CORBA *Lightweight Components*: 
An Early Report*

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Abstract. While designing and starting an implementation of the CORBA Lightweight Components (CORBA-LC) Component Model, we stated a set of requirements addressed and followed some guidelines. This early report describes which are these requirements, how they guided the design and how they are going to be addressed in the implementation of CORBA-LC. CORBA-LC is a lightweight distributed reflective component model based on CORBA. It imposes a peer network model in which the whole network act as a repository for managing and assigning the whole set of resources: components, CPU cycles, memory, etc. Thus, application deployment is automatically and adaptively performed at run-time. Requirements for component description, packaging, deployment, reflection, logical network cohesion, distributed resource queries and fault-tolerant protocols are identified. Finally, we show the validity of the identified requirements and guidelines in dealing with CSCW and Grid Computing applications and show how current component models fail on addressing some of them.

1 Introduction

Component-based development[1,2], resembling integrated circuits (IC) connections, promises developing application connecting independently-developed self-describing binary components. These components can be developed, built and shipped independently by third parties, and allow application builders to connect and use them.

As applications become bigger, they must be modularly designed. Components come to mitigate this need, as they impose the development of modules that are interconnected to build the complete application. Components, being binary, independent and self-described, allow:

- Modular application development, which leads to maximum code reuse, as components are not tied to the application they are integrated in.

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– Soft application evolution and incremental enhancement, as enhanced versions of existing components can substitute previous versions seamlessly, provided that the new components offer the required functionality. New components can also add new functionality to be used by new components, thus allowing applications to evolve easily.

When component technology is applied in a distributed environment, programmers can develop components that interact transparently with other components residing in remote machines. However this makes applications and components management harder.

**CORBA Lightweight Components (CORBA-LL)**[3], is a new distributed component model based on CORBA[4,5]. While traditional component models force programmers to decide the hosts in which their components are going to be run (deployment) using a “static” description of the application (assembly), CORBA-LL performs the deployment and component dependency management automatically. Thus, it offers the traditional component models advantages (modular applications development connecting binary interchangeable units) allowing automatic placement of components in network nodes, intelligent component migration and load balancing, leading to maximum network resource utilization. CORBA-LL introduces a more peer network-centered model in which all node resources, computing power and components can be used at run-time to automatically satisfy applications dependencies.

While CORBA-LL is described elsewhere[3], this paper focuses on the requirements the design and implementation of the CORBA-LL component model must address to cope with the demands of CSCW and Grid computing applications. The paper is organized as follows; Section 2 describes the general design and implementation guidelines of CORBA-LL. Section 3 outlines the needs of both CSCW and Grid applications and how CORBA-LL addresses them. Section 4 includes some related work on general purpose component models and how CORBA-LL relates to it. Finally, Section 5 presents conclusions, status and future work.

## 2 Design and implementation guidelines for CORBA-LL

While designing the CORBA-LL Component Model[3], we identified some design and implementation guidelines and requirements. These requirements state what we demand from component-based development in a distributed environment. We were interested in Computer Supported Cooperative Work (CSCW) and Grid Computing. We identified:

1. **Simplicity and performance.** The model should be simple enough to accommodate component-based development and to be implemented efficiently; it must be lightweight.

2. **Heterogeneity.** It must support heterogeneous resource integration at any level: language, hardware, operating system and network. CORBA[5, 4] is here a perfect election.
3. **Peer** or **Network-Centered Model**. We are interested in integrating the whole computation power available, including distributed network-connected machines, so all the nodes connected must collaborate as peers depending on their available resources. The traditional client and server distinction is not applicable, as nodes may change their role as needed. The network (with help of nodes composing it) becomes the entity in charge of maintaining and administering the available resources (components, CPU cycles, etc.).

4. **Scalable and fault-tolerant.** In order to accommodate a potentially large number of hosts in a distributed environment, the need for distributed scalable and fault-tolerant protocols arise.

5. **Seamlessly integrate new components.** It must be possible to add new components into the system (without the need of compiling) and make them instantly available to be used by *any* application in *any* host.

