# A Collaborative Environment for Distributed Web-based CAD

by

Gangadhar Konduri

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Author ............................................................ [illegible]
Department of Electrical Engineering and Computer Science
December 18, 1998

Certified by ............................................................ [illegible]
Anantha Chandrakasan
Associate Professor of EECS
Thesis Supervisor

[illegible]

Accepted by ............................................................ [illegible]
Arthur C. Smith
Chairman, Department Committee on Graduate Students

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## Abstract

The increasing complexity and geographical separation of design data, tools and teams has created a need for a collaborative and distributed Computer-Aided Design environment. The high integration levels call for tools and generators that allow the exploration of the design space irrespective of the geographical location of the design tools.

The World Wide Web serves as a desirable platform for distributed access to libraries and design tools. The web has several properties that can provide an important platform for VLSI CAD, when combined with distributed object technologies and platform independent languages. In this thesis an environment for collaborative and distributed Web-based CAD is presented. In this environment, the designers can efficiently utilize the capabilities of existing design tools on the Web and also build hierarchical Web-tools in a collaborative fashion. The environment includes a Java hierarchical collaborative schematic editor and the required interfaces to distributed Web-tools and cell libraries. The environment also includes the infrastructure to store and manipulate design objects and the protocols for communication with tools, message passing and collaboration.

Thesis Supervisor: Anantha Chandrakasan
Title: Associate Professor of EECS

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# Chapter 1

# Introduction

In the design of large integrated systems, design teams use various CAD tools that is distributed across several sites. The tools used in the design process might be situated in different locations. Such distribution of tools and the data calls for a framework facilitating distributed design. Diverse expertise is required at various levels of abstraction during the design process, and the design teams are expected to be geographically separated, requiring that the design environment be collaborative in nature.

## 1.1 Challenges in designing "Systems-on-a-chip"

Deep submicron scaling enables integration of tens of millions of transistors on a single chip, allowing the implementation of an entire system on a chip. Such a design of "$systems - on - a - chip$" increases both the complexity of design and the issues of management in the design process. CAD tools that are capable of handling the increased complexity are required to design such systems. Making tools that integrate these large designs and that efficiently test and verify them is a major challenge.

Modular approach helps in easier and better management of the designs. These complex chips consist of various modules requiring diverse design knowledge. Reuse of existing modules and libraries in the design helps significantly in the design process, by reducing the design time and by simplifying the design.

Therefore, there is a need for a design environment exhibiting the following properties:

- It simplifies the design process, as seen by the user, by automating design flows and by allowing collaboration among the users.

- The environment gives collaborative access to the remote libraries and design tools, at all levels of design abstraction, with simple and standard user interfaces.
- It enables a modular/hierarchical approach to the design.

Such a requirement motivated us to develop an environment that facilitates collaborative, distributed and hierarchical design. The WorldWideWeb(WWW) provides a nice channel of communication required for the tool.

## 1.2 The Web and the Internet

The advent of Internet has opened new vistas in the area of collaboration. The WWW has emerged as the most desirable platform for distributed access to information. The Web can serve as a very attractive platform for distributed applications because of the following reasons:

- The protocols and mechanisms of WWW are simple and do not rely on the underlying hardware.
- The popularity of the WWW is mainly due to its simple and standard browser interface. This means that many users are already familiar with a friendly user interface that WWW has to offer.
- The limitation of only server-side computation of the WWW using form based CGI programming has been alleviated with the emergence of a platform independent programming language, Java. Client-side processing can be done through the Java applets.
- The limitations of state-less connection are also overcome with Java as a full programming language being integrated in the browsers.
- The Object technologies and the Java serialization mechanisms facilitate the easy communication of large data between clients and server and among different clients.
- The WWW has also emerged as a strong platform for remote access to tools, enabling the designer to access web-tools using a browser.

Java applets can be embedded in the webpages and therefore the designers can use their browsers to use the tools implemented as an applet. All these factors, along with the advantages of Java, make the WWW an ideal platform for collaborative and distributed micro-system design.

## 1.3 The model of Web-based CAD

The World Wide Web has led to a paradigm shift in the research, development and integration of EDA tools. Web-based CAD poses to define a new era of electronic design in which tools, models and cell libraries are accessible from any remote location. VLSI design involves many compute-intensive steps like simulation and verification. These jobs should be executed nodes on the network with significant computation power. Typically, server-side computation meets such requirements, and less compute-intensive jobs can be performed at the client end. A Web-based framework should optimally partition the client-side and server-side jobs efficiently. It should integrate the tools seamlessly in the framework. At all levels, it should allow the designers to collaborate in the design process.

In the model of Web-based CAD, the designers use a Web browser on their desktop and access cell libraries and design tools irrespective of their location. The designer can also collaborate in the design process. The tool utilizes the existing cells and tools from different places without the user having to install these locally. This is a design-centric approach, with the designer at the center of the methodology and the tool takes care of the distributed access.

The following are the various aspects of Web-based CAD that are fundamentally different from the way VLSI design is done today:

- **No installation of CAD tools:** Web-based CAD does not require any client end installation of tools. Tools are either downloaded via internet or the input is sent to the server, where the tool is executed. The location of the tool on the Web and the interfaces of the tool are required for accessing it through Web-based CAD framework.

- **No Maintenance:** It reduces the maintenance cost of the CAD tools. The latest version of the tool can be maintained and distributed by the vendor at their site so that the designer can use it. Currently, much of the designers' effort go into tool

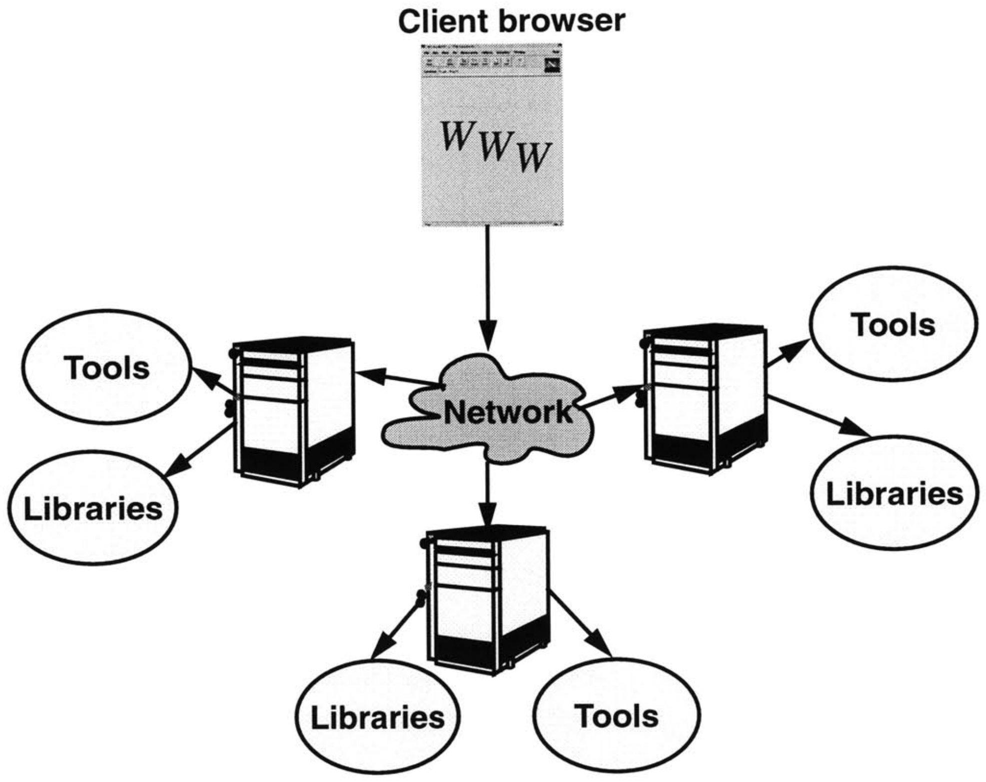


Figure 1-1: Distributed CAD Environment

installation and maintenance in terms of version controls, license controls etc. Since all of the burden falls on the vendor with web-based CAD, the designers are simply left with the use of the tool in this framework.

- **Access to Powerful Computers:** Many CAD tools require extensive computational power, which many small designer houses cannot afford to have. With the server based computation of Web-based CAD, users could make use of the high performance computing power of the servers.

- **Pay-per-use CAD:** Making tools available on the Web will allow tool vendors to use a pay-per-use model.

- **Ease of Collaboration:**The framework creates a collaborative environment so that the designers could easily cooperate in the design process.

Irrespective of the business prospects, Web-based CAD allows designers to use a collaborative framework in a distributed design environment. The WWW can help better utilization of resources through distributed design and in bringing together team of experts from all over the world into the design space through collaboration. The information exchange between the tools should be efficient in this framework to make effective use of the wide variety of tools available.

## 1.4 The Distributed Microsystem Design Framework, WebTop

A distributed design environment, WebTop, has been developed at M.I.T. It is a web-based CAD framework providing all the advantages mentioned in the previous section. The environment makes it easier for the designer to use the tools or data without having to think about their physical location and versioning.

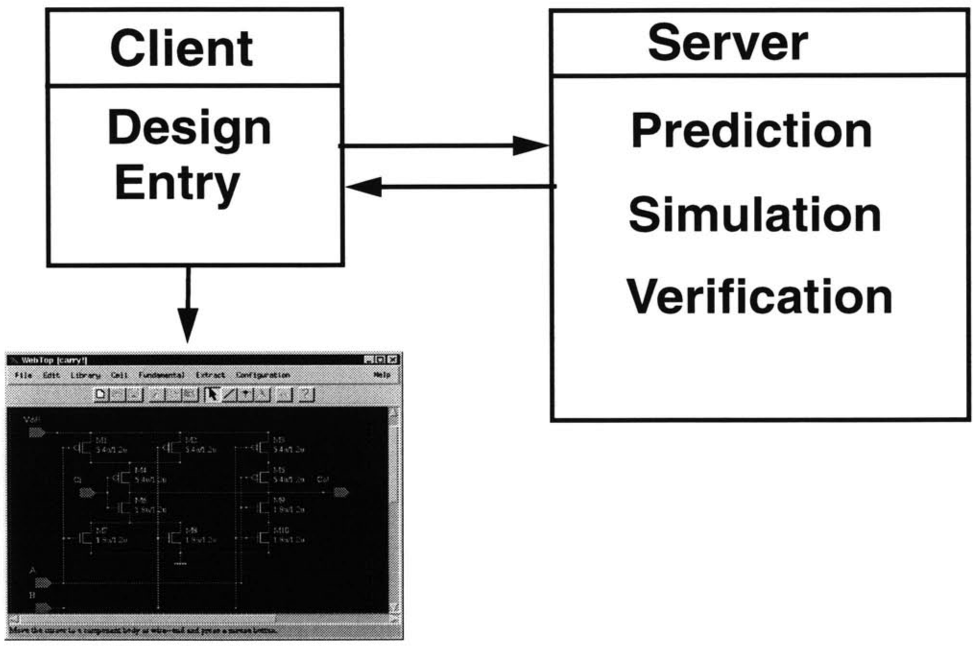


Figure 1-2: WebTop: The distributed framework

The entry point for the design is a schematic editor that supports hierarchical design. WebTop is capable of accessing cell libraries located on different servers through the internet. The users can extract the netlist, that conforms to the input specification of several web-tools, from their design. They can submit such a netlist to the corresponding webtool and view the results. The tool uses the CGI mechanisms for remote tool invocation. There are certain fundamental cells, inbuilt and defined by WebTop, that can be included in the design. The tool has a very easy-to-use and intuitive user interface.

## 1.5 The Collaborative environment

Collaborative design involves various designers co-operating in the design process. The environment used by the designers to access the distributed tools and libraries has to enable collaboration among the designers because of various reasons as mentioned in Section 1.1. The environment should provide an efficient way to exchange the information and allow designers to be involved in parallel sessions at the same time. Though the parallel sessions increase the load on the server, it is sometimes convenient for the designer to participate in more than one session at the same time.

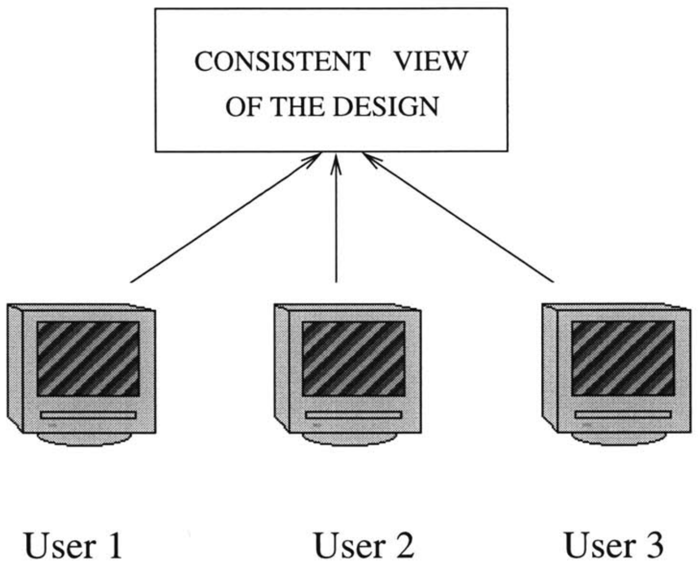


Figure 1-3: The Concept of the Collaborative Environment

The collaboration should also allow one designer to use the tools and all the designers to view and use the results to enhance the design.

In this model the issues with limited internet bandwidth and secure communications need to be addressed critically. Since, the data has to be transferred to the location where the tool is available, the limitation in bandwidth is of concern. Similarly, the security of communications of the design data over the internet is an important aspect of the design.

The web-tools should have the capability to exchange information efficiently and in a secure manner.

## 1.6 Related Work

The popularity of the internet and the WWW has lead to many web-based tools. Bentz et al. have proposed an information based design environment[2]. They describe an environment which helps the users to collect and manage information in a uniform fashion, independent of the abstraction levels or implementation platforms. Lidsky and Rabaey present a World Wide Web based prototype tool, PowerPlay[3], which helps in system level exploration of power consumption. PowerPlay uses a HTML form-based user interface which prompts the user to select a subset of the available library and their parameters. The design is then submitted to a script which calculates the power, area and timing information. The methodology combines pre-characterized and user defined modes to provide quick and power estimation in a spread sheet like format at the earliest stages of design, using a distributed modeling environment.

The WELD project at UC Berkeley [4], aims to construct a distributed CAD environment enabling Internet-wide IC design for the US electronic industry. They have developed a Java Object Database Server supporting persistent object class management. Boglilo et al. describe PPP, a gate-level power simulator[5], which provides a Web-based integrated environment for synthesis and simulation of low-power CMOS circuits. The graphical interface of PPP is a dynamically generated tree of interactive HTML pages that allow the user to access and execute the tool by using a Web browser.

