigms:

- Remote subprograms: For the programmer, a remote subprogram call is similar to a regular subprogram call. Run-time binding using access-to-subprogram types can also be used with remote subprograms. These remote subprograms are mostly declared in library units categorized as remote call interface (RCI).
- Distributed objects: Special-purpose access types can be defined which designate remote objects. When a primitive dispatching operation is invoked on an object designated by such a remote access, a remote call is performed transparently on the partition on which the object resides. The types of these distributed objects are declared in library units categorized as remote types (RT).
- Shared objects: Global data can be shared between active partitions, providing a repository similar to a shared memory, a shared file system or a database. Entry-less protected objects allow safe concurrent access and update shared objects. This feature is orthogonal to the notion of distributed objects, which are only accessed through exported services. These shared objects are declared in library units categorized as shared passive (SP).

The remotely-called subprograms declared in a library unit categorized as remote call interface (RCI) or remote types (RT) may be either statically or dynamically bound. The partition on which a statically bound remote subprogram is executed can be determined before the call. This is a static remote subprogram call. In contrast, A remote method or a dereference of an access to remote subprogram are dynamically bound remote calls, because the partition on which the remote subprogram is executed is determined at runtime, by the actuals of the call.

In the following example, Data_1 and Data_2 are shared passive (SP) library units. Data_1 is configured on a passive partition mapped on a storage node. Partition_1 and Partition_2 are active partitions. Note that under some circumstances, a partition, for instance Partition_2, can be duplicated. To be duplicated, Unit_2 and Unit_3 which are configured on Partition_2 have to provide only dynamically bound remote subprograms. Otherwise, a partition calling a remote subprogram on Unit_2 would not be able to statically determine where to perform the remote call between the two instances of Unit_2.


Data_1
Storage Node
Passive_Partition
* File
* Database
* Shared Memory
Processing Node
Partition_1
Partition_2
Unit_1
Data_2
Unit_2 (*)
Unit_3 (*)
Processing Node
Partition_2
Unit_2 (*)
Unit_3 (*)
Network

## 2.2 Categorization Pragmas

Library units can be categorized according to the role they play in a distributed program. A categorization pragma is a library unit pragma that restricts the kinds of declarations that can appear in a library unit and possibly in its child units, as well as the legal semantic dependences that the categorized unit can have. There are several categorization pragmas :

- Remote_Call_Interface
- Remote_Types
- Shared_Passive
- Pure

The following paragraphs do not present the detailed semantics of these pragmas (formal details will be found in the Ada95 Reference Manual). Their purpose is to give the reader an intuitive overview of the purpose of these pragmas. If a library unit is not categorized, this unit is called a normal unit and plays no special role in the distributed application. Such a unit is duplicated on any partition in which it is mentioned.

A parenthetical remark: to avoid the need for specific run-time libraries for the DSA, the notion of remote rendez-vous has not been introduced in Ada95: tasks cannot be invoked directly from one partition to another. Therefore, declarations of task types and general protected types with entries are not allowed in categorized Ada library units.

## 2.3 Pragma Declared Pure

This pragma is not specific to the Distributed Systems Annex. A pure package can appear in the context of any package, categorized or not. A pure package is a preelaborable package that does not contain the declaration of any variable or named access type. It is particularly useful to define types, constants and subprograms shared by several categorized packages. In contrast, normal packages cannot appear in the context of categorized package declarations. Because a pure package has no state, it can be duplicated on several partitions.

## 2.4 Pragma Remote_Call_Interface

### 2.4.1 Overview of Pragma Remote_Call_Interface

Library units categorized with this pragma declare subprograms that can be called and executed remotely. An RCI unit acts as a server for remote calls. There is no memory space shared between server and clients. A subprogram call that invokes one such subprogram is a classical RPC operation; it is a statically bound operation, because the compiler can determine the identity of the subprogram being called.

Dynamically bound calls are provided through two mechanisms:

- The dereference of an access_to_subprogram value, i.e. a value whose type is a remote_access_to_subprogram (RAS).
- A dispatching call whose controlling argument is an access-to-class-wide operand, (remote access on class wide types - RACW). These remote access types can be declared in a RCI package as well.

A remote access type (RAS or RACW) can be viewed as a fat pointer, that is to say a structure with a remote address and a local address (like an URL: `<protocol>`://-`<remote-machine>/<local-directory>`). The remote address must denote the host of the partition on which the entity has been created; the local address describes the local memory address within the host.

It is very unlikely that RCI units can be duplicated in the distributed system. An implementation may allow separate copies of a RCI unit as long as it ensures that the copies present a consistent state to all clients. In the general case, preserving consistency is very costly. For this reason, the implementation may require a RCI unit to be unique in the distributed system.

### 2.4.2 Regular Remote Subprograms (RCI)

In the following example, a RCIBank offers several remote services: Balance, Transfert, Deposit and Withdraw. On the caller side, the bank client uses the stub files of unit RCIBank. On the receiver side, the bank receiver uses the skeleton files of unit RCIBank including the body of this package.

```
package Types is
   pragma Pure;

   type Customer_Type is new String;
   type Password_Type is new String;
end Types;
```

```
with Types; use Types;
package RCIBank is
   pragma Remote_Call_Interface;

   function Balance
     (Customer : in Customer_Type;
      Password : in Password_Type)
      return Integer;

   procedure Transfer
     (Payer    : in Customer_Type;
      Password : in Password_Type;
      Amount   : in Positive;
      Payee    : in Customer_Type);

   procedure Deposit
```

```
     (Customer : in Customer_Type;
      Amount   : in Positive);

   procedure Withdraw
     (Customer : in Customer_Type;
      Password : in Password_Type;
      Amount   : in out Positive);
end RCIBank;


with Types; use Types;
with RCIBank; use RCIBank;
procedure RCIClient is
   B : Integer;
   C : Customer_Type := "rich";
   P : Password_Type := "xxxx";
begin
   B := Balance (C, P);
end RCIClient;
```

### 2.4.3 Remote Access to Subprograms (RAS)

In the following example, several mirroring banks offer their services through the same database. Each bank registers a reference to each of its services with a central bank. A client of the central bank requests a service from one of the mirroring banks. To satisfiy requests, the RCI unit RASBank defines Balance_Type, a remote access to subprogram (Recall that an access type declared in a remote unit has to be either remote access to subprogram or remote access to class wide type).

Note that to obtain a remote access to subprogram, the subprogram that delivers the remote access must be remote itself. Therefore, MirrorBank is a RCI library unit.

```
with Types; use Types;
package RASBank is
   pragma Remote_Call_Interface;

   type Balance_Type is access function
     (Customer : in Customer_Type;
      Password : in Password_Type)
      return Integer;

   procedure Register
      (Balance : in Balance_Type);

   function Get_Balance
      return Balance_Type;

   --  [...] Other services
```

```
end RASBank;
```

In the code below, a mirroring bank registers its services to the central bank.

```
with Types; use Types;
package MirrorBank is
   pragma Remote_Call_Interface;

   function Balance
     (Customer : in Customer_Type;
      Password : in Password_Type)
      return Integer;

   --  [...] Other services
end MirrorBank;


with RASBank, Types; use RASBank, Types;
package body MirrorBank is

   function Balance
     (Customer : in Customer_Type;
      Password : in Password_Type)
      return Integer is
   begin
      return Something;
   end Balance;

begin
   --  Register a dynamically bound remote subprogram (Balance)
   --  through a statically bound remote subprogram (Register)
   Register (Balance'Access);
   --  [...] Register other services
end MirrorBank;
```

In the code below, a central bank client asks for a mirroring bank and calls the Balance service of this bank by dereferencing a remote access type.

```
with Types; use Types;
with RASBank; use RASBank;
procedure BankClient is
   B : Integer;
   C : Customer_Type := "rich";
   P : Password_Type := "xxxx";
begin
   --  Through a statically bound remote subprogram (Get_Balance), get
   --  a dynamically bound remote subprogram. Dereference it to
   --  perform a dynamic invocation.
```

```
   B := Get_Balance.all (C, P);
end BankClient;
```

### 2.4.4 Remote Access to Class Wide Types (RACW)

A bank client is now connected to a bank through a terminal. The bank wants to notify a connected client, bu means of a message on its terminal, when another client transfers a given amount of money to his account. In the following example, a terminal is designed as a distributed object. Each bank client will register its terminal object to the bank server for further use. In the code below, Term_Type is the root type of the distributed terminal hierarchy.

```
with Types; use Types;
package Terminal is
   pragma Pure;

   type Term_Type is abstract tagged limited private;

   procedure Notify
     (MyTerm   : access Term_Type;
      Payer    : in Customer_Type;
      Amount   : in Integer) is abstract;

private
   type Term_Type is abstract tagged limited null record;
end Terminal;
```

In the code below, the RCI unit RACWBank defines Term_Access, a remote access to class wide type. Term_Access becomes a reference to a distributed object. In the next section, we will see how to derive and extend Term_Type, how to create a distributed object and how to use a reference to it.

```
with Terminal, Types; use Terminal, Types;
package RACWBank is
   pragma Remote_Call_Interface;

   type Term_Access is access all Term_Type'Class;

   procedure Register
     (MyTerm   : in Term_Access;
      Customer : in Customer_Type;
      Password : in Password_Type);

   --  [...] Other services
end RACWBank;
```

### 2.4.5 Summary on Pragma Remote_Call_Interface

Remote call interface units:

- Allow subprograms to be called and executed remotely
- Allow statically bound remote calls (remote subprogram)
- Allow dynamically bound remote calls (remote access types)
- Forbid variables and non-remote access types
- Prevent specification from depending on normal units

## 2.5 Pragma Remote_Types

### 2.5.1 Overview of Pragma Remote_Types

Unlike RCI units, library units categorized with this pragma can define distributed objects and remote methods on them. Both RCI and RT units can define a remote access type as described above (RACW). A subprogram defined in a RT unit is not a remote subprogram. Unlike RCI units, a RT unit can be duplicated on several partitions in which case all its entities are different with each other. This unit is different on each partition in which it is defined.

### 2.5.2 Distributed Object

If we want to implement the notification feature proposed in the previous section, we have to derive Term_Type. Such a derivation is possible in a remote types unit like NewTerminal (see below). Any object of type New_Term_Type becomes a distributed object and any reference to such an object becomes a fat pointer or a reference to a distributed object (see Term_Access declaration in Section 2.4.4 [Remote Access to Class Wide Types (RACW)], page 16).

```
with Types, Terminal; use Types, Terminal;
package NewTerminal is
   pragma Remote_Types;

   type New_Term_Type is
      new Term_Type with null record;

   procedure Notify
     (MyTerm   : access New_Term_Type;
      Payer    : in Customer_Type;
      Amount   : in Integer);

   function Current return Term_Access;
end NewTerminal;
```

In the code below, a client registers his name and his terminal with RACWBank. Therefore, when any payer transfers some money to him, RACWBank is able to notify the client of the transfer of funds.

```
with NewTerminal, RACWBank, Types; use NewTerminal, RACWBank, Types;
procedure Term1Client is
   MyTerm   : Term_Access   := Current;
   Customer : Customer_Type := "poor";
   Password : Password_Type := "yyyy";
begin
   Register (MyTerm, Customer, Password);
   --  [...] Execute other things
end Term1Client;
```

In the code below, a second client, the payer, registers his terminal to the bank and executes a transfer to the first client.

```
with NewTerminal, RACWBank, Types; use NewTerminal, RACWBank, Types;
procedure Term2Client is
   MyTerm   : Term_Access   := Current;
   Payer    : Customer_Type := "rich";
   Password : Password_Type := "xxxx";
   Payee    : Customer_Type := "poor";
begin
   Register (MyTerm, Payer, Password);
   Transfer (Payer, Password, 100, Payee);
end Term2Client;
```

In the code below, we describe the general design of Transfer. Classical operations of Withdraw and Deposit are performed. Then, RACWBank retrieves the terminal of the payee (if present) and invokes a dispatching operation by dereferencing a distributed object Term. The reference is examined at run-time, and the execution of this operation takes place on the partition on which the distributed object resides.

```
with Types; use Types;
package body RACWBank is
   procedure Register
     (MyTerm   : in Term_Access;
      Customer : in Customer_Type;
      Password : in Password_Type) is
   begin
      Insert_In_Local_Table (MyTerm, Customer);
   end Register;

   procedure Transfer
     (Payer    : in Customer_Type;
      Password : in Password_Type;
      Amount   : in Positive;
      Payee    : in Customer_Type)
   is
      --  Find Customer terminal.
```

```
      Term : Term_Access
        := Find_In_Local_Table (Payee);
   begin
      Withdraw (Payer, Amount);
      Deposit  (Payee, Amount);
      if Term /= null then
         --  Notify on Payee terminal.
         Notify (Term, Payer, Amount);
      end if;
   end Transfer;

   --  [...] Other services
end RACWBank;
```

### 2.5.3 Transmitting Dynamic Structure

```
with Ada.Streams; use Ada.Streams;
package StringArrayStream is
   pragma Remote_Types;

   type List is private;
   procedure Append (L : access List; O : in String);
   function  Delete (L : access List) return String;

private
   type String_Access is access String;

   type Node;
   type List is access Node;

   type Node is record
      Content : String_Access;
      Next    : List;
   end record;

   procedure Read
     (S : access Root_Stream_Type'Class;
      L : out List);
   procedure Write
     (S : access Root_Stream_Type'Class;
      L : in List);
   for List'Read use Read;
   for List'Write use Write;
end StringArrayStream;
```

Non-remote access types cannot be declared in the public part of a remote types unit. However, it is possible to define private non-remote access types as long as the user provides its marshalling procedures, that is to say the mechanism needed to place a value of the type into a communication stream. The code below describes how to transmit a linked structure.