6. **Automatic component dependency management.** In a distributed system with hundreds or thousands of components, managing component interdependencies is not an easy task. New components installed in a host may require other components or new version of existing, not present in that host. Instead of forcing all required components to be installed locally, the network as a whole can be used as a repository for resolving component requirements, fetching them from the host they are installed or using them remotely.

7. **Use the same component model for all application tiers.** Particularly, for CSCW applications, it would be desirable to include the GUI and presentation logic tiers components within the same design process of the rest of the application tiers.

8. **Integration of tiny devices.** The resource utilization logic must be intelligent enough to accommodate from PDAs to high-end servers.

### 2.1 Components

Components are the key abstraction in CORBA-LC. Although there is some controversy on what is a component[2], in part because the term “component” being overused, we define them in the CORBA-LC model as *binary independent units, with explicitly defined dependencies and offerings, which can be used to compose applications*. This natural definition of components allows us to state the requirements we impose to the whole idea of Component-based Development[1] from a practical point of view.

Components must allow application development by assembling independent components. They could be developed, described and packaged by third parties and must interact seamlessly with other components.

These two properties (independence and explicit dependencies) allow components to be substituted by others with the same (or even superior) offerings but with enhanced implementation or Quality of Service (QoS) guarantees. Substitutability enables soft applications migration, enhancing them incrementally.

For this to happen, components must describe their interaction with the rest of components, in form of what they demand from the system and what they offer
to it. Components also inherit from the Object-Oriented paradigm the fact that they are also a description of the run-time behavior and requirements of their instances. The instances become running representations of the code stored in a component. Component descriptions then must satisfy at least two dimensions: the binary package or static dimension and the component type or dynamic dimension.

**Binary package** Static properties include those referring to the binary package in which the component is shipped. This information is necessary to handle, store and manipulate this component in binary form. Concretely, components must include information which allows them: (1) to be installed in a given host, (2) to be extracted from, and brought to, a given host, (3) to be dynamically loaded and unloaded as a Dynamic Link Library (DLL) either on client’s behalf or attending to memory, CPU or bandwidth load, and (4) to be instantiated. Static properties must include at least\[6]:

- Hardware, Operating System and Object Request Broker dependencies.
- Other components needed.
- Static description of offerings and needs, including:
  - **Mobility**: if the component can be extracted from a given host or it must be used remotely from this location.
  - **Replication**: if component instances can be replicated, either because they are stateless or they know how to interact with the framework to maintain replica consistency.
  - **Aggregation\[7]**: if this component knows how to split itself in different instances to process a set of data (data-parallel components) and how to gather partial results into a complete solution.
  - **Pay-per-use information**: describes the component’s licensing model.
  - **Security information**: The installer must be sure of who really made this component by verifying the component’s cryptographic signature, for example, from the component’s writer Web site.

This information is described using XML files for convenience, and stored in the package jointly with the component binary, as described in §23. The *Document Type Definitions* (DTDs) describing those files are based upon the WWW Consortium’s *Open Software Descriptor*\[8] DTD\[1].

**Component Type** Component instances are run-time incarnations of the behavior stored in a component; they are also a description of run-time properties and requirements of their instances. This can be considered the dynamic dimension. These properties and requirements can be **internal** or **external**, and allow components instances to be connected together to perform the applications behavior.

Internal properties are those that instances expose to the framework in which they are immerge. Components must be executed in a controlled way, so they

\[1\] As the CORBA Component Model\[9\] (CCM) does.
have to follow an agreed protocol to specify which are their run-time environment requirements and what they offer to the environment; they have to follow the framework rules. This framework is described in the following subsections.

External properties are those services that component instances expose to their clients (including other components or applications). Those external communication points are collectively called ports. Ports allow components to be connected together to accomplish the required task.

CORBA-LL does not limit the different port kinds that a component can expose. However, there are two basic kinds of ports: interfaces and events.

A component can indicate that its instances implement (provide) or use some interfaces\(^2\) for their internal work. Interfaces represent agreed synchronous communication points between components.

Events can be used as asynchronous communication means for components. They can also specify that they produce or consume some kind of event in a publish/subscribe fashion. For each event kind produced by a component, the framework opens a push event channel. Components can subscribe to this channel to express its interest in the event kind produced by the component.