There have been efforts to provide Web-based Interfaces to executable CAD/CAM software. Links to different Web-based tools can be found at [6]. Fortes et al. present a network based simulation laboratory which can be accessed via standard WWW browser. The Purdue University Network Computing Hub (PUNCH) [7], is a set of network-based laboratories that provide toolkits of programs for various fields.

A stand-alone utility, XMX[8], for sharing an X Window system session on multiple X displays has been developed at Brown university. It acts as an intermediary between XClient and XServer and takes advantage of the networked nature of the X Window system. Though it leads to a collaborative environment, it works only on X-based systems. It is not platform-independent and not web-based, the two features that are essential for distributed design. Xplexer[9] is a distributed application sharing system for X Windows. It allows sharing of stand-alone X window applications, in a heterogeneous environment. This tool restricts the applications to those developed in X Windows. Some other such systems that are available include Xshare and XTV. Lavana et al. use executable directed hypergraphs to describe collaborative design activities on the internet[10].

Although there are numerous instances of design tools being available over the Web, there has been limited attention to design an environment which would allow designers to utilize the different tools over the Web and do design in a collaborative fashion. In this paper we show how a collaborative and distributed environment could be built over the Web, utilizing the core Web technologies, to support efficient communication and data exchange between different Web-based tools and to allow the designers to collaborate in the design.

# Chapter 2

# Web based Technologies and Java

*"Web is a planetary nervous system", – John Barlow, 1996.*

There are several technologies, mechanisms and protocols available that support distributed applications with the standard Web interface. In this chapter, we briefly explain some mechanisms that have been used in developing this framework. They include protocols that support the transfer of information through the Web using the HyperText Transfer Protocol, HTTP and those that support remote execution like the Common Gateway Mechanism, CGI. There are mechanisms that create applications that could be executed locally on the client machines using Java technology, scripts and plug-ins. The mechanisms for communication use object technologies to define, locate and request computational services from participating applications, both remotely and locally. In these approaches, the Web takes the role of providing uniform access and presentation mechanisms. For creators and users of CAD, the Internet is an ideal mechanism for facilitating collaborative design and real time communication.

## 2.1 The Hypertext Transport Protocol

The Hypertext Transport Protocol (HTTP) is the principal means by which a Web server and a client communicate with each other[11]. This communication could be to retrieve a document or to execute a script. Under this protocol, a client sends a *request* to the server. The server compiles such a request and replies with a *response* containing the requested output or with an error message. Together, the request and the response form a *transaction*, a single interaction between the server and the client. The protocol is basically stateless, a transaction consisting of a *connection, request, response* and a *disconnection.* A feature of HTTP is the negotiation of data representation, which allows systems to be built independently of the development of new advanced representations.

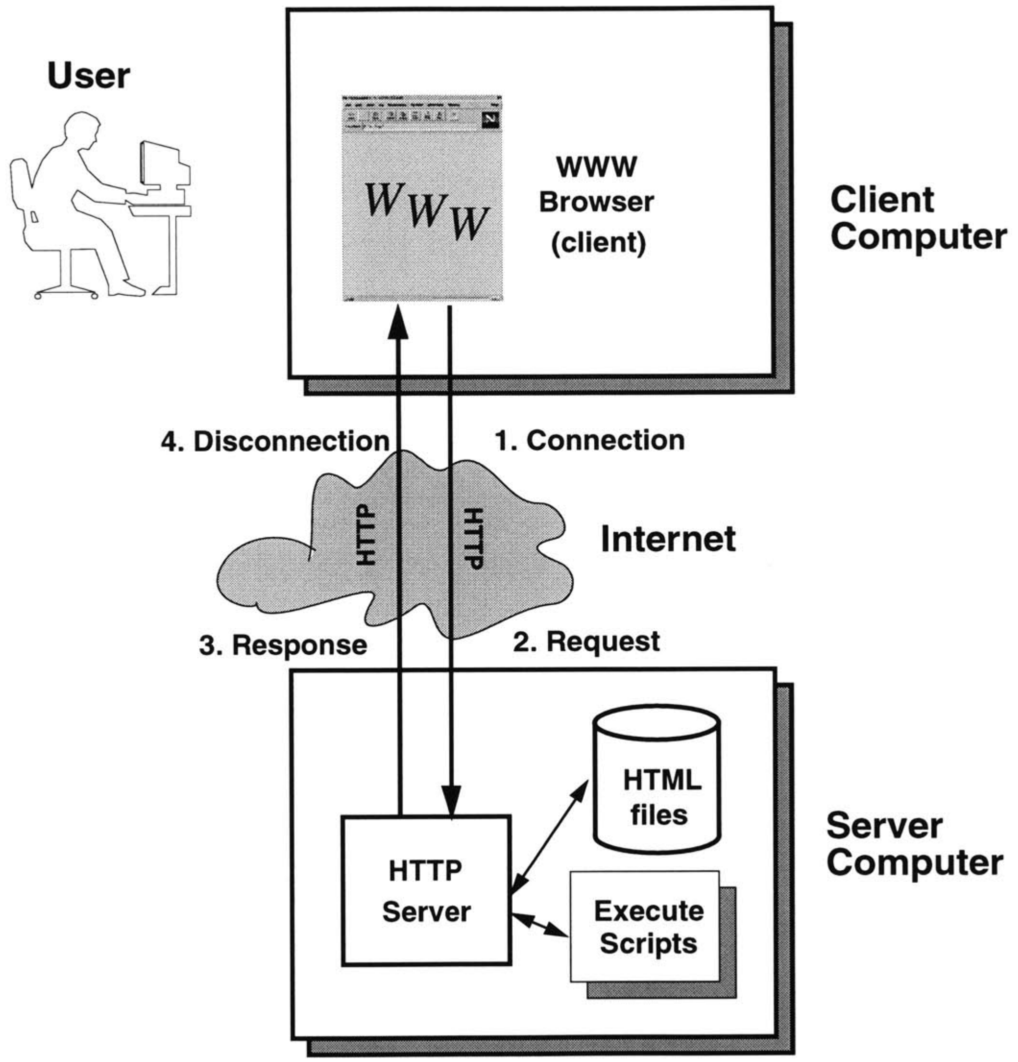


Figure 2-1: The components of a simple WWW interaction

There are two common methods or syntax for the request line, GET and POST methods. GET method is generally used for simple document retrieval, database lookup and similar operations. POST method is useful when the client wants to send a relatively large amount of data to the server. The POST method uses the method body to send the additional information from the user, rather than encoding it in the part of URL as in GET. The client can use different encodings, that the server and the script can understand, for sending the data. The default HTML[12] encoding is `application/x-www-form-urlencoded` which encodes the data as ampersand-limited name/value pairs. The data that needs to be transmitted from the client to the CAD tools in the Web-based CAD paradigm tends to be large and it would be useful to send large files with a single HTML tag. File uploads with the HTML tag `<input type=file>`, use the encoding of `multipart/form-data`. Error responses are supplied in human readable text in HTML syntax. The error messages and the response messages are different only in the content of the text.

The server breaks the TCP-IP connection when the whole document has been transferred. The client may abort the transfer by breaking the connection before this, in which case, the server does not record any error condition. In the environment of collaborative and distributed CAD, we are dealing with non-deterministic delays, corresponding to the execution time of the tools. The client might have to wait for longer time for some responses in Web-based CAD tools because of these delays. The http server times out after waiting for a specific period of time, which is defined by a server variable. Therefore, the methodology used should be robust with respect to these delays. To allow the users to continue working with the design while waiting for the results from a web-tool, these jobs could be spawned as a thread of execution.

## 2.2 The Common Gateway Interface (CGI)

Sometimes we need the server to generate information depending on the client input. The Common Gateway Interface[14] is a mechanism to present dynamically generated information on the World Wide Web. A Hypertext Transport Protocol (HTTP) server is often used as a gateway to a legacy information system: for example, an existing body of documents or an existing database application. The Common Gateway Interface (CGI) is an agreement between HTTP server implementors about how to integrate such gateway scripts and programs. CGI programs are usually referred to as scripts. They run on the server machine and produce the output (usually HTML output) to be displayed on the client's browser.

CGI is the component of the Web server that can communicate with other programs running on the server. With CGI, the Web server can execute a program, while passing user specific data to that program. The program processes the data and passes its response back to the server, which sends this data back to the client. CGI transforms the Web from a simple collection of static hypermedia documents into an interactive medium, in which users can ask questions and execute remote applications.

The request for a CGI program looks the same as it does for all Web documents. The difference is that when a server recognizes that the address being requested is a CGI program, the server does not return the file content, but instead it tries to execute the program.

CGI scripts provide a very useful mechanism to provide remote access to CAD tools. Since many CAD tools take inputs which are either files or some parameters in plain text, HTML forms can easily be used to capture the inputs from a browser interface and can be submitted to CGI scripts. For example, a power estimation tool could have a simple Web interface using the CGI mechanism.

## 2.3 Java Programming Language

Though the CGI mechanisms allow the client to execute server-side programs, they lack the interactivity and good user interface. Designers would not be satisfied with the limited display of a CGI based program and HTML output. They need to modify and view different designs in real time. Java[13] helps us overcome this problem by allowing us to do complex client-side processing in a platform independent manner.

Java is an object-oriented programming language and comes with a rich set of Application Programmers Interface (APIs) as shown in Figure 2-2. Java has been widely accepted as the standard for Web computing. Java source code is compiled to byte-codes whose target architecture is the Java Virtual Machine (JVM). This JVM can be embedded within other environments, like the web-browser and operating systems. A class loader can load classes over the network and a byte-code verifier verifies the byte-codes while reading them. Java has been designed such that a compiled Java class can be conveniently handled with ordinary text and graphics. Java *applets* can be embedded in HTML pages, which are loaded from the Web server. The browser interprets the Java byte-codes and executes them as an application on the client side.

Since Java is a programming language, it is much easier to make an applet interactive

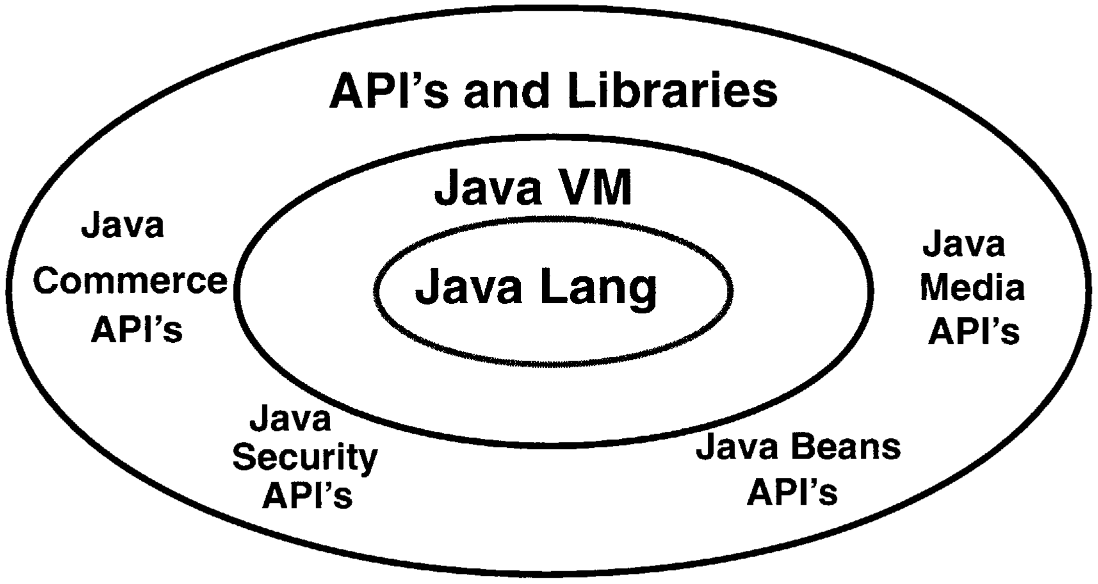


Figure 2-2: Java language and its APIs

than making interactive CGI programs Complex user interfaces where the users use the mouse to draw and edit images, which are not easy to create with HTML and CGI, can be easily incorporated in a Java applet. Java applets use modern graphical user interfaces (GUI) like text boxes, buttons, list boxes etc. With Java, the processing is off-loaded to the user's system and thus Java enables client side processing without the need to go across the network for every small application. Moreover, the problems of the non-persistent connection of HTTP and CGI are alleviated since Java applets run as independent applications.

The Virtual Machine refers to the active interpreter which executes Java byte-codes. Since the Virtual Machine does not necessarily correspond to any particular hardware or operating system, the Java class files are portable to any implementation of the Virtual Machine. This is the essence of Java's portability. Therefore, applications which do not need extensive computational power could be handled well with Java based interface. But leaving all the work to Java based client-side processing would hinder our attempts to do CAD with a simple desktop. Therefore what we need is a partitioning of an application into Java based client processing and the traditional remote server-side computation. Java enables a philosophy of *"Write once, Run anywhere"* for programs. The features which make Java so attractive are listed below.

- Java is Object-oriented.
- Java is a cross platform language enabling easy portability.
- Java inherently supports multi-threading, enabling a Java Server to time multiplex several tasks.
- Java has API's for transparent network access and can be inlined in a HTML document in a Java-capable browser.

To prevent the creation of malicious applets that can damage the file system on the client side, there are some security restrictions on the applets. One of these is that the Java applets are not allowed to examine the file system on the client side. So, the applets can not save designs on the client machines. In a web-based CAD application, the designer, using an applet, might want to save the design on the local machine. This is a limitation on the Java applets that needs to be worked around.

### 2.3.1 New Features in Java1.1

Several new features have been added in the new version 1.1 of the Java programming language. Out of them, the new event model, the security features, and the serialization mechanisms are extensively used in developing this distributed framework, WebTop into the collaborative environment. The event model is described briefly in this section and the serialization mechanisms are explained in Section2.4.

#### Event Model:

WebTop was originally developed using Java1.0 event model. In Java 1.0, there are certain Graphical User Interface(GUI) component classes and the applets or the GUIs have to subclass these components and handle events. This model is not suitable for developing complex programs. All these events should be managed in one method *action*. This necessitates the method to check the cause of the event to take appropriate action.

Java1.1 defines a new model for dispatching and handling events. The new event handling model is a "callback" model. When a GUI component is created, the methods that should be invoked on the occurrence of different events, have to be declared. Since Java does not support first-class functions (functions that can be passed as parameters), an instance of this class has to be passed to the GUI component to specify the callbacks. The GUI component invokes the appropriate method of the object specified. These interfaces are called *listeners*(e.g., MouseMotionListener, WindowListener). Given below is an example of how this event model has to be programmed with:

- A componentBox has a button. If the user clicks on the button, it disappears and takes the appropriate action. The componentBox class contains an instance of the Button GUI component.
- The componentBox is added to the button's actionListenerList.
- The componentBox which implements ActionListener interface implements the actionPerformed method with the signature as specified in the interface.
- When the user clicks on the button, the button component calls the corresponding method in the componentBox class, which takes the necessary action.