The package declaration provides a type definition of single-linked lists of unbounded strings. An implementation of the marshalling operations could be the following:

```
package body StringArrayStream is
   procedure Read
     (S : access Root_Stream_Type'Class;
      L : out List) is
   begin
      if Boolean'Input (S) then
         L := new Node;
         L.Content := new String'(String'Input (S));
         List'Read (S, L.Next);
      else
         L := null;
      end if;
   end Read;

   procedure Write
     (S : access Root_Stream_Type'Class;
      L : in List) is
   begin
      if L = null then
         Boolean'Output (S, False);
      else
         Boolean'Output (S, True);
         String'Output (S, L.Content.all);
         List'Write (S, L.Next);
      end if;
   end Write;

   --  [...] Other services
end StringArrayStream;
```

### 2.5.4 Summary on Remote Types Units

Remote types units:

- Support the definition of distributed objects
- Allow dynamically bound remote calls (via remote access types)
- Allow non-remote access type (with marshalling subprograms)
- Cannot have a specification that depends on normal units

## 2.6 Pragma Shared_Passive

### 2.6.1 Overview of Pragma Shared_Passive

The entities declared in such a categorized library unit are intended to be mapped on a virtual shared address space (file, memory, database). When two partitions use such a library unit, they can communicate by reading or writing the same variable in the shared unit. This supports the conventional shared variables paradigm. Entryless protected objects can be declared in these units, to provide an atomic access to shared data, thus implementing a simple transaction mechanism. When the address space is a file or a database, the user can take advantage of the persistency features provided by these storage nodes.

### 2.6.2 Shared and Protected Objects

In the code below, we define two kinds of shared objects. External_Synchronization requires that the different partitions updating this data synchronize to avoid conflicting operations on shared objects. Internal_Synchronization provides a way to get an atomic operation on shared objects. Note that only entry-less subprograms are allowed in a shared passive unit.

```
package SharedObjects is
   pragma Shared_Passive;

   Max : Positive := 10;
   type Index_Type is range 1 .. Max;
   type Rate_Type is new Float;

   type Rates_Type is array (Index_Type) of Rate_Type;

   External_Synchronization : Rates_Type;

   protected Internal_Synchronization is
      procedure Set
        (Index : in Index_Type;
         Rate  : in Rate_Type);

      procedure Get
        (Index : in Index_Type;
         Rate  : out Rate_Type);
   private
      Rates : Rates_Type;
   end Internal_Synchronization;
end SharedObjects;
```

### 2.6.3 Summary on Pragma Shared_Passive

- Allow direct access to data from different partitions
- Provide support for shared (distributed) memory
- Support memory protection by means of entryless protected objects

- Prevent specification from depending on normal units

## 2.7 More About Categorization Pragmas

### 2.7.1 Variables and Non-Remote Access Types

In RT or RCI package declarations, variable declarations are forbidden, and non-remote access types are allowed as long as their marshaling subprograms are explicitly provided (see Section 2.5.3 [Transmitting Dynamic Structure], page 19)..

### 2.7.2 RPC Failures

Calls are executed at most once: they are made exactly one time or they fail with an exception. When a communication error occurs, *System.RPC.Communication_Error* is raised.

### 2.7.3 Exceptions

Any exception raised in a remote method or subprogram call is propagated back to the caller. Exceptions semantics are preserved in the regular Ada way.

```
package Internal is
   Exc : exception;
end Internal;


package RemPkg2 is
   pragma Remote_Call_Interface;

   procedure Subprogram;
end RemPkg2;


package RemPkg1 is
   pragma Remote_Call_Interface;

   procedure Subprogram;
end RemPkg1;
```

Let us say that RemPkg2, Internal and RemExcMain packages are on the same partition Partition_1 and that RemPkg1 is on partition Partition_2.

```
with RemPkg1, Ada.Exceptions; use Ada.Exceptions;
package body RemPkg2 is
   procedure Subprogram is
   begin
      RemPkg1.Subprogram;
```

```
      exception when E : others =>
         Raise_Exception (Exception_Identity (E), Exception_Message (E));
      end Subprogram;
   end RemPkg2;
```

```
   with Internal, Ada.Exceptions; use Ada.Exceptions;
   package body RemPkg1 is
      procedure Subprogram is
      begin
         Raise_Exception (Internal.Exc'Identity, "Message");
      end Subprogram;
   end RemPkg1;
```

```
   with Ada.Text_IO, Ada.Exceptions; use Ada.Text_IO, Ada.Exceptions;
   with RemPkg2, Internal;
   procedure RemExcMain is
   begin
      RemPkg2.Subprogram;
   exception when E : Internal.Exc =>
      Put_Line (Exception_Message (E)); -- Output "Message"
   end RemExcMain;
```

When RemPkg1.Subprogram on Partition_1 raises Internal.Exc, this exception is propagated back to Partition_2. As Internal.Exc is not defined on Partition_2, it is not possible to catch this exception without an exception handler **when others**. When this exception is reraised in RemPkg1.Subprogram, it is propagated to Partition_1. But this time, Internal.Exc is visible and can be handled as we would in a single-partition Ada program. Of course, the exception message is also preserved.

### 2.7.4 Pragma Asynchronous

By default, a remote call is blocking: the caller waits until the remote call is complete and the output stream is received. By contrast. a remote subprogram labelled with pragma Asynchronous allows statically and dynamically bound remote calls to it to be executed asynchronously. A call to an asynchronous procedure doesn't wait for the completion of the remote call, and lets the caller continue its execution. The remote procedure must have only **in** parameters, and any exception raised during the execution of the remote procedure is lost.

When pragma Asynchronous applies to a regular subprogram with **in** parameters, any call to this subprogram will be executed asynchronously. The following declaration of AsynchronousRCI.Asynchronous gives an example.

```
   package AsynchronousRCI is
      pragma Remote_Call_Interface;
```

```
   procedure Asynchronous (X : Integer);
   pragma Asynchronous (Asynchronous);

   procedure Synchronous  (X : Integer);

   type AsynchronousRAS is access procedure (X : Integer);
   pragma Asynchronous (AsynchronousRAS);
end AsynchronousRCI;


package AsynchronousRT is
   pragma Remote_Types;

   type Object is tagged limited private;

   type AsynchronousRACW is access all Object'Class;
   pragma Asynchronous (AsynchronousRACW);

   procedure Asynchronous (X : Object);
   procedure Synchronous  (X : in out Object);
   function Create return AsynchronousRACW;

private
   type Object is tagged limited null record;
end AsynchronousRT;
```

A pragma Asynchronous applies to a Remote Access_to_Subprogram (RAS). An asynchronous RAS can be both asynchronous and synchronous depending on the designated subprogram. For instance, in the code below, remote call (1) is asynchronous but remote call (2) is synchronous.

A pragma Asynchronous applies to a RACW as well. In this case, the invocation of **any** method with in parameters is **always** performed asynchronously. Remote method invocation (3) is asynchronous but remote method invocation (4) is synchronous.

```
with AsynchronousRCI, AsynchronousRT;
use AsynchronousRCI, AsynchronousRT;
procedure AsynchronousMain is
   RAS  : AsynchronousRAS;
   RACW : AsynchronousRACW := Create;
begin
   --  Asynchronous Dynamically Bound Remote Call (1)
   RAS := AsynchronousRCI.Asynchronous'Access;
   RAS (0);  --  Abbrev for RAS.all (0)
   --  Synchronous Dynamically Bound Remote Call (2)
   RAS := AsynchronousRCI.Synchronous'Access;
   RAS (0);
   --  Asynchronous Dynamically Bound Remote Call (3)
   Asynchronous (RACW.all);
```

```
   --  Synchronous Dynamically Bound Remote Call (4)
   Synchronous (RACW.all);
end AsynchronousMain;
```

This feature supports the conventional message passing paradigm. The user must be aware that this paradigm, and asynchronous remote calls in particular, has several drawbacks:

- It violates original (remote) procedure semantics
- It allows the equivalent of a remote GOTO mechanism
- It prevents easy development and debugging in a non-distributed context
- It can introduce potential race conditions

To illustrate the latter, let us take the following example:

```
package Node2 is
   pragma Remote_Call_Interface;

   procedure Send (X : Integer);
   pragma Asynchronous (Send);
end Node2;


package body Node2 is
   V : Integer := 0;
   procedure Send (X : Integer) is
   begin
      V := X;
   end Send;
end Node2;


package Node1 is
   pragma Remote_Call_Interface;

   procedure Send (X : Integer);
   pragma Asynchronous (Send);
end Node1;


with Node2;
package body Node1 is
   procedure Send (X : Integer) is
   begin
      Node2.Send (X);
   end Send;
end Node1;
```

```
with Node1, Node2;
procedure NonDeterministic is
begin
   Node1.Send (1);
   Node2.Send (2);
end NonDeterministic;
```

Let us say that Main is configured on Partition_0, Node1 on Partition_1 and Node2 on Partition_2. If Node1.Send and Node2.Send procedures were synchronous or if no latency was introduced during network communication, we would have the following RPC order: Main remotely calls Node1.Send which remotely calls Node2.Send which sets V to 1. Then, Main remotely calls Node2.Send and sets V to 2.

Now, let us assume that both Send procedures are asynchronous and that the connection between Partition_1 and Partition_2 is very slow. The following scenario can very well occur. Main remotely calls Node1.Send and is unblocked. Immediatly after this call, Main remotely calls Node2.Send and sets V to 2. Once this is done, the remote call to Node1.Send completes on Partition_1 and it remotely calls Node2.Send which sets V to 1.

### 2.7.5 Pragma All_Calls_Remote

A pragma All_Calls_Remote in a RCI unit forces remote procedure calls to be routed through the communication subsystem even for a local call. This eases the debugging of an application in a non-distributed situation that is very close to the distributed one, because the communication subsystem (including marshalling and unmarshalling procedures) can be exercised on a single node.

In some circumstances, a non-distributed application can behave differently than an application distributed on only one partition. This can happen when both All_Calls_Remote and Asynchronous features are used at the same time (see Section 2.7.4 [Pragma Asynchronous], page 23 for an example). Another circumstance occur when the marshalling operations raise an exception. In the following example, when unit ACRRCI is a All_Calls_Remote package, the program raises Program_Error. When unit ACRRCI is no longer a All_Calls_Remote package, then the program completes silently.

```
with Ada.Streams; use Ada.Streams;
package ACRRT is
   pragma Remote_Types;
   type T is private;
private
   type T is new Integer;
   procedure Read
     (S : access Root_Stream_Type'Class;
      X : out T);
   procedure Write
     (S : access Root_Stream_Type'Class;
      X : in T);
   for T'Read  use Read;
```

```
   for T'Write use Write;
end ACRRT;


package body ACRRT is
   procedure Read
     (S : access Root_Stream_Type'Class;
      X : out T) is
   begin
      raise Program_Error;
   end Read;

   procedure Write
     (S : access Root_Stream_Type'Class;
      X : in T) is
   begin
      raise Program_Error;
   end Write;
end ACRRT;


with ACRRT; use ACRRT;
package ACRRCI is
   pragma Remote_Call_Interface;
   pragma All_Calls_Remote;

   procedure P (X : T);
end ACRRCI;


package body ACRRCI is
   procedure P (X : T) is
   begin
      null;
   end P;
end ACRRCI;


with ACRRCI, ACRRT;
procedure ACRMain is
   X : ACRRT.T;
begin
   ACRRCI.P (X);
end ACRMain;
```

### 2.7.6 Generic Categorized Units

```
generic
package GenericRCI is
   pragma Remote_Call_Interface;

   procedure P;
end GenericRCI;
```

```
with GenericRCI;
package RCIInstantiation is new GenericRCI;
pragma Remote_Call_Interface (RCIInstantiation);
```

```
with GenericRCI;
package NormalInstantiation is new GenericRCI;
```

Any of these categorized units can be generic. Instances do not automatically inherit the categorization of their generic units, and they can be categorized explicitly, If they are not, instances are normal compilation units. Like any other categorized unit, a categorized instance must be at the library level, and regular restrictions of categorized units apply on instantiation (in particular on generic formal parameters).