Finally, factory interfaces\(^10\) are needed in CORBA-LL to manage the set of instances of a component. Clients can search for a factory of the required component and ask it for the creation of an instance.

Similar to static properties, components use a set of IDL and XML files to establish the minimal set of ports they need from and offer to other components. Those files are included within the component binary package (§2.3).

Concretely, component internal properties description must include: (1) Factory properties: A description of the life cycle of the instances of the component, which allows to automatically generate the factory code for this type of component, (2) Required framework services, and (3) QoS information: such as CPU and memory utilization, communication bandwidth, etc.

Similarly, component external properties description must include, at least: (1) IDL types and interfaces, (2) Port descriptions: the minimal set of ports (interfaces, events, etc.) offered and required, and (3) Factory interface: CORBA interface which implements the factory pattern\(^10\) for this component, used for managing instances.

Note that components only state their minimal requirements. This is because CORBA-LL does not restrict the set of external properties of a component to be fixed and allows it to change at run-time, offering new services and requesting new ones. This is supported by the reflection architecture (§2.4).

In CORBA-LL, we have chosen to use IDL files for specifying component’s types and interfaces and XML files (instead of a modified IDL+CIDL combination, as proposed by the CCM) with a custom DTD to specify component-related external

\(^{10}\) We use “interface” here in the same sense that it is used in CORBA.
properties. This allows us to use CORBA 2 standard, mature IDL compilers and tools while obtaining the benefits of components, seamless integration with current CORBA 2 software and a soft migration to component technology.

2.2 Containers and Component Frameworks

Component instances are run within a run-time environment called a **container**. Containers become the instances' view of the world. Instances ask the container for the required services and it in turn informs the instance of its environment (its **context**). As in CCM and EJB, in CORBA-CC the component/container dialog is based on agreed local interfaces, thus conforming a component framework. Containers leverage the component implementation of dealing with the non-functional aspects of the component[11], such as instance activation/de-activation, resource discovery and allocation, component migration and replication, load balancing[12] and fault tolerance among others. For example, when it is determined\(^3\) that some component instance should be run in another host of the network, the container can ask the component instance (via local agreed interfaces) to resume its execution returning its internal state. Then, the component can be migrated into another host (in its binary form), instantiated, and then given the previous instance state to continue its execution.

Containers also act as component instance representatives into the network. As stated above, components require other components to perform their work. This requirement is sent to the container and may require searching the complete network of cooperating nodes for the best suited component. The container collaborates with its local node in order to find the required component following the deployment and reflection architecture described in §2.4.

2.3 Packaging

The packaging allows to build self-contained binary units which can be installed and used independently. Components are packaged in “ZIP” files containing the component itself and its description as IDL and XML files. This is similar to the CCM Packaging Model[9]. This information can be used by each node in the system to know how to install and instantiate the component. Packaging:

- Must include both the binary information and the *meta*-information for this component, including the DLLs (or *shared objects*, in the case of Unixes) and the IDL and XML files.
- Must admit compression to overcome the efficient transmission of the component through possibly long and slow communication lines.
- Must be modular enough to allow (1) storing binaries for different architectures/operating systems/ORBs, (2) describing those binaries, and (3) extracting only a set of binaries from the whole component (jointly with the component metadata) to be installed in devices with a tiny memory, such as PDAs.

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\(^3\) This determination can be taken by the container in collaboration with the network.
For instance, the same component could be implemented using a Windows DLL, a Java .class file, and a TCL script source code.

2.4 Deployment Model

Deployment describes the rules a set of components must follow to be installed and run in a set of network-interconnected machines which cooperate to perform the required applications behavior. CORBA-LC deployment model is supported by a set of main concepts: nodes, the reflection architecture, the network model, the distributed registry and applications.