In the collaborative environment, where various user actions at the clients are to be broadcast to all the clients, such a callback model would make the program flow simple. The corresponding message object can be created in this callback method to be sent over the network.

## 2.4 Distributed Object Technologies

Distributed computing enables the development of applications across several heterogeneous systems. With the growth of the internet and the advances in networking, distributed computing offers a vision of flexible computing with no boundaries. Distributed computing has gained a new direction with a vision of object-oriented computing in which, there is no essential distinction between objects that share an address space and objects that are on two different machines with different architectures and at different geographical locations. Distributed computing in this context refers to programs that make calls to other address space, possibly on other machine. Objects can therefore invoke a method of an object which may be remote to the calling object. In such a system, an object, whether remote or local, is defined in terms of a set of interfaces. The implementation of the object is independent of the interface and hidden from other objects. This can be seen as an extension to the remote procedure call (RPC) in the object-oriented paradigm.

The distributed programs can communicate through message-passing. These messages are examined by the receiver to take appropriate action on its variables. Java Serialization mechanisms could be used for this purpose to create the messages. In this section we describe in brief the Remote Method Invocation of Java and the Java Serialization mechanisms.

### 2.4.1 Java RMI

Java Remote Method Invocation (RMI) [16] enables the programmer to create distributed Java-to-Java applications, in which the methods of remote Java objects can be invoked from other Java virtual machines, which might be on different hosts. A Java program can make a call on a remote object once it obtains a reference to that remote object. This reference could be obtained either by looking up the remote object in the bootstrap naming service provided by RMI or by receiving it as an argument or as a return value. A client can make a call on a remote object in a server, and that server can also be a client of other remote objects.

Java Remote Method Invocation (RMI) is an interprocess protocol for Java, allowing Java objects located on different Java Virtual Machines to invoke transparently each others' methods. Since these Virtual Machines could be running on different computers anywhere on the network, RMI enables object-oriented distributed computing.

Java RMI provides the Java programmers with an efficient, transparent communication mechanism that frees them of all the application-level protocols necessary to encode and decode messages for data exchange.

Remote objects written in Java RMI interact in the following way:

- server objects publish their interfaces to make them available to RMI clients.
- stub classes deal with binding to the remote objects and do the client-side data marshaling.
- skeleton classes on the server-side handle incoming calls.

The communication mechanism is shown in Figure 2-3 .

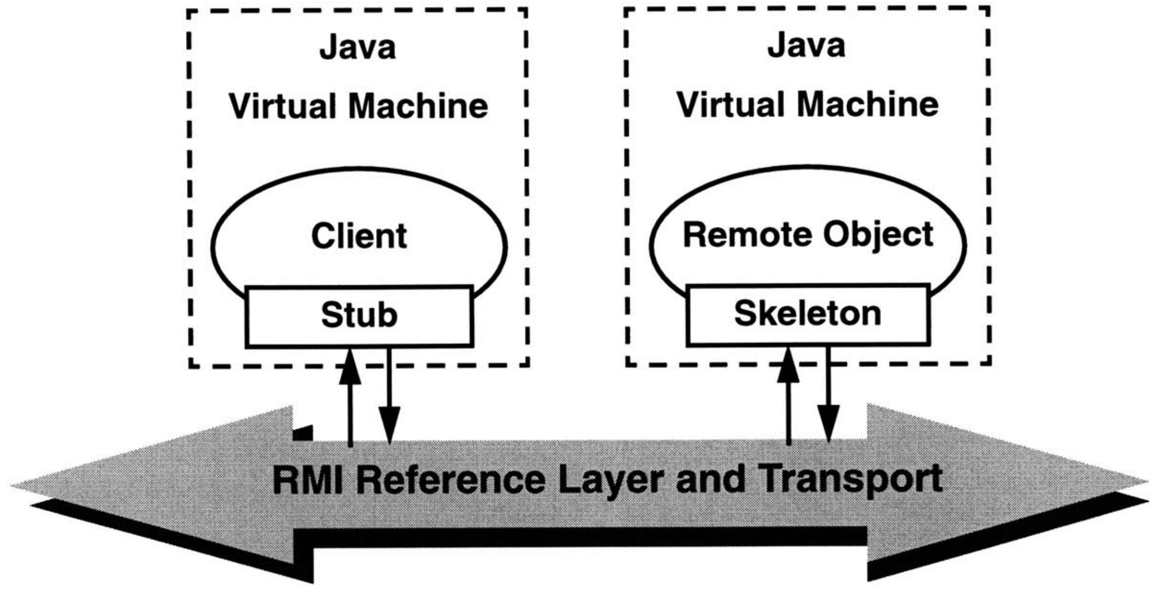


Figure 2-3: The Java RMI Mechanism

### 2.4.2 Java Serialization Mechanisms

Message-passing is another mechanism in which distributed programs could communicate with each other. They could do so by agreeing upon a protocol for communication. Though, RMI does the same thing, a user-defined protocol gives the user more control over the communication. These messages could be implemented as objects using the serialization mechanisms of Java. Programs written in Java could communicate easily in this way.

Object Serialization[17] is the mechanism in Java through which objects are written to output streams. Through deserialization, objects can be read from the input streams at the receiving end. Java writes out the values of all the fields of the object being serialized. If the object refers to another object, serialization is done recursively. Care is taken such that this serialization mechanism does not enter into infinite recursion. Classes should implement *serializable* interface for its instantiations to be serializable. The transient and static fields of an object are not serialized.

The various events at different client ends are to be sent to the server in the collaborative environment and these events are to be broadcast from the server to various clients. The Java Serialization mechanisms are used to create these messages from the Java objects.

## 2.5 Summary

In this chapter, we presented the enabling technologies for Web-based CAD. HTTP and CGI include protocols and mechanism, which provide access to tools running on the Web server. Java applets can be embedded in Web browsers to enable complex, platform independent client side processing. And finally, the distributed object technologies enable transparent, distributed method invocation on remote objects.

# Chapter 3

# Design Example with the Distributed Tool

As a first step in developing the collaborative environment for web-based CAD, a framework for distributed web-based micro-system design, WebTop, was developed[18]. WebTop is an environment in which users can design systems using either the in-built fundamental cells or other designed cells in the library, in a hierarchical fashion. Designer can access the distributed library of cells and can execute several web-based remote tools through WebTop. WebTop can be accessed at the URL *http : //apsara.mit.edu/WebTop*. An example design using the distributed tool of a single-chip media-processor is described here.

## 3.1 The Distributed Web-based CAD tool, WebTop

WebTop is a distributed Web-based CAD framework, implemented as a Java applet. It is based on a public domain applet called "Digital Simulator" (DigSim) [19]. The entry point of the design is a hierarchical schematic/block editor. This editor has a simple GUI. The design can be validated by using distributed Web-based tools. The netlist of the design can be extracted from WebTop so that it conforms to the input specification of several web-based tools. Such a netlist can be submitted to the remote web-tools.

WebTop includes a hierarchical schematic editor. It includes mechanisms to add and delete cells, to cut and paste schematic, to change properties of cells and the mechanisms to save the designs. WebTop has a number of in-built primitive cells (e.g., logic gates, MOS devices, passive circuit elements). The designer can include them in the design by selecting them from the menus in the GUI. The properties of these cells(e.g., transistor sizes) can be changed using the pop-up menus. The design can be hierarchical, meaning that a new cell designed can be included within other cells. There is a simple User Interface through which the designer can navigate a cell hierarchically. WebTop supports block editing, in which the user can create a template of the cell and provide a behavioral and structural view in SPICE or verilog.

The Library Manager helps the designer keep track of the cells. Figure 3-2 shows a snapshot of the schematic editor and the Library Manager. The designer should be able to save the schematic cells into a file and use it subsequently in the design. This can be performed in two different ways using WebTop. The schematic cells created in WebTop's editor are serializable using the Java serialization mechanisms. So, the cells created by designers can be saved in the Java object format. There is a WebTop file format in which the tool can save the cells in files. The schematic cells saved in both these formats can be loaded into WebTop's editor from the files subsequently. These cells can be downloaded from a URL and so schematic cells created and stored, using WebTop, by another designer can be downloaded and used. WebTop supports distributed cell storage and access. Cells could be stored in different Web servers and such cells can be loaded from WebTop by referring to the corresponding URL. A CellServer exists along with WebTop on the host server and it allows users to store cells remotely at the server's site after checking user authentication. Both the verilog and SPICE views of cells can be entered through a text editor in WebTop. They can also be referred to by a URL or by the location of a local file and WebTop loads them.

The main objective of the distributed environment is to give access to remote Web-tools through a single point web-tool. Therefore, WebTop has a mechanism through which the design(or parts of the design) can be submitted to the web-tools. The designer can extract a netlist from WebTop's schematic, so that it conforms to the Input Specification of the remote tool. The user can also extract the netlist of subparts of the schematic. The user can submit this extracted netlist to the corresponding web-tool through the WWW and obtain the results of its execution. WebTop provides the infrastructure to extract the netlist, to submit it to the web-tool and to get the results back to view them through the browser.

The tool uses the CGI(Common Gateway Interface) mechanisms to invoke remote tools. WebTop has interfaces with several webtools including Pythia [20], a verilog RTL power estimator tool, PowerPlay [3], a system level power exploration tool and WebSpice. The extracted netlist is submitted to a CGI script existing on the applet host. The results from the remote tool can be returned to the applet as a dynamic URL, which is used by WebTop to display the HTML page. In some other cases, a Java server is started on the applet host by the CGI tool, which accepts the results from the remote tool through a socket connection. This is also useful when these results should be submitted to a second web-tool, whose output is shown to the designer. Therefore, a new meta web-tool could be created using the CGI mechanisms and the Java server. An example in which a web server at a site $z$ creates a meta webtool, by accessing the tools at the sites $x$ and $y$, is shown in Figure 3-1 [18].

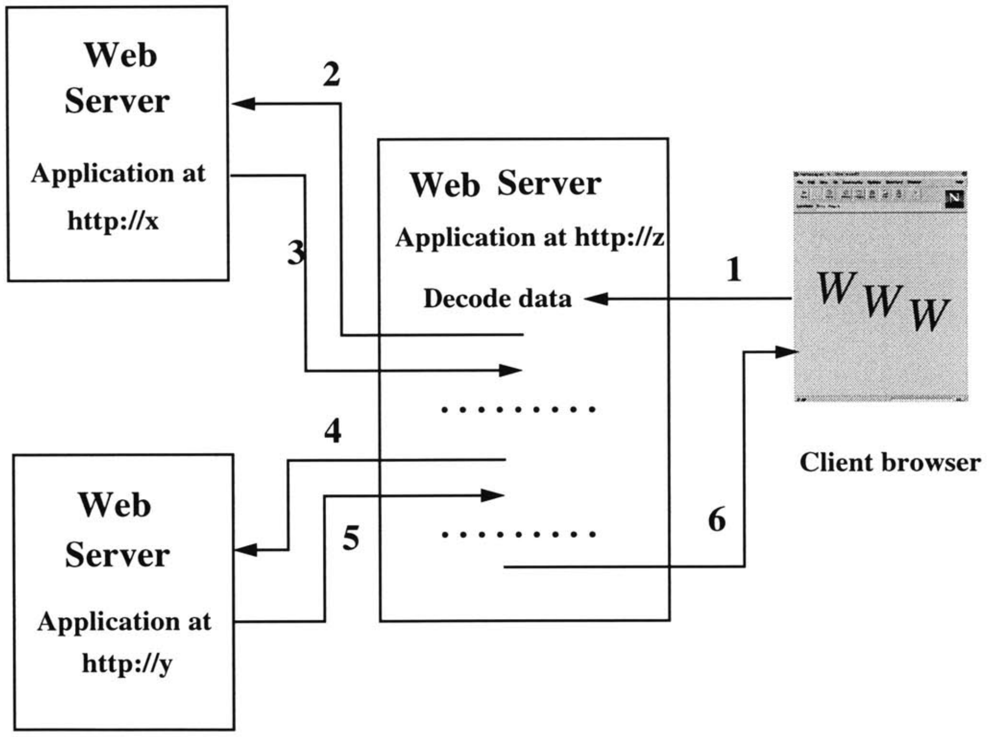


Figure 3-1: Data flow in Hierarchical tools

Originally, WebTop was developed using Java Development Kit (JDK) Version 1.0. But, as explained in Chapter 2, the event model in JDK Version 1.1 is more suitable for developing the environment into a collaborative framework. So, the whole code base for WebTop was modified to follow the JDK 1.1 format. Also, some useful features like menu

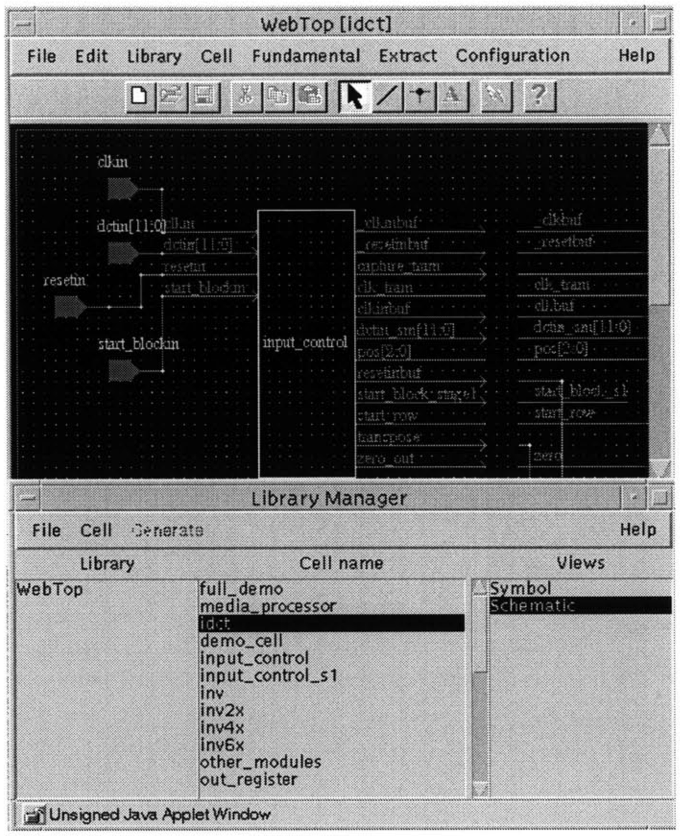


Figure 3-2: A snapshot of WebTop's schematic editor and Library Manager

shortcuts were added to the framework.