### 2.7.7 Categorization Unit Dependencies

Each categorization pragma has very specific visibility rules. As a general rule, RCI > RT > SP > Pure, where the comparison indicates allowed semantic dependencies. This means that a Remote_Types package can make visible in its specification only Remote_Types, Shared_Passive and Pure units.

## 2.8 Partition Communication Subsystem

### 2.8.1 Marshalling and Unmarshalling Operations

The Partition Communication Subsystem (PCS) marshalls and unmarshalls caller and server data into a stream of type *System.RPC.Params_Stream_Type*:

```
type Params_Stream_Type
  (Initial_Size : Ada.Streams.Stream_Element_Count) is new
    Ada.Streams.Root_Stream_Type with private;
```

This type is a container for the data to be transmitted between partitions. Its root is *Root_Stream_Type*, which defines the basic stream type and two abstract operations, *Write* and *Read*. Its purpose is to insert / remove objects of type *Stream_Element_Array* which are array of bytes representing a particular data.

Streams are read and written using four attributes:

- Write: write an element into a stream, valid only for constrained types
- Read: read a constrained element from a stream
- Output: same as Write, but write bounds and discriminants as well if needed
- Input: same as Read, but read bounds and discriminants from the stream (the Input attribute denotes a function)

An Ada compiler provides default 'Read and 'Write operations. But it is up to the implementation of the PCS to provide default 'Read and 'Write to ensure proper operation between heterogeneous architectures (see Section 3.9.2 [Heterogeneous System], page 58).

The user can overload these operations, except for predefined types. Overloading with a textual version provides the user with a way to debug its application (even outside of the Distributed Systems Annex).

```
with Ada.Streams; use Ada.Streams;
package New_Integers is
   pragma Pure;

   type New_Integer is new Integer;

   procedure Read
     (S : access Root_Stream_Type'Class;
      V : out New_Integer);
   procedure Write
     (S : access Root_Stream_Type'Class;
      V : in New_Integer);

   for New_Integer'Read  use Read;
   for New_Integer'Write use Write;
end New_Integers;
```

```
package body New_Integers is
   procedure Read
     (S : access Root_Stream_Type'Class;
      V : out New_Integer)
   is
      B : String := String'Input (S);
   begin
      V := New_Integer'Value (B);
   end Read;

   procedure Write
     (S : access Root_Stream_Type'Class;
      V : in New_Integer)
   is
   begin
      String'Output (S, New_Integer'Image (V));
   end Write;
```

```
end New_Integers;
```

The language forces the user to provide read and write opertions for non-remote access types. Transmitting an access value by dumping its content into a stream makes no sense when it is going to be transmitted to another partition (different memory spaces). To transmit non-remote access types see Section 2.5.3 [Transmitting Dynamic Structure], page 19.

### 2.8.2 Incorrect Remote Dispatching

When a remote subprogram takes a class wide argument, there is a risk of using an object of a derived type that will not be clean enough to be transmitted. For example, given a type called Root_Type, if a remote procedure takes a Root_Type'Class as an argument, the user can call it with an instance of Derived_Type that is Root_Type enriched with a field of a task type. This will lead to a non-communicable type to be transmitted between partitions.

To prevent this, paragraph E.4(18) of the reference manual explains that any actual type used as parameter for a remote call whose formal type is a class wide type must be declared in the visible part of a Pure or Remote_Types package. This property also holds for remote functions returning class wide types. To summarize, the actual type used should have been eligible for being declared where the root type has been declared. If a 'bad' object is given to a remote subprogram, *Program_Error* will be raised at the point of the call.

### 2.8.3 Partition Ids

U'Partition_ID identifies the partition where the unit U has been elaborated. For this purpose, the PCS provides an integer type Partition_ID to uniquely designate a partition. Note that a Partition_ID is represented as a universal integer, and has no meaning outside of the PCS. The RM requires that two partitions of a distributed program have different Partition_ID's at a given time. A Partition_ID may or may not be assigned statically (at compile or link time). A Partition_ID may or may not be related to the physical location of the partition.

Partition_ID's can be used to check whether a RCI package is configured locally.

```
with RCI;
with Ada.Text_IO;
procedure Check_PID is
begin
   if RCI'Partition_ID = Check_PID'Partition_ID then
      Ada.Text_IO.Put_Line ("package RCI is configured locally");
   else
      Ada.Text_IO.Put_Line ("package RCI is configured remotely");
   end if;
end Check_PID;
```

### 2.8.4 Concurrent Remote Calls

It is not defined by the PCS specification whether one or more threads of control should be available to process incoming messages and to wait for their completion. But the PCS implementation is required to be reentrant, thereby allowing concurrent calls on it to service concurrent remote subprogram calls into the server partition. This means that at the implementation level the PCS manages a pool of helper tasks. This (apart from performance) is invisible to the user.

### 2.8.5 Consistency and Elaboration

A library unit is consistent if the same version of its declaration is used in all units that reference it. This requirement applies as well to a unit that is referenced in several partitions of a distributed program. If a shared passive or RCI library unit U is included in some partition P, It is a bounded error to elaborate another partition P1 of a distributed program that that depends on a different version of U. As a result of this error, Program_Error can be raised in one or both partitions during elaboration.

U'Version yields a string that identifies the version of the unit declaration and any unit declaration on which it depends. U'Version_Body yields a string that identifies the version of the unit body. These attributes are used by the PCS to verify the consistency of an application.

After elaborating the library units, but prior to invoking the main subprogram, the PCS checks the RCI unit versions, and then accept any incoming RPC. To guarantee that it is safe to call receiving stubs, any incoming RPC is kept pending until the partition completes its elaboration.

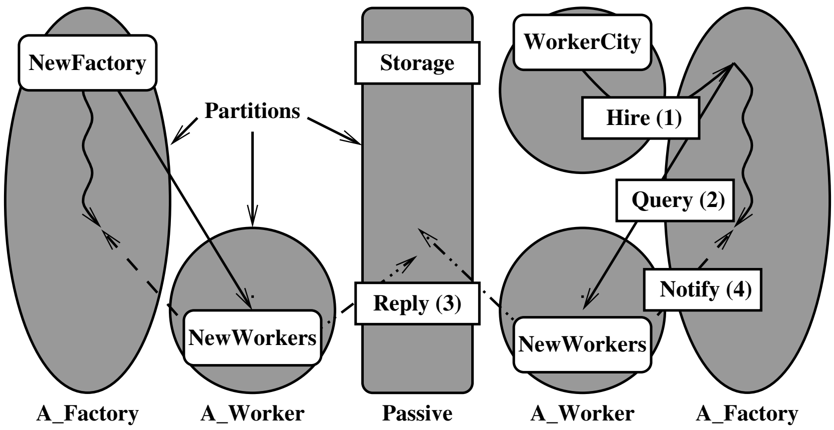
### 2.8.6 Abortion and Termination

If a construct containing a remote call is aborted, the remote subprogram call is cancelled. Whether the execution of the remote subprogram is immediately aborted as a result of the cancellation is implementation defined.

An active partition terminates when its environment task terminates. In other terms, a partition cannot terminate before the Ada program itself terminates. The standard termination mechanism applies, but can be extended with extra rules (see Section 3.5.16 [Partition Attribute Termination], page 46 for examples).

## 2.9 Most Features in One Example

The example shown on the following figure highlights most of the features of DSA. The system is based on a set of factories and workers and a storage. Each entity is a partition itself. A factory hires a worker from a pool of workers (hire - 1) and assigns a job (query - 2) to him. The worker performs the job and saves the result (reply - 3) in a storage common to all the factories. The worker notifies the factory of the end of his job (notify - 4).


NewFactory
Storage
WorkerCity
Partitions
Hire (1)
Query (2)
Reply (3)
Notify (4)
NewWorkers
NewWorkers
A_Factory
A_Worker
Passive
A_Worker
A_Factory

When a worker has completed his job, the result must be saved in a common storage. To do this, we define a protected area in SP package Storage (see following code). An entry-less protected object ensures atomic access to this area.

```
package Storage is
   pragma Shared_Passive;

   protected Queue is
      procedure Insert (Q, R : Integer);
      procedure Remove
        (Q : in Integer;
         R : out Integer);
   private
      --  Other declarations
   end Queue;
end Storage;
```

Common is a Remote_Types package that defines most of the remote services of the above system (see following code). First, we define a way for the workers to signal the completion of his job. This callback mechanism is implemented using RAS Notify.

```
with Storage; use Storage;
package Common is
   pragma Remote_Types;

   type Notify is
      access procedure (Q : Integer);
   pragma Asynchronous (Notify);

   type Worker is
      abstract tagged limited private;
   procedure Assign
     (W : access Worker;
      Q : in Integer;
      N : in Notify) is abstract;

   type Any_Worker is
      access all Worker'Class;
   pragma Asynchronous (Any_Worker);

private
   type Worker is abstract tagged limited null record;
end Common;
```

We define an abstract tagged type Worker which is intended to be the root type of the whole distributed objects hierarchy. Assign allows a factory to specify a job to a worker and a way for the worker to signal its employer the completion of this job. Any_Worker is a remote access to class wide type (RACW). In other words, it is a reference to a distributed object of any derived type from Worker class. Note that the two remote access types (Any_Worker and Notify) are declared as asynchronous. Therefore, any override of Assign will be executed asynchronously. To be asynchronous, an object of type Notify has to be a reference to an asynchronous procedure.

NewWorker is derived from type Worker and Assign is overridden.

```
with Common, Storage; use Common, Storage;
package NewWorkers is
   pragma Remote_Types;

   type NewWorker is new Worker with private;

   procedure Assign
     (W : access NewWorker;
      Q : Integer;
      N : Notify);
private
   type NewWorker is new Worker with record
      NewField : Field_Type; --  [...] Other fields
   end record;
end NewWorkers;
```

The following code shows how to derive a second generation of workers NewNewWorker from the first generation NewWorker. As mentioned above, this RT package can be duplicated on several partitions to produce several types of workers and also several remote workers.

```
with Common, Storage, NewWorkers; use Common, Storage, NewWorkers;
package NewNewWorkers is
   pragma Remote_Types;

   type NewNewWorker is new NewWorker with private;

   procedure Assign
     (W : access NewNewWorker;
      Q : Integer;
      N : Notify);
private
   type NewNewWorker is new NewWorker with record
      NewField : Field_Type; --  [...] Other fields
   end record;
end NewNewWorkers;
```

In the following code, we define a unique place where workers wait for jobs. WorkerCity is a Remote_Call_Interface package with services to hire and free workers. Unlike

Remote_Types packages, Remote_Call_Interface packages cannot be duplicated, and are assigned to one specific partition.

```
with Common; use Common;
package WorkerCity is
   pragma Remote_Call_Interface;

   procedure Insert (W : in  Any_Worker);
   procedure Remove (W : out Any_Worker);
end WorkerCity;
```

In order to use even more DSA features, Factory is defined as a generic RCI package (see sample above). Any instantiation defines a new factory (see sample above). To be RCI, this instantiation has to be categorized once again.

```
with Storage; use Storage;
generic
package Factory is
   pragma Remote_Call_Interface;

   procedure Notify (Q : Integer);
   pragma Asynchronous (Notify);
end Factory;
```

```
with Factory;
package NewFactory is new Factory;
pragma Remote_Call_Interface (NewFactory);
```

# 3 Getting Started With GLADE

This chapter describes the usual ways of using GLADE to compile Ada distributed programs.

## 3.1 Introduction to GLADE

An Ada 95 distributed application comprises a number of partitions which can be executed concurrently on the same machine or, and this is the interesting part, can be distributed on a network of machines. The way in which partitions communicate is described in Annex E of the Ada 95 reference manual.

A partition is a set of compilation units that are linked together to produce an executable binary. A distributed program comprises two or more communicating partitions.

The Distributed Systems Annex (DSA) does not describe how a distributed application should be configured. It is up to the user to define what are the partitions in his program and on which machines they should be executed.

The tool `gnatdist` and its configuration language allows the user to partition his program and to specify the machines on which the individual partitions are to execute.

`gnatdist` reads a configuration file (whose syntax is described in section Section 3.5 [The Configuration Language], page 38) and builds several executables, one for each partition. It also takes care of launching the different partitions (default) with parameters that can be specific to each partition.