Nodes The CORBA-LC network model can be effectively represented as a set of nodes that collaborate in computations. (Fig. 1). Nodes are the entities maintaining the logical network behavior. Each host participating must have running a server implementing the Node service. Nodes maintain the logical network connection, encapsulate physical host information and constitute the external view of the internal properties of the host they are running on. Concretely, they offer (Fig. 2):

- A way of obtaining both node static characteristics (such as CPU and Operating System Type, ORB) and dynamic system information (such as CPU and memory load, available resources, etc.) This is supported through the Resource Manager interface.
- A way of obtaining the external view of the local services: the Component Registry interface reflects the internal Component Repository and helps in performing distributed component queries.
- Hooks for accepting new components at run-time for local installation in the local Component Repository, instantiation and running[13]. This is performed using the Component Acceptor.
- Operations for making this node available to the network and to interact with the rest of nodes of the whole system. The Network Cohesion supports this protocol for logical network cohesion.
Reflection Architecture  The Reflection Architecture is composed of the meta-data given by the different node services. This meta-data reflects the node internal properties, both static and dynamic, and is used at various stages in CORBA–LC. The Distributed Registry (§2.4) uses this information of each node to maintain an updated view of the resources of the whole network. Concretely:

- The Component Registry provides information about (a) the set of installed components, (b) the set of component instances running in the node and the properties of each, and (c) how those instances are connected via ports (assemblies)[14]. This information is used:
  - when components or applications raise the need for either any instance or a named instance of a component,
  - by visual builder tools to offer to the user the palette of available components, instances and connections among them.

- The Resource Manager in the node collaborates with the Container in deciding initial placement of component instances and instance migration, replication and load balancing at run-time. The Resource Manager also reflects the hardware static characteristics and hardware resources dynamic usage and availability. This information is also used to determine if a component, depending on its hardware requirements, can be physically installed in the node.

With the help of the reflection architecture, new components (or new versions of existing components) can be aggregated to the system at any time, and become instantly and automatically available to be used by other components.

The set of external properties of a component is not fixed and may change at run-time. Thus, component instances can adapt to the changing environment requesting new services or offering new ones. CORBA–LC offers operations to modify the set of ports a component exposes[15].

Network Model and The Distributed Registry The CORBA–LC deployment model is a network-centered model; The complete network is considered as a repository for resolving component requirements. Each host (node) in the system maintains a set of installed components in its Component Repository. All of those are available to be used by any other component. When component instances start running, they may ask their container for some required components. These components are searched in the whole network. The network issues the corresponding distributed queries to each node’s Component Registry in order to find the component which match better with the stated QoS requirements. Once the “set” of best suited components have been found, the network must select one of them to be instantiated attending to characteristics such as location, cost, migration, etc. Once selected, the network can decide either to instantiate the component in its original node or to fetch the component to be locally installed, instantiated and run. For example, a component decoding a MPEG video stream would work much faster if it is installed locally.
This network behavior is implemented by the **Distributed Registry**. It stores information covering the resources available in the network as a whole, and is responsible of managing these. Component Registries, Resource Managers and the Network Cohesion interface of each node support the Distributed Registry behavior. Component Registries collaborate to resolve distributed component queries and reflect the internal Component Repository of each node. Populating the node's Component Repository makes the Distributed Registry aware of the change. This simplifies the application management greatly[6]. Similarly, Resource Managers supply node's resource utilization to help the Distributed Registry decisions. The Distributed Registry activities include:

- **Logical Network Management**: encompasses the protocol used
  1. to maintain the 'logical' connection between them: which nodes are available, message routing, ping/reply handshaking, etc., and
  2. to maintain updated information about the available resources in the network. This information includes the meta-data given by the Reflection Architecture in each node.

- Support for **Distributed Queries**: As the Distributed Registry stores information regarding the whole network, it is also in charge of resolving distributed component queries.

- **Network Resource Monitoring** and component instance migration and replication to achieve load balancing and fault tolerance. Resource Managers help the Distributed Registry The Resource Manager interface also supports the **Meta-Resource Managers (MRMs)** operations. Meta-Resource Managers, instead of managing one machine resources, maintain an updated view of a set of nodes' Resource Managers. This allows a hierarchical treatment of network resources, simplifying the network management.