## 3.2 Adding new cells to WebTop

As mentioned in the previous section, WebTop has several inbuilt primitive cells. All these primitive cells have the SPICE and verilog views included in their specification. Each of these cells has a java source file written with these specifications. A primitive cell can be included in the design by selecting the corresponding item from the "Fundamental" menu in the GUI. Designers might need new fundamental cells to simplify the process of design and so WebTop provides the support to add new cells.

One way in which this can be achieved is to create a new blank cell with the required number of ports, both input and output, in it. Such a cell when included in the schematic has a symbolic view which looks like a black box with all these input ports and output

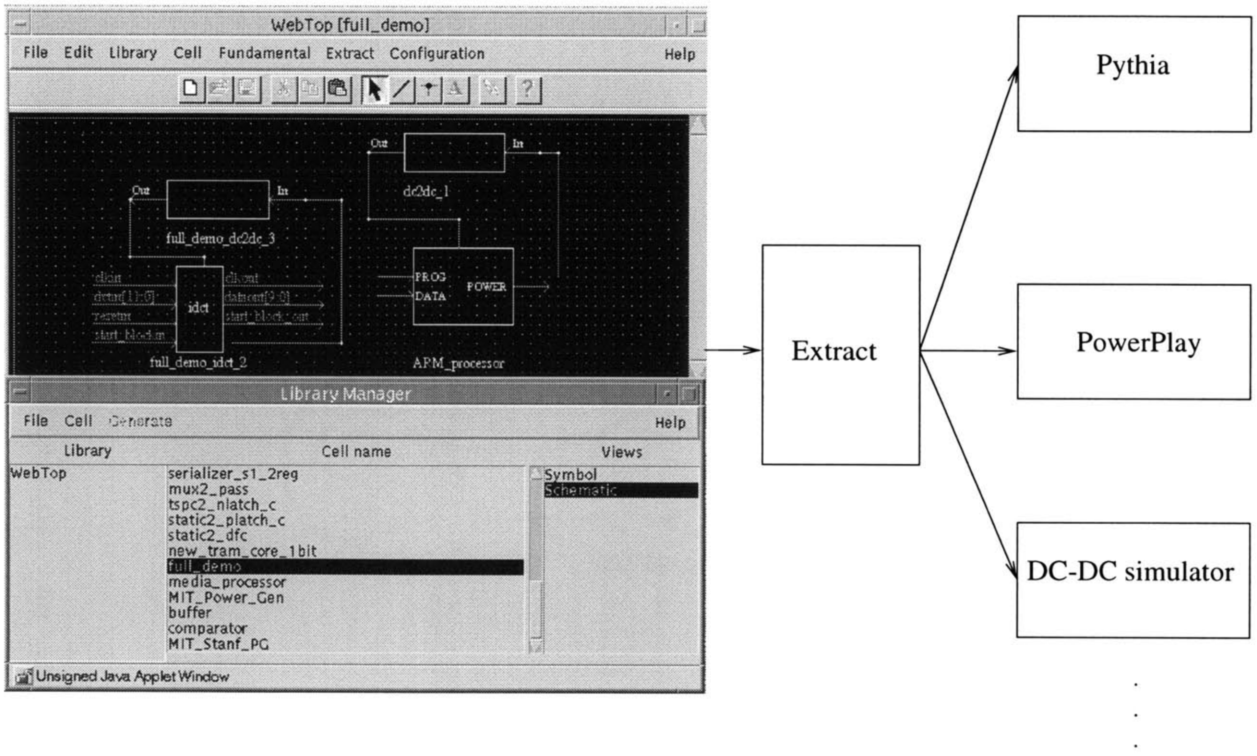
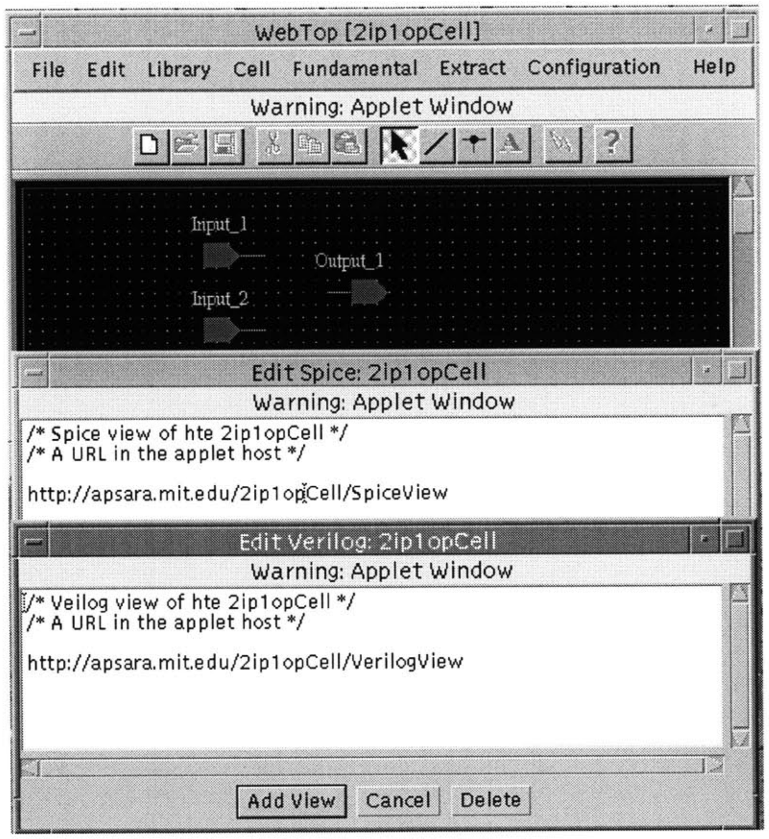


Figure 3-3: WebTop and Various tools



```
/* Spice view of hte 2ip1opCell */
/* A URL in the applet host */

http://apsara.mit.edu/2ip1opCell/SpiceView
```

```
/* Veilog view of hte 2ip1opCell */
/* A URL in the applet host */

http://apsara.mit.edu/2ip1opCell/VerilogView
```

Figure 3-4: A 2 input 1 output prototype cell with Verilog and Spice views

ports. The verilog and SPICE view of this cell could be specified as either separate URLs or as local files. This cell can be used like a primitive cell, by choosing from the library. As an example, in Figure 3-4 a prototype 2 input 1 output cell is shown in the WebTop schematic editor. The Verilog and Spice views are specified as URLs. In Figure 3-5 a cell includes this prototype cell in its schematic.

The other way in which new fundamental cell could be included into WebTop is to include another java source file that follows the format of any of such files (e.g.,AND.java). In this file, the geometry of the view, which the cell should exhibit in the schematic, has to be specified. The verilog and SPICE views are also to be specified in this file. Any new view(e.g., PowerPlay view) could be defined in this source file. The cell properties are defined in this source file (e.g.,).

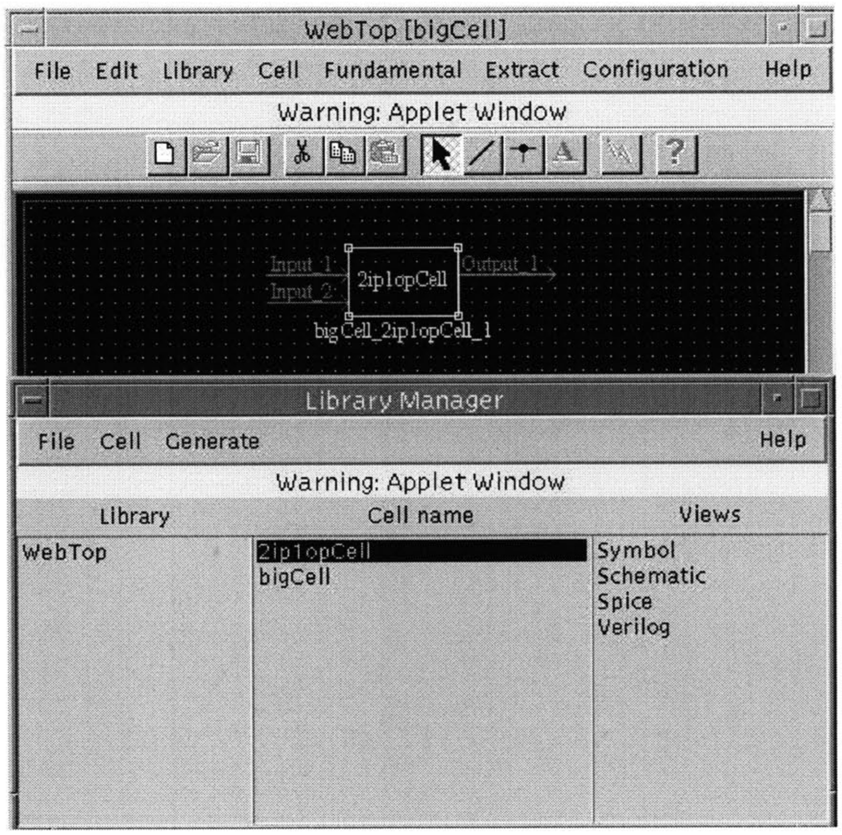


Figure 3-5: A cell including a prototype cell in its schematic

## 3.3 Interaction with tools

As explained in Section1.1, WebTop can interact with several remote web tools. The designer can extract the netlist from the design and submit it to a web tool. The tools with which WebTop can currently interact are Pythia, WebSpice, PowerPlay and a DC-DC simulator. Currently, the specifications of extraction of netlist and the manner of interaction with tools is hardwired into the source code and the CGI scripts of the framework.

The first step in making the interaction between a remote webtool and WebTop is to get output from the schematic that conforms to the input specifications(e.g., the input language of that tool). This step would be simpler if the remote tool accepts the WebTop file format as input. Pythia takes the verilog specification of a design along with some technology parameters as input. So, to interact with that tool, WebTop should output verilog specification of the schematic. Each fundamental cell in WebTop has a verilog description of it inlined in its source file. Similarly, a verilog view can be attributed to a cell, as explained in the previous section. The extractor does a hierarchical navigation of the cells to provide the necessary output from the schematic.

WebSpice accepts its input in the SPICE format. In a similar way as explained above, the SPICE views for cells can be specified and WebTop's extractor uses this information to generate the SPICE output.

To incorporate interaction with a new tool, the extraction method in WebTop should have the knowledge of the parts of the schematic that are relevant to the new tool and of the method in which the output for that parts of the design could be generated. New views of the fundamental cells might have to be incorporated in WebTop. For example, the DC-DC simulator only needs the URL of the data input file and so no new information in terms of the views of cells was needed to incorporate interaction with this new tool. In order to make this scalable, all the remote webtools should be using a common format and WebTop should have a netlist extraction capability to that common format.

The netlist extracted from WebTop is submitted to a tool-specific CGI script that is located on the applet host. The tool specific details are all incorporated in these scripts (e.g., the technology parameters in the invocation of Pythia). This CGI script invokes the corresponding webtool. The CGI script on the receiving end of the webtool sends the dynamic URL containing the output or the output itself, back to the invoking CGI script on the applet host which presents this information to WebTop.

In case of some tools, a JavaServer can be installed on the server, where the tool is located, to accept the input data and to send the output through socket connections. The CGI scripts and the tool-input-specific view information of WebTop cells are the specifications in WebTop that are to be written for incorporating interaction with a new web-tool.

## 3.4 Saving the designs

The users should be able to save the schematic designed in WebTop to obtain persistent copies of the designs. This could be done either on the user's local disk or on the applet host. The security restrictions of Java do not allow an applet to read from or write to the local disks. They cannot open a socket connection with any host except the applet host. This problem can be worked around in the following ways:

- A CellServer has been implemented on the applet host site. This is a server program written in Java, which allows the users of WebTop to store their designs on the applet host after checking user authentication. Since it runs on the applet host itself, the applet can open a socket connection with the CellServer.

- The security restrictions, that are applicable to the downloaded applets, can be set through the HotJava browser. So, if the browser being used is HotJava, the designs can be saved on local disk by choosing a less strict security mechanism for this applet.

- In JDK1.1, the *appletviewer* tool accepts digitally signed files. When it loads an applet that has been signed by a trusted entity, it runs the applet without subjecting to the usual security restrictions. So, digitally signed applets can read and write files on the local disks. Common Web browsers are expected to follow suit and give special privileges to trusted applets. Using these features in the browser, WebTop as an applet can be digitally signed so that the user can save the design on the local machine by trusting this applet.

- If the framework is used as a stand alone application for designing and extracting, without the interfaces with the distributed tools and libraries, there are no security restrictions and the user can save the designs on local machines.

## 3.5 Design Example with the Distributed Tool

As a driver application, we chose the design of a single-chip media-processor that includes an embedded low-power ARM core, a video compression module, with more than 160,000 transistors in its schematic, and power supply circuits. The design was entered using the WebTop editor and was validated using a distributed simulation strategy. The remote tools used in this process are Pythia, a Verilog RTL power estimator at MIT[20], PowerPlay, a system level power exploration tool[3] at UC Berkeley, and a DC-DC voltage converter simulation tool at Stanford. The netlist is extracted from the circuit to conform to the Basic Input Specification of the remote tools. The different remote tools being used require information about the design at different levels of the design. The method in which the remote tools are invoked varies with the tool being invoked.

Pythia, the tool present at the host at MIT, accepts as input the netlist in Verilog. The verilog netlist of the decompression module is extracted from WebTop and submitted to Pythia to get a power estimate of the module. A CGI call is made by WebTop to the Web Server where Pythia resides. After the CGI script executes Pythia, the dynamic URL containing the results as a HTML file is returned to WebTop which uses the browser's context to display it.

The PowerPlay netlist can be extracted from WebTop and the results of the behavioral level power estimate can be obtaining by executing PowerPlay with this netlist. The CGI tool at MIT is invoked by WebTop when the netlist is submitted to PowerPlay. This tool creates a file with the netlist and returns the URL to WebTop, which contains a link to the CGI script of PowerPlay containing proper links to the design URL. WebTop uses the browser's context to load the page of that URL, which is a HTML spreadsheet of the design generated by the CGI script of PowerPlay. From this spreadsheet all the utilities in PowerPlay can be used. For example, the details in the spreadsheet could be used by PowerPlay to get the behavioral level power estimate.

The mechanism through which the DC-DC simulator is invoked is different from the way in which the other two tools are invoked. The reason is that the results of the simulation from the simulator at Stanford have to be supplied to a graphing utility at MIT and the graph output is to be shown at the client side. Thus, two web-tools are used in the process. This can be viewed as the piping of the processes in UNIX. The simulator code is written in "C". It has been wrapped up in Java code, which calls the C code as a native method. The sequence of events that occur during the process of getting results from the simulator are given below and are shown in Figure 3-6.