## 3.2 How to Configure a Distributed Application

- Write a non-distributed Ada application, to get familiar with the GLADE environment. Use the categorization pragmas to specify the packages that can be called remotely.
- When this non-distributed application is working, write a configuration file that maps the user categorized packages onto specific partitions. This concerns particularly remote call interface and remote types packages. Specify the main procedure of the distributed application (see Section 3.5.6 [Partition Attribute Main], page 41).
- Type 'gnatdist <*configuration-file*>'.
- Start the distributed application by invoking the start-up shell script or default Ada program (depending on the Starter option, see Section 3.5.7 [Pragma Starter], page 42).

## 3.3 Gnatdist Command Line Options

```
gnatdist [switches] configuration-file [list-of-partitions]
```

The switches of `gnatdist` are, for the time being, exactly the same as those of gnatmake. By default `gnatdist` outputs a configuration report and the actions performed. The switch -n allows `gnatdist` to skip the first stage of recompilation of the non-distributed application.

The names of all configuration files must have the suffix `.cfg`. There may be several configuration files for the same distributed application, as the user may want to use different distributed configurations depending on load and other characteristics of the computing environment.

If a list of partitions is provided on the command line of the gnatdist command, only these partitions will be built. In the following configuration example, the user can type :

`gnatdist` <*configuration*> <*partition_2*> <*partition_3*>

## 3.4 Gnatdist Behind the Scenes

Here is what goes on behind the scenes in `gnatdist` when building a distributed application:

- Each compilation unit in the program is compiled into an object module (as for non distributed applications). This is achieved by calling gnatmake on the sources of the various partitions.
- Stubs and skeletons are compiled into object modules (these are piece of cade that allow a partition running on machine A to communicate with a partition running on machine B). Several timestamp checks are performed to avoid useless code recompilation and stub generation.
- `gnatdist` performs a number of consistency checks. For instance it checks that all packages marked as remote call interface (RCI) and shared passive (SP) are mapped onto partitions. It also checks that a RCI or SP package is mapped onto only one partition.
- Finally, the executables for each partition in the program are created. The code to launch partitions is embedded in the main partition except if another option has been specified (see Section 3.5.7 [Pragma Starter], page 42). In this case, a shell script (or nothing) is generated to start the partitions on the appropriate machines. This is specially useful when one wants to write client / server applications where the number of instances of the partition is unknown.

## 3.5 The Configuration Language

The configuration language is *Ada-like*. As the capabilities of GLADE will evolve, so will this configuration language. Most of the attributes and pragmas can be overloaded at run-time by command line arguments or environment variables.

### 3.5.1 Language Keywords

All the Ada keywords are reserved keywords of the GLADE configuration language. `gnatdist` generates full Ada code in order to build the different executables. To avoid naming conflicts between Ada and GLADE configuration language, all the Ada keywords have been reserved even if they are not used in the configuration language.

There are three new keywords:

- *configuration* to encapsulate a configuration
- *Partition* that is a predefined type to declare partitions
- *Channel* that is a predefined type to declare channels between partitions.

### 3.5.2 Pragmas and Representation Clauses

It is possible to modify the default behaviour of the configuration via a pragma definition.

```
PRAGMA ::=
   pragma PRAGMA_NAME [(PRAGMA_ARGUMENTS)];
```

It is also possible to modify the default behavior of all the partitions (or channels) via an attribute definition clause applied to the predefined type **Partition** (or **Channel**).

```
REPRESENTATION_CLAUSE ::=
   for Partition'ATTRIBUTE_NAME use ATTRIBUTE_ARGUMENTS;
 | for Channel'ATTRIBUTE_NAME use ATTRIBUTE_ARGUMENTS;
```

It is also possible to modify the default behavior of a given partition (or channel) via an attribute definition clause applied to the partition (or channel) itself.

```
REPRESENTATION_CLAUSE ::=
   for PARTITION_IDENTIFIER'ATTRIBUTE_NAME use ATTRIBUTE_ARGUMENTS;
```

When an attribute definition clause is applied to a given object of a predefined type, this overrides any attribute definition of the predefined type. In the next sections, attributes apply to a given object rather than to the predefined type.

### 3.5.3 Configuration Declaration

The distribution of one or several Ada programs is described by a single configuration unit. This configuration unit has a specification part and an optional body part. A configuration unit is declared as an Ada procedure would be. The keyword **configuration** is reserved for this purpose.

```
CONFIGURATION_UNIT ::=
   configuration IDENTIFIER is
      DECLARATIVE_PART
   [begin
      SEQUENCE_OF_STATEMENTS]
   end [IDENTIFIER];
```

### 3.5.4 Partition Declaration

In the declarative part, the user declares his partitions and can change their default behavior. `gnatdist` provides a predefined type **Partition**. The user can declare a list of partitions and can also initialize these partitions with an initial list of Ada units.

```
DECLARATIVE_PART ::= {DECLARATIVE_ITEM}
```

```
DECLARATIVE_ITEM ::=
   PARTITION_DECLARATION
 | CHANNEL_DECLARATION
 | REPRESENTATION_CLAUSE
 | SUBPROGRAM_DECLARATION
 | PRAGMA

SUBPROGRAM_DECLARATION ::=
   MAIN_PROCEDURE_DECLARATION
 | PROCEDURE_DECLARATION
 | FUNCTION_DECLARATION

PARTITION_DECLARATION ::=
   DEFINING_IDENTIFIER_LIST : Partition
      [:= ENUMERATION_OF_ADA_UNITS];

DEFINING_IDENTIFIER_LIST ::=
   DEFINING_IDENTIFIER {, DEFINING_IDENTIFIER}

STATEMENT ::=
   IDENTIFIER := ENUMERATION_OF_ADA_UNITS;

SEQUENCE_OF_STATEMENTS ::=
   STATEMENT {STATEMENT}
```

Once declared, a partition is an empty list of Ada units. The operator `":="` adds the Ada units list on the right side to the current list of Ada units that are already mapped to the partition. This is a non-destructive operation. Whether a unit is a relevant Ada unit or not is checked later on by the back-end of `gnatdist`. These assignments can occur in the declarative part as well as in the body part.

```
ENUMERATION_OF_ADA_UNITS ::= ({ADA_UNIT {, ADA_UNIT}});
```

### 3.5.5 Location Declaration

There are several kinds of location in the GLADE configuration language. We shall present them in the next subsections, but here is a short overview of these locations:

- Boot_Location defines the network locations to use to communicate with the the boot server during the boot phase
- Self_Location defines the network locations to use by others to communicate with the current partition
- Data_Location defines the data storage location used by the current partition to map its shared passive units

A location is composed of a support name and a specific data for this support. For instance, a network location is composed of a protocol name like *tcp* and a protocol data like <*machine*>*:*<*port*>. A storage location is composed of a storage support name like *dfs* (for Distributed File System) and a storage support data like a directory */dfs/glade*.

```
LOCATION      ::= ([Support_Name =>] STRING_LITTERAL,
                   [Support_Data =>] STRING_LITTERAL)

LOCATION_LIST ::= (LOCATION [,LOCATION)])
```

Note that a location may have an undefined or incomplete support data. In this case, the support is free to compute a support data. For instance, ("tcp", "") specifies that the protocol is used but that the protocol data <*machine*>*:*<*port*> is to be determined by the protocol itself.

A location or a list of locations can be can be concatenated into a single string to be used as a command line option or an environment variable (see Section 3.6 [Partition Command Line Options], page 53).

If a partition wants to communicate with another partition once the location list of the latter is known, the caller will use the first location of the callee whose protocol is locally available. For instance, if a callee exports three locations ("N1", "D1"), ("N2", "D2") and ("N3", "D3"), a caller with protocols N2 and N3 locally available will try to communicate with the callee using the protocol of name N2 and of specific data D2.

### 3.5.6 Partition Attribute Main

Basically, the distributed system annex (DSA) helps the user in building a distributed application from a non-distributed application (Of course, this is not the only possible model offered by DSA). The user can design, implement and test his application in a non-distributed environment, and then should be able to switch from the non-distributed case to a distributed case. As mentionned before, this two-phase design approach has several advantages.

In a non-distributed case, the user executes only one main executable possibly with a name corresponding to the main unit name of his application. With `gnatdist`, in a distributed case, a main executable with a name corresponding to the main unit name is responsible for starting the entire distributed application. Therefore, the user can start his application the same way he used to do in the non-distributed case.

For this reason, the configuration language provides a way to declare the main procedure of the non-distributed application.

```
MAIN_PROCEDURE_DECLARATION ::=
   procedure MAIN_PROCEDURE_IDENTIFER is in PARTITION_IDENTIFIER;
```

In this case, the partition in which the main procedure has been mapped is called the main partition. It includes in its code a call to this main procedure. The main partition has an additional specific role, because the boot server is located on it (see Section 3.9 [GLADE Internals], page 57).

The main procedures for the other partitions have a null body. However, the user can also modify this behavior by providing an alternate main procedure. To do this, an alternate main subprogram has to be declared and assigned to the partition Main attribute.

```
PROCEDURE_DECLARATION ::=
   procedure PROCEDURE_IDENTIFIER;

REPRESENTATION_CLAUSE :=
   for PARTITION_IDENTIFIER'Main use PROCEDURE_IDENTIFIER;
```

### 3.5.7 Pragma Starter

As a default, the main executable is a full Ada starter procedure. That means that it launches all the other partitions from an Ada program. The pragma Starter allows the user to ask for one starter or another. When the partition host is not statically defined (see Section 3.5.12 [Partition Attribute Host], page 44), the starter subprogram will ask for it interactively when it is executed.

```
CONVENTION_LITERAL ::= Ada   |
                       Shell |
                       None

PRAGMA ::=
   pragma Starter ([Convention =>] CONVENTION_LITERAL);
```

- The default method consists in launching partitions from the main partition Ada subprogram using a remote shell.
- The user may ask for a Shell script that starts the different partitions one at a time on the appropriate remote machines, using a remote shell. As the Ada starter, the Shell script starter ask for partition hosts interactively when a partition host is not already defined. Having a textual shell script allows the user to edit it and to modify it easily.
- The user may ask for a None starter. In this case, it is up to the user to launch the different partitions. The user may have to provide on the command line the boot server location (see Section 3.9.1 [Architecture of GLADE PCS], page 58).

### 3.5.8 Pragma Boot_Location

When a partition starts executing, one of the first steps consists in a connection to the boot partition where the boot server is located (see Section 3.9.1 [Architecture of GLADE PCS], page 58). This pragma provides one or several locations in order to get a connection with the boot partition.

```
PRAGMA ::=
   PRAGMA_WITH_NAME_AND_DATA
 | PRAGMA_WITH_LOCATION
 | PRAGMA_WITH_LOCATION_LIST
```

```
PRAGMA_WITH_NAME_AND_DATA ::=
   pragma Boot_Location
     ([Protocol_Name =>] STRING_LITERAL,
      [Protocol_Data =>] STRING_LITERAL);

PRAGMA_WITH_LOCATION ::=
   pragma Boot_Location ([Location =>] LOCATION);

PRAGMA_WITH_LOCATION_LIST ::=
   pragma Boot_Location ([Locations =>] LOCATION_LIST);
```

This boot server location can be concatenated into a single string to be used as a command line option or an environment variable (see Section 3.6 [Partition Command Line Options], page 53).

**Note: pragma Boot_Server is now obsolete. It is recommended to use pragma Boot_Location. This wording is more consistent with the rest of the configuration language (see Self_Location Section 3.6.2 [Partition Option self_location], page 54 and Data_Location Section 3.6.3 [Partition Option data_location], page 54).**

### 3.5.9 Partition Attribute Self_Location

Except for the boot partition on which the boot server is located, a partition is reachable through a dynamically computed location (for instance, the partition looks for a free port when the protocol is tcp). The user may want such a partition to be reachable from a given location, especially if the user wants to make this partition a boot mirror. To do so, he can force the partition location with self_location feature.

```
REPRESENTATION_CLAUSE ::=
   for PARTITION_IDENTIFIER'Self_Location use LOCATION;
 | for PARTITION_IDENTIFIER'Self_Location use LOCATION_LIST;
```

If the attribute definition clause applies to the predefined type **Partition**, the locations have to be incomplete. Otherwise, all the partitions would be reachable through the same locations, which is definitively not recommended.

When an attribute self_location definition clause applies to a given partition, the protocol units needed for this partition are linked in the executable. By default, when the self_location attribute is not redefined, the default protocol used by the partition and loaded in its executable is the *tcp* protocol.