Obtaining the network management required by the Distributed Registry behavior in distributed environments is never an easy task. To be realistic in a truly distributed, scalable system, the protocol must support spurious node failures and node disconnections (and re-connections) gracefully. Also, the network must integrate seamlessly the whole set of nodes present in a given system. As the number of nodes can become arbitrarily large, the need for efficient protocols arise. The logical network extension can also become potentially large, raising the need for hierarchical protocols[6] (Fig. 3). Concretely, the guidelines we have identified for the network management protocol include:

- **Hierarchical protocol**: The protocol must allow logical grouping and incremental resource lookup.

- **“Soft” network consistency**: Instead of maintaining a “strong” network consistency in which MRMs have perfect knowledge about the set of hosts, MRMs have an approximate view of the present resources.

- **Peer-replicated protocol**: To enhance fault-tolerance, the protocol must (1) allow replicated peer MRMs per group (Fig. 3), (2) decide the number and location of these replicas depending on FT requirements, and (3) adapt itself by creating new replicas as needed and catching replica failures.
As stated in §5, we are testing implementations of these protocols using techniques such as multicast, event and notification channels[16], asynchronous messaging[17] and object group service[18].

**Applications** In CORBA–LC, applications are just special components. They are special because (1) they encapsulate the explicit rules to connect together certain components and their instances (how many instances and the name of each, of which components, how are they interconnected), and (2) they are created by users with the help of visual building tools. Applications can be considered as bootstrap components; when applications start running, they expose their explicit dependencies, requiring instances of other components and connecting them following the user stated pattern for that particular application. In CORBA–LC the matching between component required instances and network-running instances is performed at run-time; the exact node in which every instance is going to be run is decided when the application requests it, and this decision may change to reflect changes in the load of either the nodes or the network.

Thus, the deployment of the application, instead of being fixed at deployment-design time, is intelligently performed at run-time. This allows the implementation of intelligent run-time scheduling, migration and load balancing schemes. The difference between fixed and run-time deployment is similar to that between static and dynamic linking of Operating Systems libraries, but augmented to the distributed, heterogeneous case.

3 Application domains

The CORBA–LC model represents a very convenient infrastructure for developing applications in a wide range of domains. It can be seen as a general purpose
infrastructure. However, we are specially interested in dealing with CSCW and Grid Computing.

3.1 Computer Supported Cooperative Work (CSCW)

Collaborative work applications allow a group of users to share and manipulate a set of data (usually multi-media) in a synchronous or asynchronous way regardless of user location. We are interested in the development and deployment of synchronous CSCW applications, including video-conferencing, shared whiteboard and workspaces, workflow and co-authoring systems. CORBA-LC represents an optimal environment for various reasons:

- It offers a peer model, which matches the inherently peer distributed nature of these applications.
- GUI components can be considered within the modular design of the application, thus allowing the replacement of the presentation layer to suit additional user or application needs.
- It allows bandwidth-limited multimedia components (such as video stream decoding) to be migrated and installed locally to minimize network load.
- It allows tiny devices such as Personal Digital Assistants (PDAs) to be used as normal nodes with limited capabilities; they can use all components remotely.

![CSCW application model](image)

**Fig. 4.** CSCW application model.

Figure 4 depicts the relationships between a CSCW application and other components, including GUI ones. The latter can be either local or remote, and use the local Display component providing painting functions. Each GUI component is in charge of a portion of the window, and applications can change how the data is shown by replacing the GUI components with others at run-time. Note that all components required by the application can be remote, thus allowing the use of thin clients such as PDAs.

3.2 Grid Computing

Our view of Grid Computation targets scalable and intelligent resource and CPU usage within a distributed system, using techniques such as *idle computation*. [20]
and volunteer computing[21]. These techniques fit seamlessly within the CORBA–CC model to suit Grid Computation needs.

Other component-based alternatives such as the Common Component Architecture (CCA)[22] and Ligature[23] have appeared in the High-Performance Computing (HPC) community. These models address the needs of scientific computing, introducing components kinds which reflect the special characteristics of the field (for example, components whose instances must be split and distributed into the network to perform a highly-parallel task). While we find this approach very interesting, those models usually become only a minimum wrapper[24] for reusing legacy scientific code and do not offer a complete component model.

FOCALE[25] offers a component model for grid computation. It uses CORBA and Java (although it supports legacy applications). It provides a system view at different levels: federation, server, factories, instances and connections.