1. The designer extracts the netlist from the schematic in WebTop and submits it to the simulator.

2. WebTop invokes the CGI script at MIT and passes on the netlist which is saved by the CGI script.

3. The CGI script starts a Java server which sends the netlist to the CGI script at Stanford as a URL.

4. The CGI script at Stanford starts the Java simulator code, which reads in the data URL and runs the simulation, the results of which are sent back to the Java server at MIT.

5. The Java server at MIT stores the simulation results in a file to be read from by the graphing utility. It returns a dynamic URL through the CGI script to WebTop. The URL points to the graphing applet to be run with this input file,

6. WebTop uses the browser's context to load the page of that URL to show the resulting graph.

Steps 2 and 3 above can be combined by making WebTop send the netlist directly to the Java server. But, to maintain the earlier sequence of the applet invoking CGI tool in other tools, steps 2 and 3 are separated.

Thus, using three different remote tools, the design of a single chip media processor has been validated using the distributed environment with the use of a simple web browser. The different ways in which the three web-tools are invoked shows us the flexibility involved and the power of Web-based CAD with respect to the invocation of the tools. Several snapshots of the tool while in the process of executing the design example are shown in Appendix A.

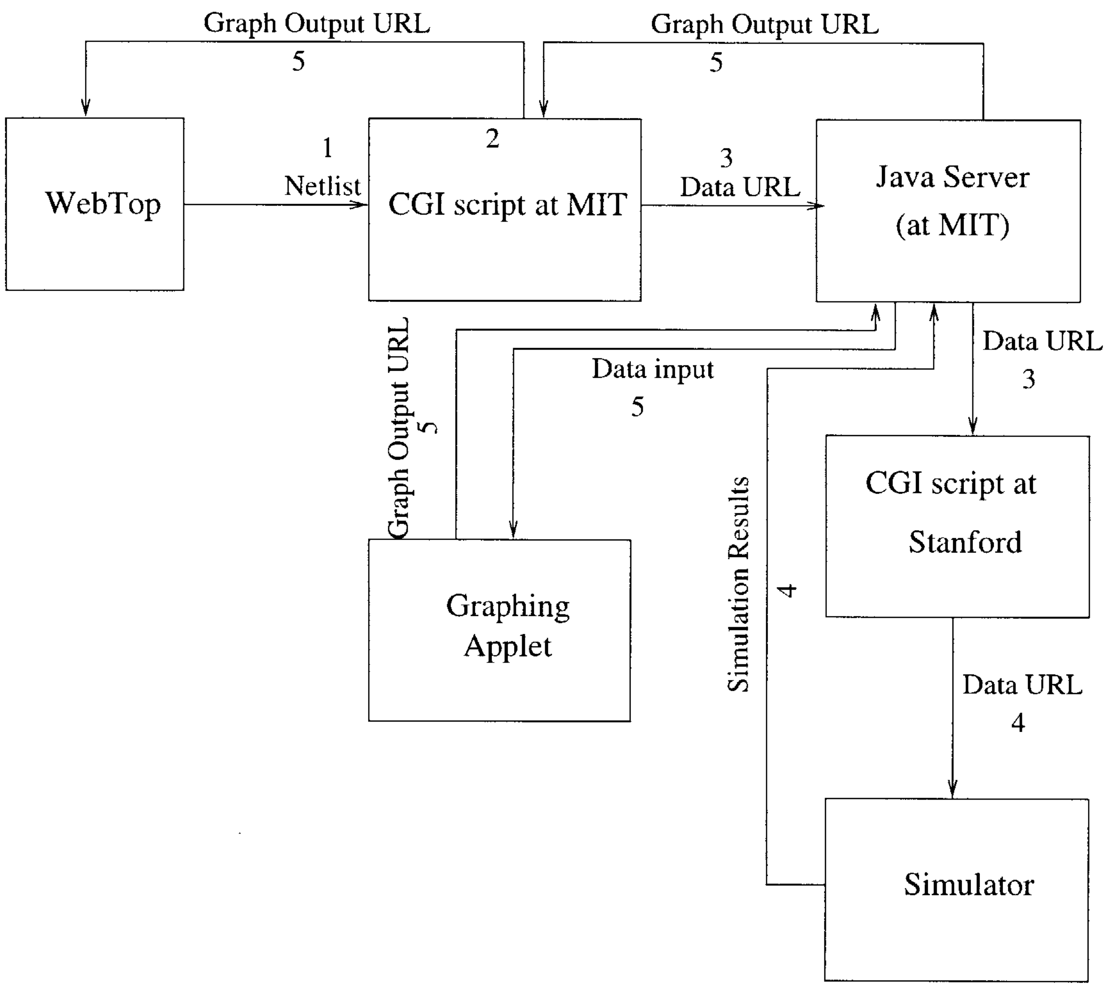


Figure 3-6: Steps involved in the DC-DC simulation

# Chapter 4

# The Collaborative Environment

WebTop allows a single designer to access distributed libraries and remote web-tools within the framework in the process of the design. It serves as an entry point as well as the center for the design. But, with the increased complexity of the designs diverse expertise is required at various stages of the design. The design teams are typically separated geographically. Thus, there is a need for the distributed framework to be collaborative in nature for it to be more useful.

## 4.1 CollabTop

The distributed Web-based CAD framework, WebTop, has been extended into a collaborative and distributed environment, called CollabTop. Conceptually, the collaborative environment should allow the designers to make changes to the design simultaneously and should show a consistent view of the design to each one of them. This is pictorially shown in Figure 4-1.

First steps in developing such a framework involves deciding a software architecture for the tool and identifying the various changes the designer could do to the design(i.e., the events that a single designer could generate in WebTop). In a typical session with WebTop, the designer creates a schematic by adding new components either from the in-built primitive cells or from the cells in the library. The cell in the library could be the cells designed by the user previously or those downloaded from distributed cell libraries. The designer can save the cell and proceed to design another cell. Or the designer might choose to extract the netlist from the design to submit to the remote Web-tools. Each of these

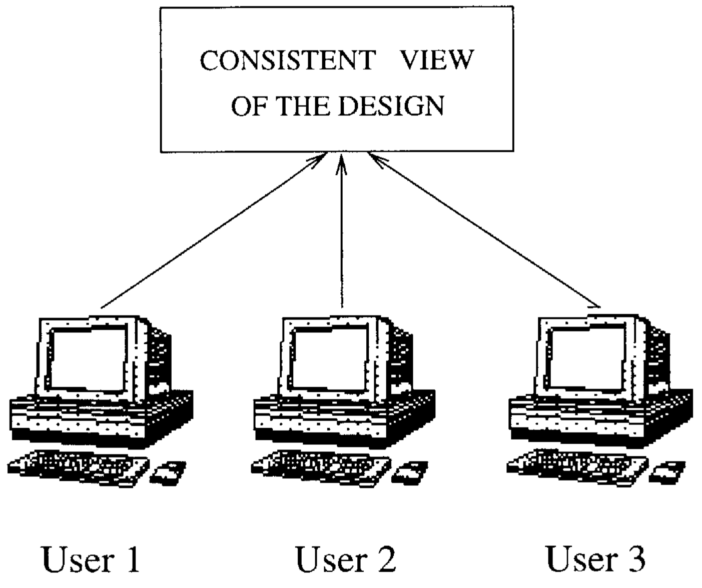


Figure 4-1: Concept of the Collaborative framework

actions of the designer cause the events that are generated through the use of the tool.

In order to make the environment collaborative, these events are to be made collaborative, i.e., the effect of all the events caused by one designer's actions should be seen by all other designers in their view of the editor. For practical use of the tool, the designers should be able to join other designers in individual sessions and several sessions should be able to run in parallel. This situation is shown in Figure 4-2. The events in one session should not effect the design in other sessions. Hereafter, as we talk about the collaborative environment, we assume that the designers are in the same session, unless specified otherwise. Also, by a user we mean an identity in a session. We can easily imagine the same designer in two parallel sessions at the same time and we consider these two identities as two different users.

### 4.1.1 Client-Server Architecture

When a designer edits a schematic, several types of events are generated. These events have to be propagated to all other designers so that they could take the corresponding action on their design. These events can be either propagated to all other designers or can be sent to a central server which broadcasts these events to all the other designers. These are the peer-to-peer and the client-server models respectively. The client-server model is used

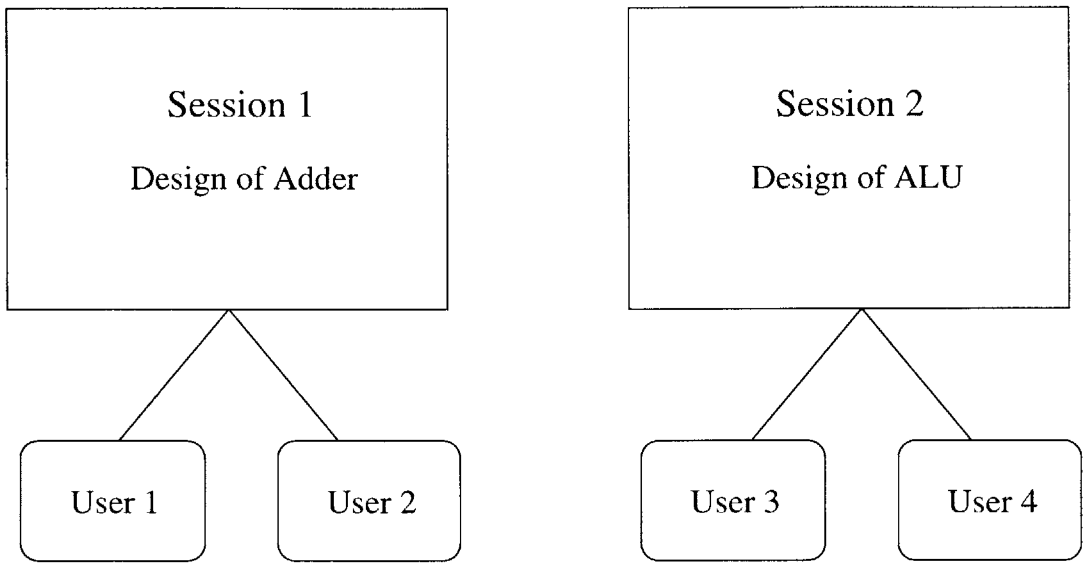


Figure 4-2: Collaborative design with several sessions

in CollabTop. The events that are generated by any client are sent to the central server which is responsible for the broadcast of these events to all the clients. The most important reason for choosing the client-server model is that it is easier to incorporate the higher level ideas, as explained in the next section( e.g., synchronization into the system), in this model. Another reason is that the number of channels involved in a client-server model is smaller than the peer-to-peer model and so it is less error prone to the network congestion due to other traffic. If $n$ is the number of designer clients in a session, the number of channels needed by a client-server model is of the order $O(n)$ whereas the number of channels needed by a peer-to-peer network is $O(n^2)$. Moreover, a client-server system can be scaled later in order to support multicasting in the connections from the server to the clients.

There is a provision to enter the session in a read-only mode. Clients with read-only capabilities can view the actions of other designers in the session (e.g., the selection of a cell). But, the client cannot cause any actions in the session. This feature is particularly useful in the design reviews. Events produced by such a client are not broadcast to the clients in the collaborative environment, but the client would be able to see the consistent view of the copy being edited. Some clients can highlight parts of the cell and edit the cell, and the read-only client can view it. It is very useful in the design review phase, where particular parts of the design can be highlighted and hierarchically edited by one or more

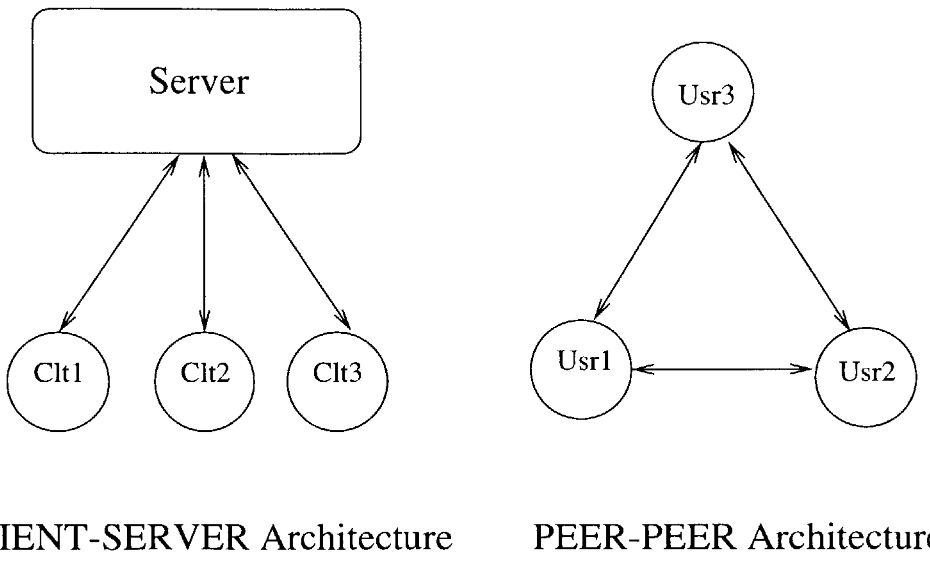


Figure 4-3: Client-Server and Peer-to-Peer Architecture

clients and the read-only client would be able to view it.

It is desirable to have designers across sessions to communicate with each other. In Java, an event is generated when a menu selection occurs. But, the client who did not generate the event does not know which menu item selection generated that event, because examining the menuitems does not generate any event in Java. When a designer selects a cell from a menu of the tool, the event of the menu popping up and the selection of a menu item is not visible to other designers as these actions do not generate any events in Java. Only after a menu item is selected, Java generates an event. A chat tool has been implemented to come into use in such situations. It follows the client-server architecture too and the designers across sessions share this tool. A ChatServer is also run along with CollabServer, the server for the collaborative events.

## 4.2 Higher Level Issues

For the framework described in the above sections to work, some higher level software design issues must be addressed. This includes the protocol of message passing, the issues of reliability of clients and recovery of the tool from the sudden death of any of the clients. The issues like reordering of messages and locking of some critical resources have to be taken into account.

### 4.2.1 Synchronization

An event in a session is triggered by a designer client. This client sends the message to the server, which broadcasts it to all the clients, which take the necessary action. The delay between sending an event and it being received at the server is network dependent. This could result in reordering of events at the destination, which might lead to undesirable results on the design. For example, if a new cell is created and subsequently deleted from the design by a designer client, reordering of these messages results in the first deletion giving an error and subsequent creation of a cell, which is clearly not desirable effect. Reordering of different clients' messages at the server causes a problem to the consistency of the views at several client editors. In order to maintain the consistency of these views it is vital that a way to synchronize these messages exists in the environment. It is crucial that the consistency of the view in the edit window of the different clients in a collaborative session is maintained.