### 3.5.10 Partition Attribute Passive

By default, a partition is an active partition. This attribute allows to define a passive partition. In this case, `gnatdist` checks that only shared passive units are mapped on the partition. As this partition cannot register itself, its location is hard-coded in all the partitions that depend on its shared passive units.

```
REPRESENTATION_CLAUSE ::=
   for PARTITION_IDENTIFIER'Passive use BOOLEAN_LITERAL;
```

### 3.5.11 Partition Attribute Data_Location

Shared passive units can be mapped on passive or active partitions. In both cases, it is possible to choose the data storage support and to configure it with the specific data of a location.

```
REPRESENTATION_CLAUSE ::=
   for PARTITION_IDENTIFIER'Data_Location use LOCATION;
 | for PARTITION_IDENTIFIER'Data_Location use LOCATION_LIST;
```

When an attribute data_location definition clause applies to a given partition, the data storage support units needed for this partition are linked in the executable. By default, when the data_location attribute is not redefined, the default storage support used by the partition and loaded in its executable is the *dfs* support. *dfs*, Distributed File System, is a storage support available as soon as files can be shared between partitions.

It is not possible to map the different shared passive units of a given partition on different data storage locations. GLADE requires all the shared passive units of a given partition to be mapped on the same storage support. When the attribute data_location applied to a partition is a list of locations, all the storage support units needed for this partition are linked in the executable. By default, only the first one is activated. The user can choose to change the activated support by another one specified in the location list. This can be done using the partition option data_location (see Section 3.6.3 [Partition Option data_location], page 54).

As passive partitions cannot be activated, it is not possible to provide a location list as a data_location attribute. It is not possible to change dynamically its location either.

### 3.5.12 Partition Attribute Host

Logical nodes (or partitions) can be mapped onto physical nodes. The host-name can be either a static or dynamic value. In case of a static value, the expression is a string literal. In case of a dynamic value, the representation clause argument is a function that accepts a string as parameter and that returns a string value. When the function is called, the partition name is passed as parameter and the host-name is returned.

```
FUNCTION_DECLARATION ::=
   function FUNCTION_IDENTIFIER
     (PARAMETER_IDENTIFIER : [in] String)
      return String;

REPRESENTATION_CLAUSE ::=
   for PARTITION_IDENTIFIER'Host use STRING_LITERAL;
 | for PARTITION_IDENTIFIER'Host use FUNCTION_IDENTIFIER;
```

The signature of the function must be the following : it takes a string parameter which corresponds to a partition name. It returns a string parameter which corresponds to the host-name. The function that returns the host-name can be an Ada function (default) or a shell script. A pragma Import is used to import a function defined in Ada or in Shell (see Section 3.5.13 [Pragma Import], page 45).

This function is called on the main partition by the GLADE PCS to launch a given partition on a given logical node. In case of load balancing, the function can return the most appropriate among a set of hosts.

### 3.5.13 Pragma Import

Two kinds of subprograms are allowed in the GLADE configuration language. A main procedure is used as a partition Main attribute and a function is used as a partition Host attribute.

```
SUBPROGRAM_DECLARATION ::=
     procedure MAIN_PROCEDURE_IDENTIFIER is in PARTITION_NAME;
   | procedure PROCEDURE_IDENTIFIER;
   | function FUNCTION_IDENTIFIER
       (PARAMETER_IDENTIFIER : [in] String)
        return String;
```

The function can be an Ada function (default) or a shell script. To import a shell script, the pragma Import must be used:

```
PRAGMA ::=
   pragma Import
      ([Entity        =>] FUNCTION_IDENTIFIER,
       [Convention    =>] CONVENTION_LITERAL,
       [External_Name =>] STRING_LITERAL);

pragma Import (Best_Node, Shell, "best-node");
```

In this case, the GLADE PCS invokes the shell script with the partition name as a command line argument. The shell script is supposed to return the partition host-name (see Section 3.5.12 [Partition Attribute Host], page 44).

### 3.5.14 Partition Attribute Directory

Directory allows the user to specify in which directory the partition executable is stored. This can be useful in heterogeneous systems when the user wants to store executables for the same target in a given directory. Specifying the directory is also useful if the partition executable is not directly visible from the user environment. For instance, when a remote command like **rsh** is invoked, the executable directory has to be present in the user path. If the Directory attribute has been specified, the executable full name is used.

```
REPRESENTATION_CLAUSE ::=
```

```
      for PARTITION_IDENTIFIER'Directory use STRING_LITERAL;
```

### 3.5.15 Partition Attribute Command_Line

The user may want to pass arguments on the command line of a partition. However, when a partition is launched automatically by the main partition, the partition command line includes only GLADE arguments. To add arguments on the command line, the user can take advantage of the following attribute.

```
   REPRESENTATION_CLAUSE ::=
      for PARTIITON_IDENTIFIER'Command_Line use STRING_LITERAL;
```

### 3.5.16 Partition Attribute Termination

The Ada95 Reference Manual does not provide any specific rule to handle global termination of a distributed application (see Section 2.8.6 [Abortion and Termination], page 31).

In GLADE, by default, a set of partitions terminates when each partition can terminate and when no message remains to be delivered. A distributed algorithm that checks for this global condition is activated periodically by the main boot server.

```
   TERMINATION_LITTERAL ::= Global_Termination |
                            Local_Termination  |
                            Defered_Termination

   REPRESENTATION_CLAUSE ::=
      for PARTIITON_IDENTIFIER'Termination use TERMINATION_LITERAL;
```

- When a partition is configured with the global termination policy, it terminates as soon as the main boot server sends a signal to do so. The main boot server checks periodically whether the application can terminate. When all partitions are ready to terminate, the main boot server sends to each partition a termination request. The global termination policy is the default policy.
- The deferred termination policy is very similar to the global termination. The only difference is that when a partition with a deferred termination policy receives a termination request, it just ignores it. This policy allows a partition to run forever without preventing a set of partitions from terminating. This policy is not yet implemented.
- When a partition is configured with the local termination policy, it terminates as soon as the classical Ada termination is detected by the partition. It means that this partition does not wait for the termination request of the main boot server.

In any case, when the boot partition dies (and when no alternate boot partition can elected, see Section 3.9.1 [Architecture of GLADE PCS], page 58), all the partitions die, whatever their termination policy might be. Note first, that a partition cannot execute without a boot partition. Second, when the user wants to kill his non-distributed application, he kills the main program. Enforcing the mechanism described above ensures that killing the main partition automatically kills all the partitions, that is to say the whole distributed application.

### 3.5.17 Partition Attribute Reconnection

When no RCI package is configured on a partition, such a partition can be launched several times without any problem. When one or more RCI packages are configured on a partition, such a partition cannot be launched more than once. If this partition were to be launched repeatedly, it would not be possible to decide which partition instance should execute a remote procedure call.

When a partition crashes or is stopped, one may want to restart this partition and possibly restore its state - with Shared_Passive packages, for instance. In such a situation, the partition is already known to other partitions and possibly marked as a dead partition. Several policies can be selected:

```
RECONNECTION_LITTERAL ::= Reject_On_Restart  |
                          Fail_Until_Restart |
                          Wait_Until_Restart

REPRESENTATION_CLAUSE ::=
   for PARTITION_IDENTIFIER'Reconnection use RECONNECTION_LITTERAL;
```

- When this partition is configured with the Reject_On_Restart reconnection policy, the dead partition is kept dead and any attempt to restart it fails. Any remote call to a subprogram located on this partition results in a Communication_Error exception. The Reject_On_Restart policy is the default policy.
- When this partition is configured with the Fail_Until_Restart reconnection policy, the dead partition can be restarted. Any remote call to a subprogram located on this partition results in an exception Communication_Error as long as this partition has not been restarted. As soon as the partition is restarted, remote calls to this partition are executed normally.
- When this partition is configured with the Wait_Until_Restart reconnection policy, the dead partition partition can be restarted. Any remote call to a subprogram located on this partition is suspended until the partition is restarted. As soon as the partition is restarted, remote calls to this partition are executed normally. The suspended remote procedure calls to this partition are resumed.

### 3.5.18 Channel Declaration

The configuration language not only describes partitions, but also the connections between them. Such a connection is called a Channel and represents a bi-directional link between two partitions.

```
CHANNEL_DECLARATION ::=
   CHANNEL_IDENTIFIER : Channel
      [:= PARTITION_PEER];
```

```
PARTITION_PEER ::= (PARTITION_IDENTIFIER, PARTITION_IDENTIFIER);
```

A partition peer is a pair of distinct partition names. The list order is not important. Of course, the designated partitions have to be declared prior to the channel itself.

```
A_Channel : Channel := (Partition_1, Partition_2);
```

This gives the link between partitions *Partition_1* and *Partition_2* the name *A_Channel*. It is not possible to declare more than one channel between the same two partitions.

### 3.5.19 Partition and Channel Attribute Filter

GLADE contains a transparent extensible filtering mechanism that allows the user to define various data transformations to be performed on the arguments and return values of remote calls. One possible application is to compress all data before sending it and to decompress it on the receiving partition.

With GLADE, it is no longer necessary for the application to take care of such transformations. Instead, users can write their own data transformations and hook them into GLADE so that they are automatically and transparently applied depending on the configuration of the distributed application.

By default, no filtering is performed by GLADE, even though the compression filter is always available. The user can choose to configure his distributed application to use this filter.

In order to define filtering, one must first declare the channels between the partitions of an application. Once a channel is defined, the data transformation that is to be applied on all data sent through it can be specified:

```
A_Channel : Channel := (Partition_1, Partition_2);

for A_Channel'Filter use "ZIP";
```

This specifies that all data sent over this channel should be transformed by the filter named *ZIP*. (There must be a filter with this name, implemented in the package *System.Garlic.Filters.Zip*.)

It may also be useful to specify that a partition use a certain filter for all remote calls, regardless of the channel (i.e., regardless of the partition that will receive the remote call). This can be specified using the attribute 'Filter on a partition:

```
for Partition_1'Filter use "ZIP";
```

or

```
for Partition'Filter use "ZIP";
```

The latter sets the default filter for all partitions of the application, the former only sets the default filter for the partition *Partition_1*. It is also possible to apply a default filter and to override this default for specific channels:

```
My_Channel : Channel := (Partition_1, Partition_2);

for My_Channel'Filter  use "ZIP";
for Partition_1'Filter use "Some_Other_Filter";
```

This makes *Partition_1* use *Some_Other_Filter* for all remote calls except for any communication with *Partition_2*, where the filter *ZIP* is applied.

`gnatdist` takes care of consistency checking of a filter definition. For instance, multiple filter definitions for the same channel are not allowed. Filtering is only active if specified explicitly in the configuration file.

```
REPRESENTATION_CLAUSE ::=
   for CHANNEL_IDENTIFIER'Filter use STRING_LITERAL;
 | for PARTITION_IDENTIFIER'Filter use STRING_LITERAL;
```

### 3.5.20 Pragma Registration_Filter

Some filtering algorithms require that some parameters be sent to the receiver first to enable it to correctly de-filter the data. If this is the case, it may be necessary to filter these parameters as well. For such purposes, it is possible to install a global filter for all partitions, which will then be used to filter the parameters of other filters. This filter is called the registration filter. It can be set by a pragma because a pragma applies to the configuration:

```
PRAGMA ::=
   pragma Registration_Filter ([Filter =>] STRING_LITERAL);
```

### 3.5.21 Pragma Version

A library unit is consistent if the same version of its declaration is used throughout (see Section 2.8.5 [Consistency and Elaboration], page 31). It can be useful to deactivate these checks, especially when the user wants to be able to update a server without updating a client.

```
PRAGMA ::=
   pragma Version ([Check =>] BOOLEAN_LITERAL);
```

### 3.5.22 Partition Attribute Task_Pool

When multiple remote subprogram calls occur on the same partition, they are handled by several anonymous tasks. These tasks can be allocated dynamically or re-used from a pool of (preallocated) tasks. When a remote subprogram call is completed, the anonymous task can be deallocated or queued in a pool in order to be re-used for further remote subprogram calls. The number of tasks in the anonymous tasks pool can be configured by means of three independent parameters.