Notable developments in the Metacomputing and Grid Computing fields include Globus[26] and Legion[27]. They are systems which offer services for applications to access to the computational grid. However, they are huge systems, difficult to manage and configure, somewhat falling in its primary intentions. Moreover, they do not address very well the interoperability and code reuse through component technology.

Recent interest has been shown by the OMG regarding parallel applications[28] and aggregated computing[7]. However, the OMG has neither agreed nor released any specification on these topics.

4 Related Work

To date, several component models have been developed. Although CORBA–CC shares some features with them, it also has some key differences.

Java Beans[29] is a framework for implementing Java-based desktop applications. It is limited to both Java and the client side of the application. Conversely, CORBA–CC is not limited to Java and allows components to be distributed among different hosts, seamlessly integrating local GUI components.

Microsoft’s Component Object Model (COM)[30] offers a component model in which all desktop applications are integrated. In our opinion, its main disadvantages are that, from a practical point of view, (1) it does not integrate very well the distributed case (DCOM) and (2) its support is rather limited to the Windows Operating System. Moreover, COM components do not expose their requirements (other required components)[14,6]. CORBA–CC inherits from CORBA its Operating System, programming language and location transparency, thus effectively adapting to heterogeneous environments. Moreover, it is designed from the beginning to automatically exploit the computing power and components installed in all hosts participating using its Reflection Architecture.
In the server side, SUN's EJB[31] and the new Object Management Group's CORBA Component Model (CCM)[9,32] offer a server programming framework in which server components can be installed, instantiataed and run. Both are fairly similar. In fact, CCM “basic” level makes both models totally compatible. EJB is a Java-only system, while CCM continues the CORBA heterogeneous philosophy. Both are designed towards supporting enterprise applications, thus offering a container architecture with convenient support for transactions, persistence, security, etc.[15] They also offer the notion of components as binary units which can be installed and executed (following a fixed assembly) in Components Servers.

Although CORBA-CC shares many features with both models, it presents a more dynamic model in which the deployment is not fixed and is performed at run-time using the dynamic system data offered by the Reflection Architecture. It also allows adding new components and modifying component instances properties and connections at run-time and reflecting those changes to visual building tools. Also, CORBA-CC is a lightweight model in which the main goal is the optimal network resource utilization instead of being oriented to enterprise applications; it does not incur in the overhead of offering services such as transactions and persistence. This overhead and complexity is one of the main reasons why complete mature CCM implementations are not expected in 2-3 years. In fact, the CCM specification still has open issues and it is not finished.

In general, component models have been designed to be either client-side or server-side. This forces programmers to follow different models for programming the different layers of applications. CORBA-CC offers a more peer approach in which applications can utilize all the computing power available, including the more and more powerful user workstations and high-end servers. Application components can be developed using a single component model and spread into the network. They will be intelligently migrated into the required hosts. Thus, a homogeneous component model can be used to develop all the tiers (GUI, application logic) of distributed multi-tiered applications.

In[6], a dynamic configuration management system is described. This work provides us with valuable ideas for our research. However, it is centered in the process of automatic component configuration, not offering a complete component model.

5 Conclusions, Status and Future Work

In this article we have described the requirements identified in the design and preliminary implementation of the CORBA-CC Component Model. Also, we have stated the validity of the design to target the CSCW and Grid Computing domains. Current CORBA-CC implementation allows building components with the stated external characteristics and packaging. However, the implementation is still incomplete, so we have some future work to do:

- Explore strategies to maintain the described Reflection Architecture and the network-awareness of both nodes and the Distributed Registry[6], also in-
Introducing fault-tolerance[33], migration, replication and load-balancing techniques[12],
- Implement visual building tools to build applications based on all available
  network components.
- Further identify CSCW and Grid-based application needs[7,23] enhancing
  CORBA-CL to better support them. We think our research can help OMG
  efforts in this direction.
- Study the integration of this model with current and future CCM implementa-
  tions.

Finally, we plan to continue enhancing CORBA-CL as a general computing plat-
form, to offer programmers both the advantages of the Component-Based Devel-
opment and Distributed Computing.

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