We model the channel between each client and server as a First In First Out (FIFO), reliable, directed communication channel. By the reliability of the channel, we mean that all messages sent by the client are received at the server end of the channel. The channel between the client and the server is a directed channel with the above properties.

At the server there is a thread dedicated to each of the clients. It is this thread that receives the messages from its client. The channel between the client and this thread is modeled as a FIFO channel. Also, we model the channels from the server to the clients as directed reliable FIFO channels. So, we could prevent the reordering of the messages, if there is a way of total ordering of the messages from different clients at the server end. What we need is a way of timestamping the messages so that the total ordering of messages can be done.

Logical time is an event dependent counter maintained at various client nodes. Several implementations[21] of logical time are available in the literature. This concept cannot be applied here because it does not model the ordering of events at different nodes. So, we need to use the real-time for the ordering of the events. We used the Greenwich Mean Time on the corresponding machines to model this. Though, this is not completely accurate and it needs elaborate synchronization algorithms[22] to get the time in different clients to synchronize, it stands as a good realistic implementation.

The message packets received by the server and clients are tuples of the type $(msg, t)$ where $msg$ is the message and $t$ is the time-stamp associated with it and the ordering of message packets is as below:
$(m_1, t_1) < (m_2, t_2)$ if $t_1 < t_2$
As soon as the server receives the message packets of this type, it puts them up in an ordered queue, messages being ordered by the time-stamps. The server takes the message that is the least in the ordering to broadcast first. All the broadcast events are to be enclosed in a critical section so that only one queue management action goes on at a time. Thus,we could prevent the reordering of the messages at the server side with the help of time-stamping with real time.

Till now, we assumed that all the clients are present in the session from the beginning and that they receive all the events of other clients from the beginning. It is reasonable to expect that a designer client joins the session at a later stage of the design, when the design session is already in progress. The concept of time-stamping also helps in this phase of synchronization. This type of synchronization is when a client joins a session which is already in progress. Synchronizing this new client into the session involves bringing all the details of the consistent view to this new client. These details include major things like the presently edited design, and the stored cells in the libraryManager and the minor things like the cutSchematic details(eg., if a cut in the design is done by a client before, a paste later should paste the schematic which was cut). The new client sends a message $("sync- < id > ", t)$, where $id$ is the identifier of the client, to the server which is broadcast to all other clients in that session. This is the synchronization request. The clients when they get this message send a reply $(sync - reply, t)$ to the server which sends it to the new client. So the new client gets replies to its synchronize request from each one of the other clients in the same session. The following analysis shows that all these replies have the same details. So it uses the first one it gets to construct the starting view of its editor.

The server broadcasts from the queue in a critical section of the code and as the channels from client to server are modeled as FIFO channels it maintains that all clients receive the synchronize message in the same relative position in the queue. So all the replies are similar because of the consistency constraint we had due to the time-stamping. So the new client can use any one of the replies of the synchronize request and then can start taking actions as usual. The explanation below formally proves that this is true under our assumptions.

Proof: Suppose two clients had sent two different snapshot views to the new client. Without loss of generality, we can say that client1 received at least one message before getting the sync-request from the new client and the client2 had received the same message after receiving the sync-request from the new client. But the action of broadcast is in the critical section in the server and the thread doesn't start broadcasting another message till the present message is broadcast to all the clients. So, it means that they are sent in proper order at the server end and they got rearranged in the channel. This contradicts our assumption that the channels are reliable FIFO channels. So, all the clients should receive these messages in the same order and the new client gets the same snapshots from all other clients.

So, with the mechanism of synchronization request and synchronization reply, synchronizing a new client into a session in progress can be done. But, some more things have to be taken care of for the smooth execution of this algorithm. The new client might be having an event in its queue of events, which it got before the sync-reply but whose action has been taken by the client which had sent the reply. In that case, the new client should not be taking the corresponding action. An example is shown in the Figure 4-4. The message for synchronization request will be received by the client 1 only after it had received the wireMode and mouseEvt messages. But the sync-reply given by the client 1 is given after the corresponding actions on messages 1 and 2 but before message 4. So the new client should queue up message 4 and take the corresponding action after it takes the action for the sync-reply message.

The new client queues up all the events that it received before receiving its synchronization replies. After finishing the the work with the synchronizing view, it will take the corresponding action on the events with time-stamps greater than the synchronization-reply message in the start queue. The pseudo-code the new client follows to achieve the same is given below:

```
ClientRcvPacket(pkt)
{
if(SessionInProgress)
{
   if(pktIsSyncReplyMessage(pkt))
  {
```

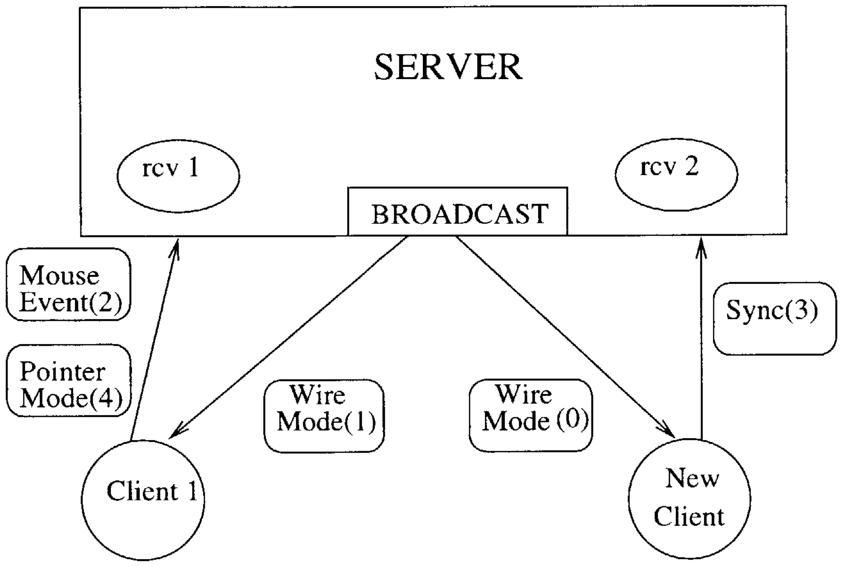


Figure 4-4: Synchronization of the System

```
TakeSyncReplyAction(pkt);
TakeActionOnStartQueue(pkt.timeStamp);
// Take action on the packets in
// start queue with larger time-stamp.
 }
 else
    PutInStartQueue(pkt);
}
else
TakeAction(pkt);
}
```

### 4.2.2 Recovery

Since the tool is a browser-based applet, the unreliability of the browsers has to be taken into account. Some clients may get disconnected from the session because of the same. Even the loss of network connectivity of the client results in the death of the client process as far as the remaining clients view goes. The tool should be robust enough for these failure of the clients not to affect the tool. Recovery from the failure of any client is another important issue in the collaborative environment. The failure of the client can be modeled in two ways. A process can exhibit a *stoppingfailure* by stopping somewhere in the middle of the execution. It can also exhibit what is called a *Byzantinefailure*[23], by which it can generate next messages in an arbitrary, unpredictable way. Since the reasons for the failure of clients, as mentioned before, refer to the stopping failure of the clients, we model the failures as in that category. We modeled the channels as reliable and the clients always send meaningful information. If the client program gracefully exits the code, it sends an exit message to the server. The server then deletes all the resources used for this client. If the client gets killed otherwise, a server vulture which keeps track of the time for which a client has not sent an event, sends a message to that client. If no reply is received for that, it assumes that the client is killed and takes the required action. The assumption that the channel is reliable plays a crucial role here. The server has to release all the locks held by such a client explicitly.

### 4.2.3 Locking

Mutual exclusive execution of certain resources may be needed in some cases of execution. Locking of critical resources is a required behavior to be incorporated into the collaborative environment. One such resource is the mouse movements in wire mode. If this is not locked and if more than one client uses the mouse at the same time, they do not get expected results as shown in Figure 4-5. In this example, two designers are simultaneously trying to draw wires, one being horizontal and the other being vertical. The screen might show the wire with parts of both at an instance as shown in the figure.

To take care of this situation, a resource lock has to be maintained at the server for each such critical resource. Whenever this lock is not set and there is request for the lock, the resource is granted. If the lock is already set, this message is sent to the requesting client. It is also important to clear these locks if a lock-holding client fails. A lock for the wire mode mouse movement is implemented in the collaborative environment and is described below.

Each session has a corresponding wireModeLock in the server and it gets set automatically whenever a client sends a WireModeRequest message when it is not already set. The lock gets released when the same client sets to another mode. The mouse movements from other clients are blocked from being broadcast when the lock is held. The locks are also removed when the vulture finds that the lock-holding client got killed.

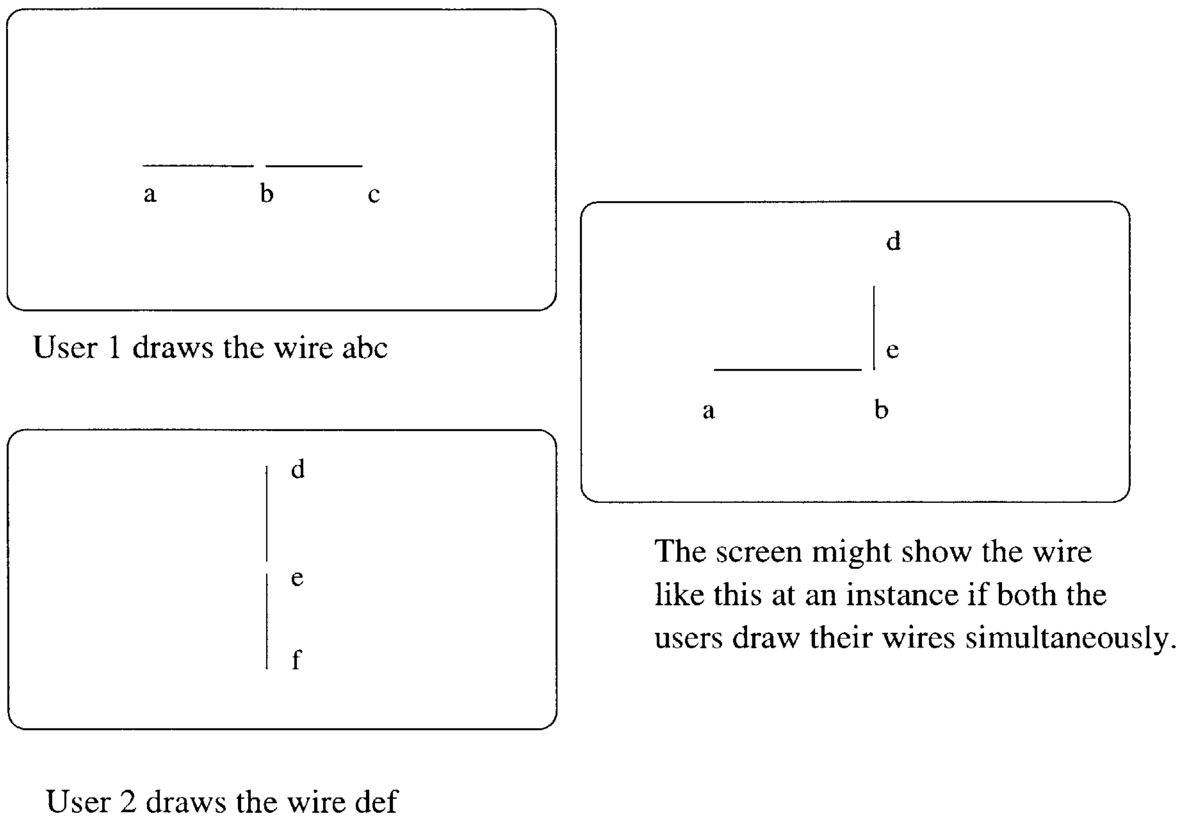

a
b
c
User 1 draws the wire abc
d
e
f
User 2 draws the wire def
d
e
a
b
The screen might show the wire like this at an instance if both the users draw their wires simultaneously.

Figure 4-5: An example of mouse movements where locking is required

## 4.3 Implementation Details

The implementation details of the collaborative tool are given briefly in this section. The programming language in which the whole tool was implemented is Java (Version 1.1.6). The tool is implemented as a Java applet and can be run from a browser which supports this version of Java(e.g., netscape version 4.5). The tool is available for use at *http : //apsara.mit.edu/CollabTop*. The Java 1.1 observer-based event model suits the needs of the event message passing. A snapshot of the tool with two users' editors who are in the same session is given in Figure 4-6.

Different clients send various events as messages to the server asynchronously. Also, several parallel sessions run in parallel at the same time. The server should be able to receive these messages from different clients at the same time. *Muiltithreading* is a feature in Java that provides support for multiple threads of execution that can handle different tasks. These are also called light-weight processes. This feature is utilized in making the server run several threads, one for each client to receive messages.

Whenever there are multiple threads running in the programs, specific care should be taken that individual threads do not modify resources or variables common to all the threads without obtaining a lock on them. Normally such code segments which access these common resources are called critical sections and a lock on the critical resources is acquired before entering this section and is released before leaving and these operations have to be atomic in nature[24]. Java enables the user to create critical sections by putting them within a *synchronized* statement. This feature of Java is used for implementing the critical sections of the code for mutual exclusion. This is needed in all the queue management events in the server and in the resource lock management (eg.,wireModeLock) events.

WebTop was developed as a Java applet and uses the CGI mechanisms to submit the extracted netlist to various web-tools. The events that are generated from the user actions, prompt the applet to take the necessary action. But, CollabTop follows the client-server architecture. In the new architecture, each client event gets passed on as a message to the server which broadcasts them to each of the clients, which take the corresponding action on receiving the message. The server is a stand-alone Java program executing on the applet host.

Initially, each designer client notifies the server of the designer name(*id*) and the session name to join. Then it proceeds to generate events and take actions after finishing the synchronization with the session if it is already in progress. The server can be broadly thought of as three components. One is the NameServer, which takes all the messages regarding the session names and the designers in the sessions. It can provide the designer with the information on various designer clients present in a session. Another component is the ChatServer which takes the messages in the accompanying Chat tool. The third component is the CollabServer which takes care of all the other messages. In all the figures, by server we mean the CollabServer, although all the servers follow the same architecture as in Figure 4-7. The designer chooses a session to enter while starting the applet. Designs in different sessions are not effected by each others' events. A pictorial representation of the clients in sessions and the server is given in Figure 4-7.