- The task pool minimum size indicates the number of anonymous tasks preallocated and always available in the GLADE PCS. Preallocating anonymous tasks can be useful in real-time systems to prevent task dynamic allocation.
- The task pool high size is a ceiling. When a remote subprogram call is completed, its anonymous task is deallocated if the number of tasks already in the pool is greater than the ceiling. If not, then the task is queued in the pool.
- The task pool maximum size indicates the maximum number of anonymous tasks in the GLADE PCS. In other words, it provides a way to limit the number of remote calls in the PCS. When a RPC request is received, if the number of active remote calls is greater than the task pool maximum size, then the request is kept pending until an anonymous task completes its own remote call and becomes available.

```
REPRESENTATION_CLAUSE ::=
   for PARTITION_IDENTIFIER'Task_Pool use TASK_POOL_SIZE_ARRAY;

TASK_POOL_SIZE_ARRAY ::=
  (NATURAL_LITERAL,   -- Task Pool Minimum Size
   NATURAL_LITERAL,   -- Task Pool High Size
   NATURAL_LITERAL);  -- Task Pool Maximum Size
```

In order to have only one active remote call at a time, the task pool configuration is declared as follows:

```
for Partition'Task_Pool use (0, 0, 1);
```

### 3.5.23 A Complete Example

Almost every keyword and construct defined in the configuration language has been used in the following sample configuration file.

```
configuration MyConfig is

  Partition_1 : Partition := ();
  procedure Master_Procedure is in Partition_1;

  Partition_2, Partition_3 : Partition;

  for Partition_2'Host use "foo.bar.com";

  function Best_Node (Partition_Name : String) return String;
  pragma Import (Shell, Best_Node, "best-node");
  for Partition_3'Host use Best_Node;
```

```
13
14    Partition_4 : Partition := (RCI_B5);
15
16    for Partition_1'Directory use "/usr/you/test/bin";
17    for Partition'Directory use "bin";
18
19    procedure Another_Main;
20    for Partition_3'Main use Another_Main;
21
22    for Partition_3'Reconnection use Block_Until_Restart;
23    for Partition_4'Command_Line use "-v";
24    for Partition_4'Termination use Local_Termination;
25
26    pragma Starter (Method => Ada);
27
28    pragma Boot_Server
29      (Protocol_Name => "tcp",
30       Protocol_Data => "`hostname`:`unused-port`");
31
32    pragma Version (False);
33
34    Channel_1 : Channel := (Partition_1, Partition_4);
35    Channel_2 : Channel := (Partition_2, Partition_3);
36
37    for Channel_1'Filter use "ZIP";
38    for Channel_2'Filter use "My_Own_Filter";
39    for Partition'Filter use "ZIP";
40
41    pragma Registration_Filter ("Some_Filter");
42
43 begin
44     Partition_2 := (RCI_B2, RCI_B4, Normal);
45     Partition_3 := (RCI_B3);
46 end MyConfig;
```

1. **Line 01** Typically, after having created the following configuration file the user types:

   ```
   gnatdist myconfig.cfg
   ```

   If the user wants to build only some partitions then he will list the partitions to build on the `gnatdist` command line as follows:

   ```
   gnatdist myconfig.cfg partition_2 partition_3
   ```

   The name of the file prefix must be the same as the name of the configuration unit, in this example `myconfig.cfg`. The file suffix must be `cfg`. For a given distributed application the user can have as many different configuration files as desired.

2. **Line 04** Partition 1 contains no RCI package. However, it will contain the main procedure of the distributed application, called *Master_Procedure* in this example. If the line *procedure Master_Procedure is in Partition_1;* was missing, Partition 1 would be completely empty. This is forbidden, because a partition has to contain at least one library unit.

   `gnatdist` produces an executable with the name of *Master_Procedure* which will start the various partitions on their host machines in the background. The main partition is launched in foreground. Note that by killing this main procedure the whole distributed application is terminated.
3. **Line 08** Specify the host on which to run partition 2.
4. **Line 12** Use the value returned by a program to figure out at execution time the name of the host on which partition 3 should execute. For instance, execute the shell script `best-node` which takes the partition name as parameter and returns a string giving the name of the machine on which partition_3 should be launched.
5. **Line 14** Partition 4 contains one RCI package RCI_B5 No host is specified for this partition. The startup script will ask for it interactively when it is executed.
6. **Line 16** Specify the directory in which the executable of partition partition_1 will be stored.
7. **Line 17** Specify the directory in which all the partition executables will be stored (except partition_1, see Section 3.5.2 [Pragmas and Representation Clauses], page 39). Default is the current directory.
8. **Line 20** Specify the partition main subprogram to use in a given partition.
9. **Line 22** Specify a reconnection policy in case of a crash of Partition_3. Any attempt to reconnect to Partition_3 when this partition is dead will be blocked until Partition_3 restarts. By default, any restart is rejected (Reject_On_Restart). Another policy is to raise Communication_Error on any reconnection attempt until Partition_3 has been restarted.
10. **Line 23** Specify additional arguments to pass on the command line when a given partition is launched.
11. **Line 24** Specify a termination mechanism for partition_4. The default is to compute a global distributed termination. When Local_Termination is specified a partition terminates as soon as local termination is detected (standard Ada termination).
12. **Line 26** Specify the kind of startup method the user wants. There are 3 possibilities: Shell, Ada and None. Specifying *Shell* builds a shell script. All the partitions will be launched from a shell script. If *Ada* is chosen, then the main Ada procedure itself is used to launch the various partitions. If method *None* is chosen, then no launch method is used and the user must start each partition manually.

    If no starter is given, then an Ada starter will be used.

    In this example, Partition_2, Partitions_3 and Partition_4 will be started from Partition_1 (ie from the Ada procedure Master_Procedure).
13. **Line 30** Specify the use of a particular boot server. It is especially useful when the default port used by the GLADE PCS (randomly computed during GLADE installation) is already assigned.

14. **Line 32** It is a bounded error to elaborate a partition of a distributed program that contains a compilation unit that depends on a different version of the declaration of an RCI library unit than the one included in the partition to which the RCI library unit was assigned. When the pragma Version is set to False, no consistency check is performed.
15. **Line 335** Declare two channels. Other channels between partitions remain unknown.
16. **Line 37** Use transparent compression / decompression for the arguments and results of any remote calls on channel *Channel_1*, i.e. between *Partition_1* and *Partition_4*.
17. **Line 38** Use filter *My_Own_Filter* on any declared channel ie *Channel_1* amd *Channel_2*. As *Channel_1* filter attribute is already assigned, this applies only to *Channel_2*. This filter must be implemented in a package *System.Garlic.Filters.My_Own_Filter*.
18. **Line 39** For all data exchanged between partitions, use the filter *ZIP*. (I.e. for both arriving remote calls as well as for calls made by a partition.)
19. **Line 41** *Some_Filter* will be used to exchange a filter's parameters between two partitions. *Some_Filter* itself must be an algorithm that doesn't need its own parameters to be filtered again. This filter must be implemented in a package *System.Garlic.Filters.Some_Filter*.
20. **Line 43** The configuration body is optional. The user may have fully described his configuration in the declaration part.
21. **Line 44** Partition 2 contains two RCI packages RCI_B2 and RCI_B4 and a normal package. A normal package is not categorized.
22. **Line 45** Partition 3 contains one RCI package RCI_B3

## 3.6 Partition Command Line Options

Most of the previous attributes and pragmas can be modified at run-time. The user can redefine some of the configuration options by defining shell environment variables or by passing arguments on the command line of a partition executable. In general, for a given feature (Aa_Bb_Cc), there is a corresponding environmnent variable (AA_BB_CC) and a corresponding command line option (--aa_bb_cc).

The environment variable (AA_BB_CC) can be set to a value of the expected type. When a partition is executed from such a shell, the value assigned in the configuration file is replaced by the value of the environment variable. If the user shell is `sh`, `bash` or `zsh`, type:

```
AA_BB_CC=<x>
export AA_BB_CC
```

If the user shell is `csh` or `tcsh`, type:

```
setenv AA_BB_CC <x>
```

where `<x>` is a value of the expected type.

When the partition is launched with a command line option --aa_bb_cc `<x>`, the value assigned in the configuration file or by the shell environment variable is replaced by `<x>`.

For some environment variables, the value of the environment variable may be irrelevant. For some command line options, no extra argument is needed. In the following, type None means that extra information is not needed. The feature is activated as soon as the environment variable exists or as soon as the option is passed on the command line.

The precedence order for specifying a run-time parameter is as follows: first the the command line option, then the environment variable and finally the configuration attribute or pragma.

A location can be concatenated into a single string to be used as a command line option or an environment variable. The formatted string must conform to the notation <support_name>://<support_data>. Most commonly, a network location string is tcp://<machine>:<port>, that means that the protocol name is *tcp*, the protocol data which is specific to the protocol name is *<machine>:<port>*.

A list of locations can be concatenated into a single string as well. Location strings are separated by spaces. To be used as a command line option, it is possible to quote this string. Most commonly, a network locations string is "tcp://<machine>:<port1> tcp://<machine>:<port2>".

### 3.6.1 Partition Option boot_location

This option sets the boot server location (see Section 3.5.8 [Pragma Boot_Location], page 42 for details).

| Environment Variable | Command Line Option | Type |
|---|---|---|
| BOOT_LOCATION | --boot_location | Formatted String |

The formatted string must conform to the location notation (see Section 3.5.5 [Location Declaration], page 40 and Section 3.6 [Partition Command Line Options], page 53. Most commonly, this would be tcp://<machine>:<port>.

### 3.6.2 Partition Option self_location

This option sets the current partition location (see Section 3.5.9 [Partition Attribute Self_Location], page 43 for details).

| Environment Variable | Command Line Option | Type |
|---|---|---|
| SELF_LOCATION | --self_location | Formatted String |

| Environment Variable | Command Line Option | Type |
|---|---|---|
| SELF_LOCATION | --self_location | Formatted String |

The formatted string must conform to the location notation (see Section 3.5.5 [Location Declaration], page 40 and Section 3.6 [Partition Command Line Options], page 53. Most commonly, this would be tcp://<machine>:<port>.

### 3.6.3 Partition Option data_location

This option sets the location of the data storage on which the shared passive units of the current partition are mapped (see Section 3.5.11 [Partition Attribute Data_Location], page 44 for details). This location has to be compatible with one of locations provided in the configuration file, that means the partition option data_location must have a support name of one of the storage locations specified in the configuration file.

| Environment Variable | Command Line Option | Type |
|---|---|---|
| DATA_LOCATION | --data_location | Formatted String |

| Environment Variable | Command Line Option | Type |
|---|---|---|
| DATA_LOCATION | --DATA_location | Formatted String |

The formatted string must conform to the location notation (see Section 3.5.5 [Location Declaration], page 40 and Section 3.6 [Partition Command Line Options], page 53. Most commonly, this would be dfs://<directory>.

### 3.6.4 Partition Option nolaunch

This feature is useful when the configuration has been built with an Ada starter. When this feature is activated, the main partition does not launch the other partitions anymore. The user has to launch them by hand.

| Environment Variable | Command Line Option | Type |
|---|---|---|
| NOLAUNCH | --nolaunch | None |

### 3.6.5 Partition Option detach

This option is not intended to be specified by the user. When this feature is activated, the process forks itself and the child closes its standard input, output and error descriptors. This feature is always activated when a partition is launched from the main partition using a remote shell (with a starter Ada or Shell).

The only case where it can be useful is for a configuration built with a Shell starter. In this case, the user can edit the shell script to pipe the output of a partition into a file. To do so, the detach feature has to be removed.

| Environment Variable | Command Line Option | Type |
|---|---|---|
| DETACH | --detach | None |

### 3.6.6 Partition Option slave

This feature is not supposed to be used by the user. When this feature is activated, this partition cannot be a boot server partition anymore. This is useful when a partition has been configured as a boot partition and when the user does not want it to be a main partition anymore.

| Environment Variable | Command Line Option | Type |
|---|---|---|
| SLAVE | --slave | None |

### 3.6.7 Partition Option boot_mirror

By default, a partition is not a boot mirror, except for a boot partition on which the boot server is located. The user can force a partition to be a boot mirror.

| Environment Variable | Command Line Option | Type |
|---|---|---|
| BOOT_MIRROR | --boot_mirror | None |

### 3.6.8 Partition Option mirror_expected

This option suspends the execution of the distributed application until there is at least one boot mirror partition available, excluding the boot server.

| Environment Variable | Command Line Option | Type |
|---|---|---|
| MIRROR_EXPECTED | --mirror_expected | None |

### 3.6.9 Partition Option connection_hits

This option sets the number of times a partition tries to connect to the boot server before raising a Communication_Error exception.

| Environment Variable | Command Line Option | Type |
|---|---|---|
| CONNECTION_HITS | --connection_hits | Natural |

### 3.6.10 Partition Option reconnection

This option sets the reconnection policy (see Section 3.5.17 [Partition Attribute Reconnection], page 47 for details).

| Environment Variable | Command Line Option | Type |
|---|---|---|
| RECONNECTION | --reconnection | Reconnection_Type |

### 3.6.11 Partition Option termination

This option sets the termination policy (see Section 3.5.16 [Partition Attribute Termination], page 46 for details).

| Environment Variable | Command Line Option | Type |
|---|---|---|
| TERMINATION | --termination | Termination_Type |

### 3.6.12 Partition Option trace

GLADE has a facility for trace/replay-based debugging. If trace mode is turned on, GLADE will record into a trace file all messages received by a partition. The trace file can then be used to replay the execution of the partition, in isolation.

To get a partition to generate a trace file, it has to be given the command line argument --trace. This is most easily done by using a command line option (see Section 3.5.15 [Partition Attribute Command_Line], page 46) in the configuration file to add --trace to the command lines of the partitions whose executions are to be replayed. When the application has been built, and started using the starter, as usual, the trace files will be generated. It is also possible to build the distributed application with the None starter and then to include the --trace argument on the command line.

As a default, the file name of the trace file is the name of the partition's executable (i.e. the string returned by the standard procedure Ada.Command_Line.Command_Name) with a suffix `.ptf`. `ptf` stands for Partition Trace File. It contains all the incoming requests delivered to the current partition. The file name can be changed with the --trace_file <othername> command line argument.

Note that when a remote partition is launched with `rsh` under Unix, GLADE invokes the executable's name of this partition with its absolute path included. Therefore, when

--trace is passed on the command line, the partition trace file includes the absolute path as well. If a file name with a relative path is passed on the command line following the --trace_file argument, then the home user's directory is concatenated to the --trace_file argument.

### 3.6.13 Partition Option replay

In order to replay a partition whose execution has been previously traced, the command line argument --replay is required. In addition, the special boot server location "replay://" has to be specified, i.e. by using the --boot_location replay:// command line argument.

To replay a traced execution of partition whose executable is named `part`, we start it with the command

```
% part [--nolaunch] [--slave] --replay --boot_location replay://
```

possibly under the control of a debugger, such as gdb.

Since the exact contents of the messages received is recorded, differences in input from external sources (such as standard input) during replay will most likely give unexpected results. Also, replay of applications whose behavior is inherently non-deterministic - for example if they use tasking - will be problematic.

N.B. It is important that the same executable is used for replay as when the trace file was generated, otherwise strange behavior can be expected.

## 3.7 Debugging Facilities

To trace his application, the user sets the following two environment variables to true. The variable S_RPC provides information on what is going on the execution of remote procedure calls (resolved in System.RPC - s-rpc.adb). The variable S_PARINT provides information on partitions and units status (resolved in System.Partition_Interface - s-parint.adb). For instance, using sh, bash or zsh, type:

```
S_RPC=true;    export S_RPC
S_PARINT=true; export S_PARINT
```

## 3.8 GLADE File Hierarchy

All GLADE intermediate files (object files, etc) are stored under a common directory named "dsa". The user may remove this whole directory and its content when he does not intend to rebuild his distributed applications.

## 3.9 GLADE Internals

The GLADE PCS is called GARLIC, which stands for Generic Ada Reusable Library for Interpartition Communication. Most of the previous features like filtering, trace / replay, termination, reconnection, version consistency and remote launching are provided via `gnatdist` specific features. Some of these features are not configurable by the user.

### 3.9.1 Architecture of GLADE PCS

When a partition starts executing, one of the first elaboration steps is a registration with the partition id server and with the RCI name server. These two servers are located on a boot server.

The partition id server is used to allocate a unique partition id when a new partition registers. The id server also replies to information queries from other partitions. This information includes the ip address, the port on which the partition is waiting for requests and all its configuration parameters (termination policy, reconnection policy, filters, ...).

The RCI name server is used to register newly elaborated RCI packages. This RCI package registration occurs once the partition has been allocated a partition id. The partition registers its RCI and SP packages with their names, their version ids and internal information.

As described previously, the boot server partition can be replicated on boot mirrors, in order to prevent this partition from being a single point of failure. A partition has always to connect to a boot server or a boot mirror in order to get a minimal information set on the other existing partitions.

The boot server is the first boot mirror of the system. A new partition declared as a boot mirror joins the group of boot mirrors. The group of boot mirrors operates as a token ring: any request from a new partition to a boot mirror is sent on the ring through a token. A request can traverse the ring once or twice before being approved by all the other boot mirrors.

When the boot server dies, a new boot server is elected among the remaining boot mirrors. A boot server is responsible for the global termination detection. That is why a new boot server has to be elected.

### 3.9.2 Heterogeneous System

The GNAT environment provides default stream attributes, except for non-remote access types (see Section 2.5.3 [Transmitting Dynamic Structure], page 19 and Section 2.8.1 [Marshalling and Unmarshalling Operations], page 28). The implementation of the default attributes of predefined types can be found in *System.Stream_Attributes* (s-stratt.adb).

The GLADE implementation overloads the GNAT default marshalling and unmarshalling subprograms with its own subprograms, which format data according to a *XDR*-like protocol. Therefore, any GLADE application will work in an heterogeous environment.

If the user wants to keep using the GNAT default attributes for performance purposes, or to use another protocol to marshall and unmarshall predefined types, he can replace `s-stratt.adb` by a more appropriate implementation.

### 3.9.3 Allocating Partition Ids

The Partition_ID is allocated dynamically, at run-time. Each partition connects to a Partition ID Server which is located on the boot server and asks for a free Partition_ID. The advantage of this approach is that it supports easily client / server solution (client partitions may be duplicated, they will obtain different Partition Ids). There is no need to recompile or relink all the partitions when a new partition is added to the system. The Partition_ID is not tight in any way to a specific protocol or to a specific location.

### 3.9.4 Executing Concurrent Remote Calls

When multiple remote subprogram calls occur on the same partition, they are handled by several anonymous tasks. The number of tasks in the anonymous tasks pool can be configured by three figures (see Section 3.5.22 [Partition Attribute Task_Pool], page 49). Therefore, the user may have to synchronize global data in the Remote_Call_Interface or Remote_Types unit to preserve concurrent access on data. If the user want to suppress the multiple requests features, he can force the configuration of the anonymous tasks pool to `(0 | 1, 0 | 1, 1)`. That means that there will be at most one anonymous task running at a time.

### 3.9.5 Priority Inheritance

It is compiler-dependent whether the caller priority is preserved during a remote procedure call. In fact, it can be unsafe to rely on priorities, because two partitions may have different priority ranges and policies. Nevertheless, GLADE preserves the caller priority. This priority is marshalled and unmarshalled during the remote procedure call and the priority of the anonymous task on the server is set to the caller priority. There is no way currently to disable this feature.

### 3.9.6 Remote Call Abortion

When a remote procedure call is aborted, GLADE will abort the calling task on the caller side. It will also try to abort the remote anonymous task performing the remote call. This task will be aborted without being requeued in the anonymous tasks pool.

### 3.9.7 User Filter Implementation

As has been briefly mentioned above, a filter with a name "NAME" must be implemented in a package called *System.Garlic.Filters.Name*. The user may write his own filters, which must implement their filtering of data in the primitive operations of a type derived from the type *System.Garlic.Filters.Filter_Type*. His filter package must then register an instance of his newly derived type with GLADE by calling *System.Garlic.Filters.Register*. From that on, his filter is ready to be used.

For more information on how to write filter packages see the sample implementation of a ZIP filter in files `s-gafizi.ad[bs]` in the distribution. The user might also want to look at the example in the `Filtering` directory of the GLADE distribution.

## 3.10 Remote Shell Notes

To start a partition, the main partition executes a remote shell - except when the distributed application is built with a None starter. Thus the user has to make sure that he is authorized to execute a remote shell on the remote machine. In this case, a first step would be to add into his $HOME/.rhosts file a line like : <remote-machine> <user-name>

If he is not authorized at all, he can bypass this problem. All he has to do is:

- Open a session on each machine listed in his configuration file.

- If MAIN_PART is the partition that includes the main procedure and if he wants to start MAIN_PART on host MAIN_HOST:
  - Choose a TCP port number PORT_NUM
  - Then for each partition PART, start manually the corresponding executable on the corresponding host as follows

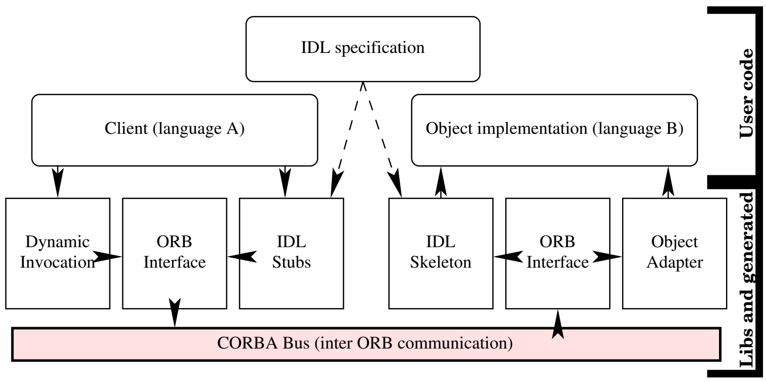
    ```
    % PART [--nolaunch] --boot_location tcp://MAIN_HOST:PORT_NUM
    ```

    The –nolaunch parameter must be included for the main partition, it means that this partition is not in charge of launching others.
- If he wants to kill the distributed application before it terminates, kill MAIN_PART.

# Appendix A DSA and CORBA

## A.1 CORBA Architecture

CORBA is an industry-sponsored effort to standardize the distributed object paradigm via the CORBA Interface Definition Language (IDL). The use of IDL makes CORBA more self-describing than any other client/server middleware. The Common Object Request Broker: Architecture and Specification, revision 2.2 describes the main features of CORBA which are Interface Definition Language, Language Mappings, Stubs, Skeletons and Object Adapters, ORB, Interface Repository, Dynamic Invocation, ORB protocols and CORBA services.


IDL specification
Client (language A)
Object implementation (language B)
User code
Dynamic
Invocation
ORB
Interface
IDL
Stubs
IDL
Skeleton
ORB
Interface
Object
Adapter
Libs and generated
CORBA Bus (inter ORB communication)

The IDL specifies modules, constants, types and interfaces. An object interface defines the operations, exceptions and public attributes a client can invoke or access. CORBA offers a model based only on distributed objects. In some respects, it can be compared to Java as this language provides only an object-oriented programming model, and discards the classical structured programming model.

An IDL translator generates client stubs and server skeletons in a host language (`C++`, `C`, Java, Smalltalk, Ada95); a language mapping specifies how IDL entities are implemented in the host language. Depending on the features available in the host language, the mapping can be more or less straightforward. When an IDL feature is not defined in the host language, the mapping provides a standardized but complex way of simulating the missing feature. Although the user works with the generated code, a good understanding of the language mapping is often necessary.

When the host language does not provide object-oriented features, the user has to deal with a complex simulation of those functions. A `C++` programmer has to follow several rules related to parameters passed by reference. Defining whether the callee or the caller is responsible for parameter memory allocation can be regarder as an issue of `C++` programming conventions. The most difficult parts of the Ada mapping, which an Ada programmer should avoid whenever possible, are multiple inheritance and forward declarations.

The IDL translator produces several host language source files depending on the language mapping: client files called stubs and server files called skeletons. These files are specific to a vendor and product, as they make calls to a proprietary communication subsystem, but their structure and interface are supposed to follow a standard canvas. The client stubs convert user queries into requests to the ORB, which transmits these requests through an object adapter to the server skeleton.

## A.2 Interface Definition Language

In DSA, the IDL is a subset of Ada95. The user identifies interface packages at compile time. Some library-level packages are categorized using pragmas and these interface packages have to be library units.

In CORBA, the IDL is a description language; it supports `C++` syntax for constant, type and operation declarations. From IDL descriptions, a translator can directly generate client header files and server implementation skeletons.

An IDL file can start by defining a module. This provides a name-space to gather a set of interfaces. This is a way to introduce a level of hierarchy (<*module*>::<*interface*>::<*operation*>). The Ada95 binding maps this element into a (child) package. `#include` will make any other namespaces visible.

A module can define interfaces. An interface defines a set of methods that a client can invoke on an object. An interface can also define exceptions and attributes. An exception is like a `C++` exception: a data component can be attached to it. An attribute is a component field. For each *Attribute*, the implementation automatically creates the subprograms Get_*Attribute* and Set_*Attribute*. Only Get is provided for *readonly* attributes. An interface can derive from one or more interfaces (multiple inheritance).