The messages hold the key to the tool. These messages go from the clients to the server and vice-versa. There are a variety of ways in which this message-passing can be implemented using the object-web technologies. Two such methods are Common Object Request Broker architecture(CORBA)[15] and Java Remote Method Invocation(RMI). The other way of implementing this is to send messages as objects, using the Java serialization mechanism, and the sockets to send and receive the messages. We used this approach to implement the message-passing in CollabTop. The implementation of several higher level issues, like synchronization, will be easy and intuitive, if this mechanism is chosen.

The several events that are passed as messages include the mouseEvents(e.g., mouseDrag to move an object), the schematic edit events (e.g., cellSelect event), the extract events (e.g., verilog netlist extract) and all the UI events involved in the editor(e.g., menu selections). After an event object is constructed Java serialization mechanism is used in order to pass them over the network. All these message objects are derived from a base object, called sendObject. Apart from the constructors, it has methods that send these messages to the server and methods that test for the type of these messages.

The server just broadcasts these objects after checking the type of the events that caused these messages. If it is of the type changeOfMode or a MouseEvent it has to do the lock book-keeping. It broadcasts the message if the lock is held by the sender and the wireMode is on or rejects the message otherwise. Rejecting the message results in none of the clients taking the appropriate action.

The clients on receiving a message put it in their queue. The message with the least time-stamp is taken up for action. Each main component of WebTop that handles user actions has a collabHandler method. Depending on the type of message, it is delegated to the corresponding collaborative message handler method. As explained in the previous section, a vulture program is required to run for the recovery of the tool from sudden death of clients. The vulture is implemented as a thread in server which checks on the inactive clients at specific intervals.

It is crucial for these messages to be complete in themselves for the tool to behave correctly. For the synchronization implementation to work, each message has to be an event in itself and an event should not be split into more than one message. Otherwise, the assumptions based on which the synchronization time-stamping method is developed fail.

In the case of late arrival of a client, all the information in the schematic has to be sent to the new client as a single message in the synchronization reply message. It includes the zoom level of the editor, the schematic cell in the editor, all the cells in the library of the session, the mode in which editing is, and the pop-up property boxes if any on the screen. A Java object syncNode has all these fields in it and is serializable. This object also is derived from the sendObject node. and is used to send the synchronization reply.

In the case of loading file from URL the collaborative event broadcast by the server makes every client in the session read the file from that URL. Similarly, if one user in a session extracts the netlist, an extract window pops up on all the users' screens. The submission of the netlist to a web-tool is also collaborative. But, once the dynamic URL from that web-tool is loaded by the browser, the events on that HTML page are not broadcast, as they are not events in CollabTop.

There is a ColorManager associated with WebTop, using which, users can change the colors of their pins and sub-cells in their schematic. This feature is made non-collaborative and so users can change the colors at any time and they will get immediate response on their screens. Also, different users can have different settings in their colorManager.

## 4.4 Example Collaborative Flow

An example flow of events in the use of the Collaborative framework is given in this section to demonstrate all the concepts developed in the earlier sections. In order to show the use of the synchronization mechanisms in effect, in this example, one designer joins the session after the other starts the session, in this example flow. Also, the number of designer clients has been chosen to be two in order to simplify the flow. To show an example of distributed tool invocation, Pythia is invoked remotely.

The example flow runs as follows. Designer A starts the design session and starts creating and editing the schematic in the editor using the library cells in the tool. Designer B joins the session and the synchronization mechanisms bring the consistent view of the design and the saved cells in the library, if any, into B's editor. Then, they collaboratively editing the design. In the process, B initiates downloading of WebTop cells from a URL. This generates collaborative events and these cells appear in both A's and B's library managers. After editing, one designer saves the cell in the library which generates collaborative events to save it on both sides. Then one designer extracts the verilog netlist from the schematic which makes the extract window with the netlist on it show up on both of their screens.

One designer submits it to Pythia and the results can be viewed by both on their screens. Then they store the design in CellServer and quit the session. This flow is shown in Figure 4-8.

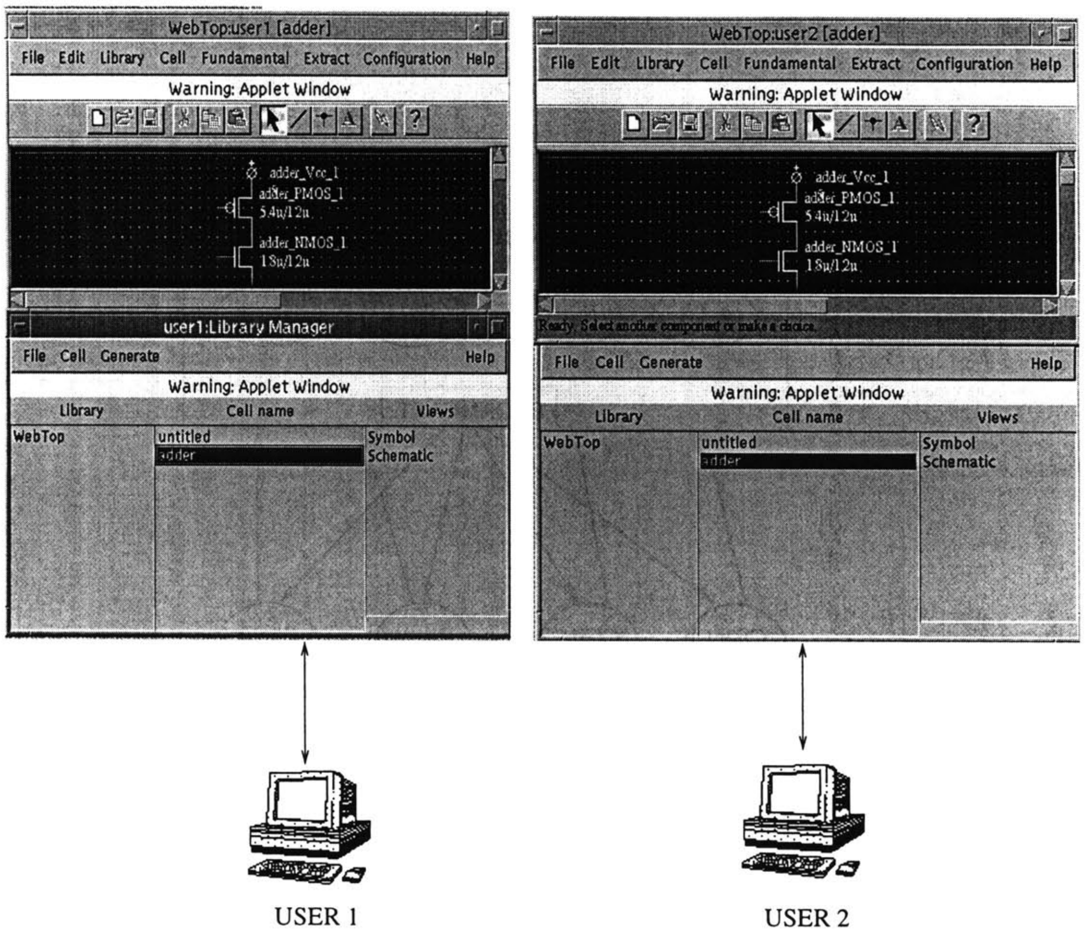


Figure 4-6: Snapshot of the Collaborative framework

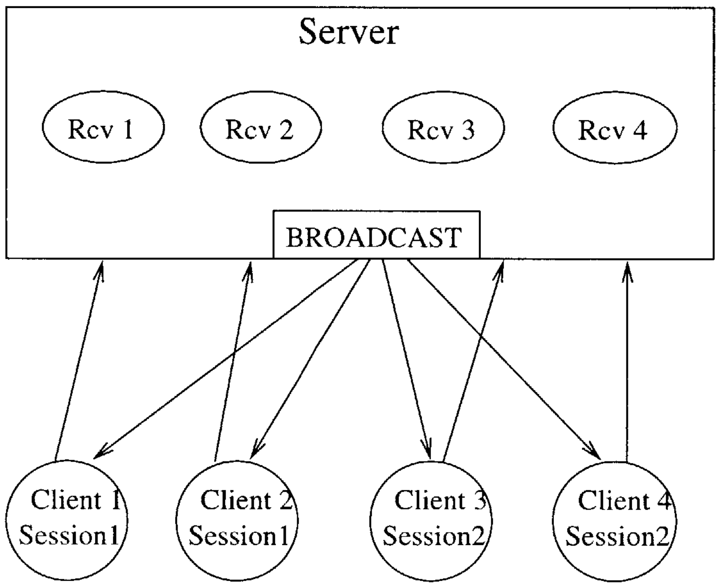


Figure 4-7: Client-Server Architecture of the System

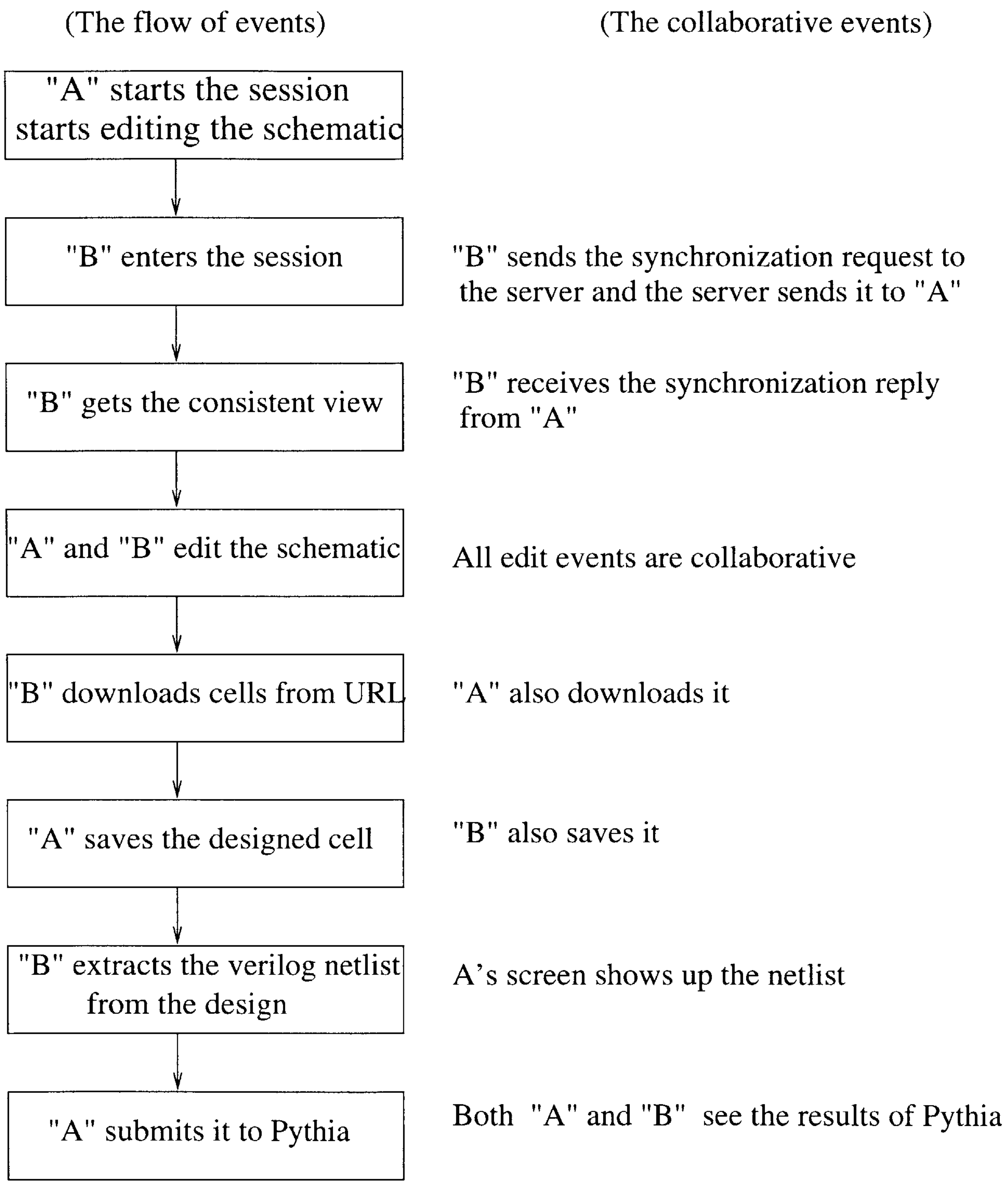

(The flow of events)
(The collaborative events)
"A" starts the session starts editing the schematic
"B" enters the session
"B" sends the synchronization request to the server and the server sends it to "A"
"B" gets the consistent view
"B" receives the synchronization reply from "A"
"A" and "B" edit the schematic
All edit events are collaborative
"B" downloads cells from URL
"A" also downloads it
"A" saves the designed cell
"B" also saves it
"B" extracts the verilog netlist from the design
A's screen shows up the netlist
"A" submits it to Pythia
Both "A" and "B" see the results of Pythia

Figure 4-8: Example flow in the Collaborative framework

# Chapter 5

# Summary and future work

The distributed Web-based CAD tool, WebTop, has been extended into a collaborative environment. The tool, CollabTop, is available for use at the URL *http : //apsara.mit.edu/CollabTop.*

The emergence of the Internet and the WorldWideWeb has led to the concept of Web-based CAD enabling distributed library access and distributed tool access. The advent of the platform independent programming languages and the markup languages like HTML helped the interactivity of such frameworks.

Managing the bandwidth and the latency of communication in the Internet are important issues in this Web-based CAD paradigm. In particular, the nondeterministic delays of the CAD tools cause concern. Significant amounts of data involved in CAD tools, has to be transmitted in doing designs across the Web. Therefore, the security and the speed of communication are important. The transmission of data has to be minimized to speed-up this process. Client-side caching of data is a feature needed for this. In some cases where applicable, it might be more convenient to transport a tool and have the data processed locally, rather than the traditional way of transporting the data to have it processed at the tools' site.

Collaborative design environment allows the designers to cooperate in the design process and utilize the diverse expertise available. Collaborative environment, with the capabilities of distributed tool and library access, enables designer-centric dynamic design space exploration.

There are some extensions and developments that could be done to the tool. The tool is vulnerable to a single point of failure (at the server). Implementing fault-tolerant leader election algorithms and allowing any node to be able to perform the role of a server eliminates this problem.

The functionality of client-side caching and client-side saving of the files is required. Now the designers can save their files in the CellServer, run at the applet host. This is because the Java applets can only save their data at their host. Another improvement to the tool involves the modification of the client-server model to the model of multicasting.