The Ada95 binding maps this element into a package or a child package. For the client stub, the implementation will automatically create a tagged type named Ref (which is derived from CORBA.Object.Ref or from another Ref type defined in another interface) in a package whose name matches the one of the interface. For the server skeleton, the implementation will automatically create a tagged type named Object (which is derived from an implementation defined private tagged type Object) in a package named Impl, which is a child package of a package named after the interface name (`<interface>`.Impl).

```
module CosNaming {
  typedef string Istring;
  struct NameComponent {
    Istring id;
    Istring kind;
  };
  typedef sequence <NameComponent> Name;
  enum BindingType {nobject, ncontext};
  struct Binding {
    Name binding_name;
    BindingType binding_type;
  };
  typedef sequence <Binding> BindingList;

  interface BindingIterator;

  interface NamingContext {
      exception CannotProceed {
          NamingContext cxt;
          Name rest_of_name;
        };
      void bind (in Name n, in Object obj)
        raises (CannotProceed);
      void list
        (in unsigned long how_many,
         out BindingList bl,
         out BindingIterator bi);
      // Other declarations not shown
    };

  interface BindingIterator {
      boolean next_n
        (in unsigned long how_many,
         out BindingList bl);
      // Other declarations not shown
    };
};
```

A method is defined by a unique name (no overloading is allowed) and its signature (the types of its formal parameters). Each parameter can be of mode **in**, **out** or **inout**, whose meanings are comparable to their Ada homonyms. Every exception that can be raised by a method must also be declared as part of the method signature.

The **oneway** attribute can be applied to a subprogram, giving it at-most-once semantics instead of the exactly-once default. This precludes a method from having output parameters, a return value, or from raising an exception. It is not portable to assume that the caller resumes its execution once the input parameters are transmitted.

Most CORBA data types map in a straightforward way onto predefined Ada types, with the exception of `any` and `sequence`. `any`, that can designate any CORBA type, is mapped onto a stream type with `read` and `write` operations. A `sequence` holds a list of items of a given type and is represented in Ada using a pair of lengthy generic packages. One may note that the CORBA `string` type is mapped onto the `Unbounded_String` Ada95 type. The IDL does not provide an equivalent to unconstrained arrays.

The Ada95 mapping provides special mechanisms to implement two difficult-to-map CORBA features. First, it provides a translation of multiple inheritance. As described above, an Ada95 package defines a type derived from the first interface, and extends the list of its primitive operations to achieve inheritance from other interfaces. Another unnatural feature of CORBA for an Ada programmer comes from forward declarations. In Ada, two package specifications cannot "with" each others, but this can occur between two IDL interfaces. To solve this, the mapping can create "forward" packages. This can result in a very non-intuitive situation where the client stub does not "with" its usual interface packages but withs "forward" packages instead.

When developping a distributed application with CORBA, two situations can arise. On the server side, the programmer is responsible for the IDL file. He has to understand the Ada95 language mapping in order to avoid structures with a non-trivial implementation whenever possible, such as forward declaration and multiple inheritance. On both the server and the client side, the programmer has to deal with the generated code. A good understanding of the mapping is useful to get back and forth from the IDL file to the generated code in order to keep an overview of the distributed application. Understanding this mapping can be a tedious task depending of the host language.

IDL interface information can be stored on-line in a database called Interface Repository (IR). A CORBA specification describes how the interface repository is organized and how to retrieve information from it. The reader will note that this information is close to what the Ada Semantic Interface Specification (ASIS) can provide.

The interface repository allows a client to discover the signature of a method which it did not know at compile time. It can subsequently use this knowledge together with values for the method's parameters to construct a complete request and invoke the method. The set of functions that permits the construction of a method invocation request at run time is the Dynamic Invocation Interface (DII).

The IR API allows the client to explore the repository classes to obtain a module definition tree. From this tree, the client extracts subtrees defining constants, types, exceptions, and interfaces. From an interface subtree, the client can select an operation with its list of parameters (type, name and mode) and exceptions.

A client has then three ways to make a request. As in the static case, he can send it and wait for the result; he can also do a one-way call and discard the result. With dynamic requests, a third mechanism is offered: the client can send the request without waiting for the result, and obtain it later, asynchronously.

The DII has a server-side counterpart, called Dynamic Skeleton Interface (DSI). Both mechanisms are powerful but very complex and tedious to use. In some respects, they also violate the Ada95 philosophy, because strong typing is not preserved. Most users will keep working with static invocations.

## A.3 Network Communication Subsystem

The communication subsystem is one of the key points of a distributed system: it offers basic services such as the capability to transmit a message from one part of the distributed program to another. Those elementary services are then used by higher level services to build a fully functional distributed system.

The limit between what belongs to the communication subsystem and what belongs to an external service may sometimes be difficult to draw. Moreover, something considered as a service in CORBA may be viewed as purely internal in DSA.

### A.3.1 DSA PCS

In the DSA world, everything that is not done by the compiler in regard to the distribution belongs to the partition communication subsystem (PCS). For example, figuring out on which partition a package that will be called remotely is located is part of the PCS's responsibility.

The PCS entry points are well defined in DSA, and described in the `System.RPC` package declaration. By looking at this package, one can notice that there is nothing related to abortion of remote subprogram calls, although the Annex states that if such a call is aborted, an abortion message must be sent to the remote partition to cancel remote processing. That means that the PCS is in charge of detecting that a call to one of its entry points has been aborted and must send such an abortion message, without any help from the compiler.

Another interesting characteristic of the PCS is its behavior regarding unknown exceptions. When an exception is raised as a result of the execution of a remote subprogram call, it is propagated back to the caller. However, the caller may not have any visibility over the exception declaration, but may still catch it with a `when others` clause. However, if the caller does not catch it and let it be propagated upstream (maybe in another partition), and if the upstream caller has visibility over this exception, it must be able to catch it using its name. That means that the PCS must recognize that a previously unknown exception maps onto a locally known one, for example by being able to dynamically register a new exception into the runtime.

### A.3.2 CORBA ORB

In CORBA, a much more fragmented approach to communication services was adopted: they are essentially defined externally. For example, the naming service (which maps object names to object references) is a distributed object with a standard IDL interface.

While this approach seems more pure, it has performance drawbacks. Being itself a distributed object, the naming service cannot be optimized for the needs of a specific ORB.

A special case is also required in the ORB for it to be able to locate the naming service itself (chicken and egg problem): in order to get a reference on a distributed object (an IOR, Interface Object Reference) to start with, the programmer needs to have an IOR for the naming service. This IOR can be retrieved from the command line, from a file or by invoking the ORB Interface, depending on the CORBA version.

Regarding exception propagation, an ORB is not able to propagate an exception that has not been declared in the IDL interface. This restriction, although annoying because it restricts the usage of exceptions, is understandable given the multi-language CORBA approach: what should be done, for example, when a `C++` exception reaches a caller written in Ada? Note that an implementation may provide more information in the CORBA exception message, such as the `C++` or Ada exception name.

## A.4 Distributed Application Development

### A.4.1 DSA Application Development

The DSA does not describe how a distributed application should be configured. It is up to the user (using a partitioning tool whose specification is outside the scope of the annex) to define what the partitions in his program are and on which machines they should be executed.

GLADE provides a Configuration Tool and a Partition Communication Subsystem to build a distributed application. The `gnatdist` tool and its configuration language have been specially designed to let the user partition his program and specify the machines where the individual partitions will be executing. The Generic Ada Reusable Library for Interpartition Communication (GARLIC) is a high level communication library that implements the interface between the Partition Communication Subsystem defined in the Reference Manual and the network communication layer with object-oriented techniques.

### A.4.2 CORBA Application Development

The ORB provides a core of basic services. All other services are provided by objects with IDL. The OMG has standardized a set of useful services like Naming, Trading, Events, Licensing, Life Cycle, Events, ... A CORBA vendor is free to provide an implementation of these services.

The Naming Service allows the association (*binding*) of an object reference with user-friendly names. A name binding is always defined relative to a *naming context* wherein it is unique. A naming context is an object itself, and so can be bound to a name in another naming context. One thus creates a *naming graph*, a directed graph with naming contexts as vertices and names as edge labels. Given a context in a naming graph, a sequence of names can thus reference an object. This is very similar to the naming hierarchies that exist in the Domain Name System and the UNIX file system. A typical scenario to start working with the Name Service consists in providing a well-known remote reference that defines the root of a naming and naming context hierarchy. Then, many naming operations can be executed on this hierarchy. The Trading Service provides a higher level of abstraction than the Naming Service. If the Naming Service can be compared to the White Pages, the Trading Service can be compared to the Yellow Pages.

The Events service provides a way for servers and clients to interact through asynchronous events between anonymous objects. A *supplier* produces events when a *consumer* receives notification and data. An *event channel* is the mediator between consumers and suppliers. *consumer admins* and *supplier admins* are in charge of providing *proxies* to allow consumers and suppliers to get access to the event channel. Suppliers and consumers produce and receive events through their associated proxies. From the event channel point of view, a *proxy supplier* (or *proxy consumer*) is seen as a consumer (or a supplier). Therefore, a proxy supplier (or proxy consumer) is an extended interface of consumer (or supplier). The Events service defines *push* and *pull* methods to exchange events. This allows to define four models to exchange events and data.

## A.5 Some Elements of Comparison

CORBA provides an outstanding and very popular framework. The IDL syntax is close to `C++`. The object model is close to Java: CORBA defines only distributed objects. Furthermore, when using the Ada mapping, the stub and skeleton generated code is close to Java with two root classes, Ref for clients and Object for servers.

DSA provides a more general model. This includes distributed objects, but also regular remote subprograms and references to remote subprograms. Shared passive packages can be defined as an abstraction for a (distributed) shared memory, a persistency support or a database. Basically, the IDL is a subset of Ada95 and the remote services are defined in packages categorized by three kinds of pragmas (RCI, RT, SP). The distributed boundaries are more transparent as the application is not split into IDL and host language sources.

In DSA, any Ada type can be used except access types, but this can be solved by providing the marshalling operations for such a type. The exception model is entirely preserved. Overloading is allowed in DSA (not in CORBA). The user can also define generic packages and use mixin mechanism to obtain some kind of multiple inheritance.

The DSA user can design, implement and test his application in a non-distributed environment, and then switch to a distributed situation. With this two-phase design approach, the user always works within his favorite Ada95 environment. The use of pragma All_Calls_Remote also facilitates debugging of a distributed application in a non-distributed context.

To work on client stubs or server skeletons, the CORBA user will have to deal with generated code. In any case, understanding the host language mapping is always very useful. It can be required for some languages like `C++`. An Ada programmer should avoid using forward declaration or multiple inheritance (and in some respects, sequence).

The CORBA user has to re-adapt his code to the code generated by the translator from the IDL file anytime the latter is modified. He also has to use the predefined CORBA types instead of Ada standard types; he has to call ORB functions or a naming service to obtain remote object references.

As Ada95 is its own IDL, the user does not deal with any generated stub or skeleton code. The configuration environment takes care of updating object, stub and skeleton files when sources have been updated. The system automatically provides some naming functions like declaring RCI services. It also takes care of aborting remote procedure calls, detecting distributed termination, checking version consistency between clients and servers, and preserving and propagating any remote exception. Note that none of these features are immediatly available in CORBA.

The RM does not require a DSA implementation to work on heterogeneous systems but GLADE, like any reasonable implementation, provides default XDR-like marshalling operations. This feature can be inhibited for performance reasons. An ORB is required to implement a Common Data Representation (CDR) to ensure safe communications between heterogeneous systems.

CORBA is a very rich but very complex standard. Its drawbacks include the high learning curve for developing and managing CORBA applications effectively, performance limitations, as well as the lack of portability and security. These drawbacks are the price to pay for language interoperability, a facility the Ada95-oriented DSA does not provide.

Interoperability between compilers is not yet an issue with DSA because there is only one implementation available (GLADE). But it is a validation requirement to permit the user to replace his current PCS with a third-party PCS. We can note this issue was not resolved in CORBA until revision 2.2. For the same reasons, we can expect future DSA implementations to ensure PCS compatibility.

Using its IDL, the OMG has described a number of `Common Object Services` (COS) that are frequently needed in distributed systems. Unfortunately, these specifications are limited to IDL descriptions, and most of the semantics are up to the vendor. The DSA misses such user-level libraries, including basic distributed software components. More generally, the lack of component libraries has always been a problem for Ada.

Implementing CORBA services as native Ada95 distributed objects, taking advantage of the standard language features, yields a simpler, easy to understand and use specification. We have already implemented the Naming service, the Events service and a service close to the Concurrency one with DSA. Developping the CORBA services was an interesting experience. We realized that although those services are nicely specified by an IDL file, their semantics is quite vague in such a way portability is dramatically broken. This work will be described in a future paper.

Another major goal of the GLADE team is to export DSA services to the CORBA world.

The idea is to translate all DSA features to equivalent IDL features using ASIS. This would allow the DSA user to connect his DSA server to an ORB. This would also allow applications written in other languages to invoke DSA features. We are also seeking to use this approach to offer a DII mechanism for DSA.

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Version 1.1, March 2000



## 0. PREAMBLE

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