Outputting the netlist in *ediff*, a format to describe circuits supported by many CAD tools is a desired functionality to be included in the tool. It would be interesting to add the capability of dynamic invocation of tools. That would involve invoking tools transparently and does not require recompilation of the applet to add interfaces to tools. This requires all such tools to exhibit a basic common interface to the web framework. This calls for agreements on standards for data communication and tool protocols between tool vendors and the CAD users.

A database backend to the central cell storage is also an interesting extension to the tool in present state. The Java DataBase Connectivity (JDBC) could be used for this purpose.

The tool could be of great use in design projects that involve collaboration among students and can be used as an application in the coursework. The tools used in the design could be maintained centrally. The feature making a client a "read-only" designer can be of great utility in such situations. CollabTop gives the designers all the advantages of distributed and collaborative Web-based CAD with easy-to-use user interfaces.

# Appendix A

# Snapshots from the design example

In this appendix, snapshots during the execution of the design example with the distributed tool, WebTop are given. This example is explained in Chapter 3. The snapshots include the editor, the extracted netlist and the view of the browser when the corresponding tool is invoked. The tools invoked are Pythia, PowerPlay and Stanford Power Simulator.

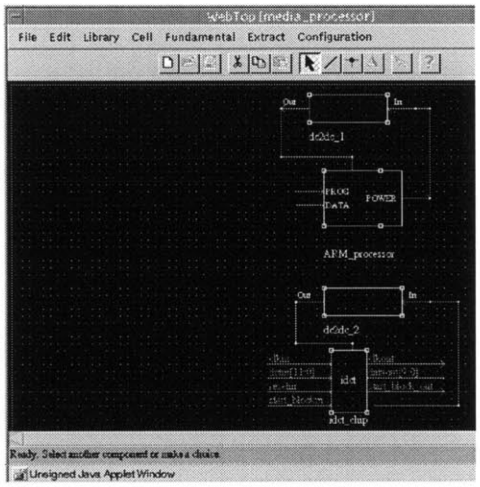
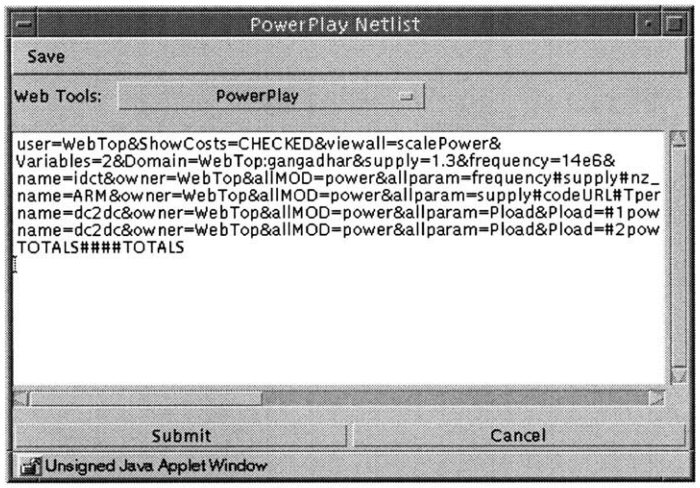
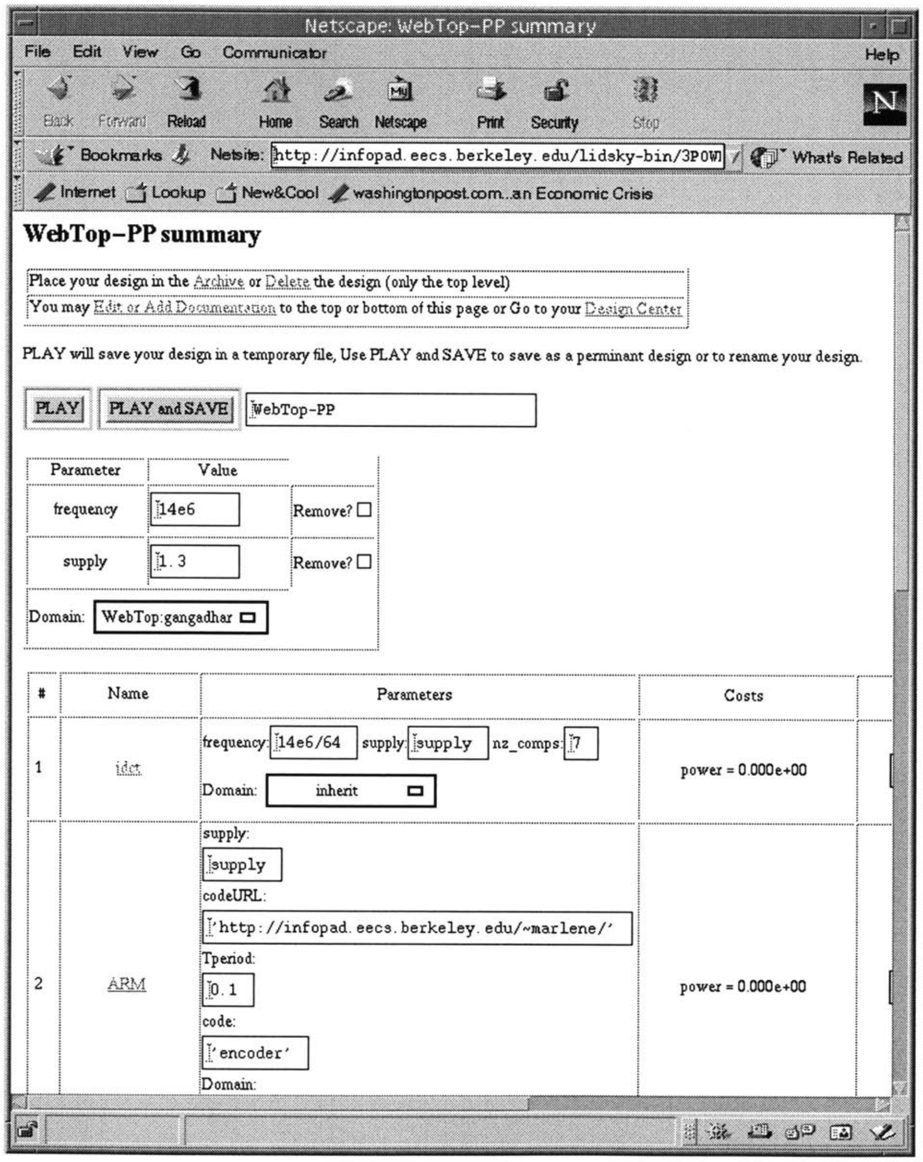


Figure A-1: The Schematic of the media processor



```
user=WebTop&ShowCosts=CHECKED&viewall=scalePower&
Variables=2&Domain=WebTop:gangadhar&supply=1.3&frequency=14e6&
name=idct&owner=WebTop&allMOD=power&allparam=frequency#supply#nz_
name=ARM&owner=WebTop&allMOD=power&allparam=supply#codeURL#Tper
name=dc2dc&owner=WebTop&allMOD=power&allparam=Pload&Pload=#1pow
name=dc2dc&owner=WebTop&allMOD=power&allparam=Pload&Pload=#2pow
TOTALS####TOTALS
```

Figure A-2: The netlist from the media processor that is submitted to PowerPlay


Netscape: WebTop-PP summary

File Edit View Go Communicator Help
Back Forward Reload Home Search Netscape Print Security Stop
Bookmarks Netsite: http://infopad.eecs.berkeley.edu/lidsky-bin/3P0W What's Related
Internet Lookup New&Cool washingtonpost.com...an Economic Crisis

**WebTop–PP summary**

Place your design in the Archive or Delete the design (only the top level)

You may Edit or Add Documentation to the top or bottom of this page or Go to your Design Center

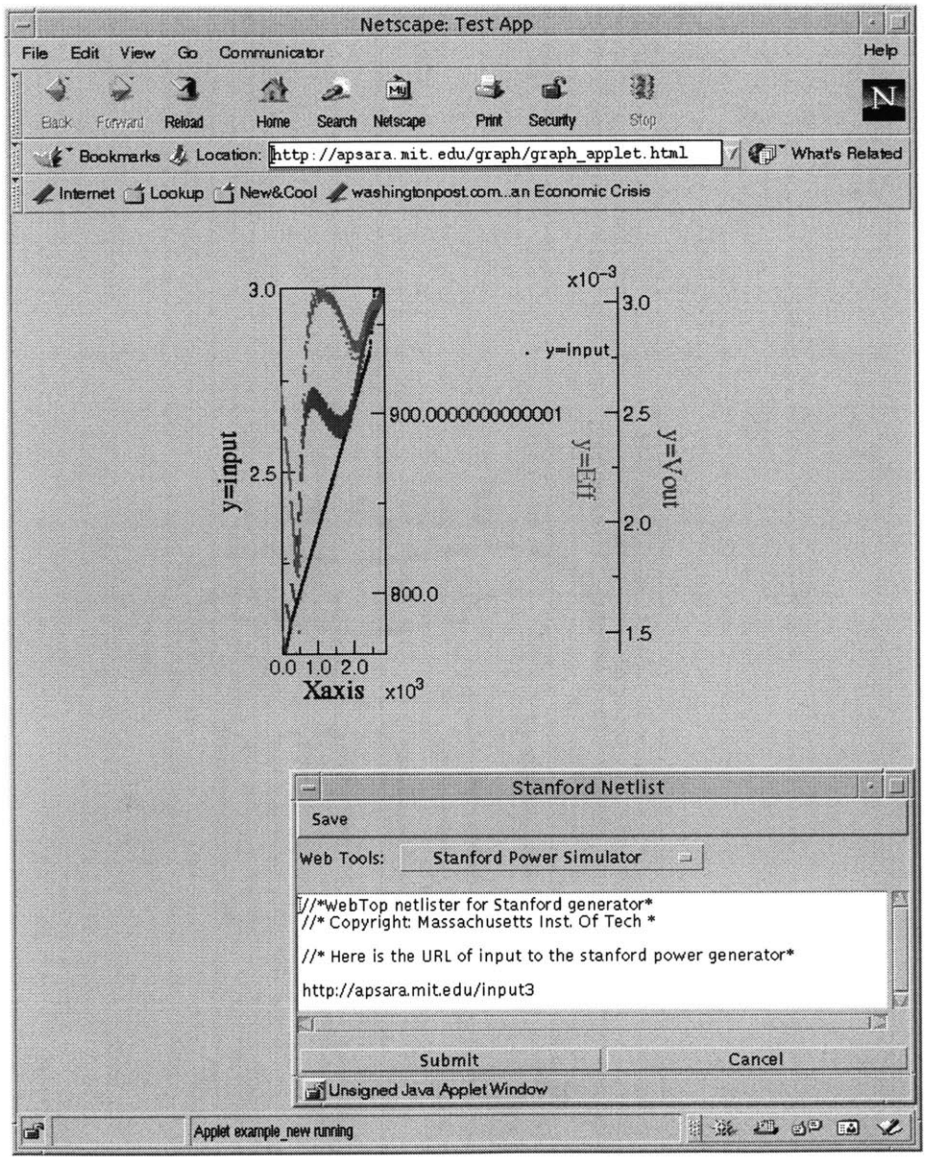
PLAY will save your design in a temporary file, Use PLAY and SAVE to save as a perminant design or to rename your design.

PLAY | PLAY and SAVE | WebTop-PP

| Parameter | Value | |
|---|---|---|
| frequency | 14e6 | Remove? ☐ |
| supply | 1.3 | Remove? ☐ |
| Domain: WebTop:gangadhar | | |

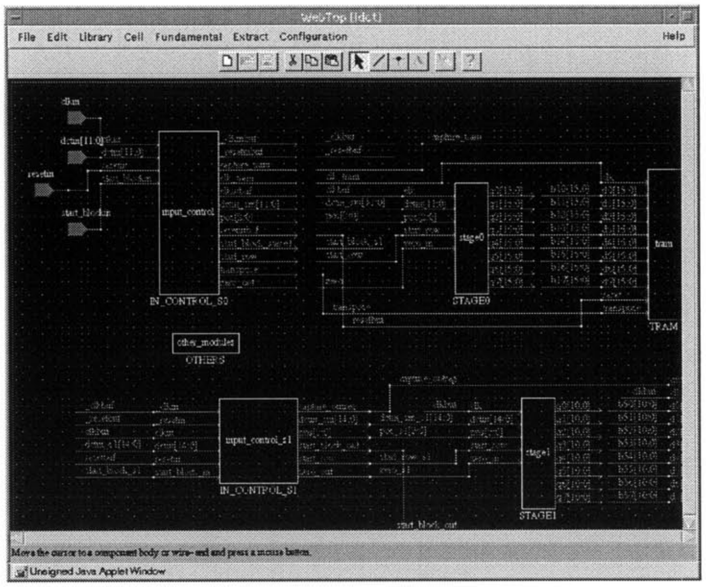
| # | Name | Parameters | Costs |
|---|---|---|---|
| 1 | idct | frequency: 14e6/64 supply: supply nz_comps: 7 Domain: inherit | power = 0.000e+00 |
| 2 | ARM | supply: supply codeURL: 'http://infopad.eecs.berkeley.edu/~marlene/' Tperiod: 0.1 code: 'encoder' Domain: | power = 0.000e+00 |

Figure A-3: The snapshot of PowerPlay after it receives the netlist from WebTop


Netscape: Test App
File Edit View Go Communicator Help
Back Forward Reload Home Search Netscape Print Security Stop
Bookmarks Location: http://apsara.mit.edu/graph/graph_applet.html What's Related
Internet Lookup New&Cool washingtonpost.com...an Economic Crisis
3.0
2.5
y=input
900.0000000000001
800.0
0.0 1.0 2.0
Xaxis x10^3
x10^-3
3.0
2.5
2.0
1.5
y=input
y=Eff
y=Vout
Stanford Netlist
Save
Web Tools: Stanford Power Simulator
Submit Cancel
Unsigned Java Applet Window
Applet example_new running

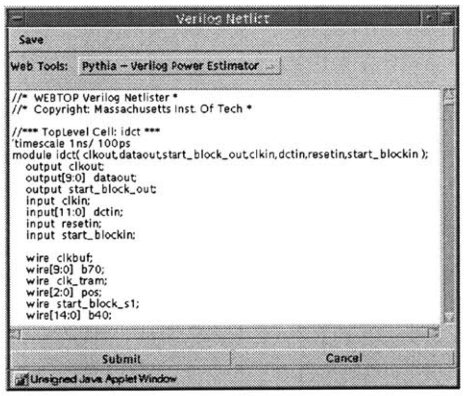
```
//*WebTop netlister for Stanford generator*
//* Copyright: Massachusetts Inst. Of Tech *

//* Here is the URL of input to the stanford power generator*

http://apsara.mit.edu/input3
```

Figure A-4: The output of Stanford Power Simulator and the netlist from WebTop



Move the cursor to a component body or wire-end and press a mouse button.

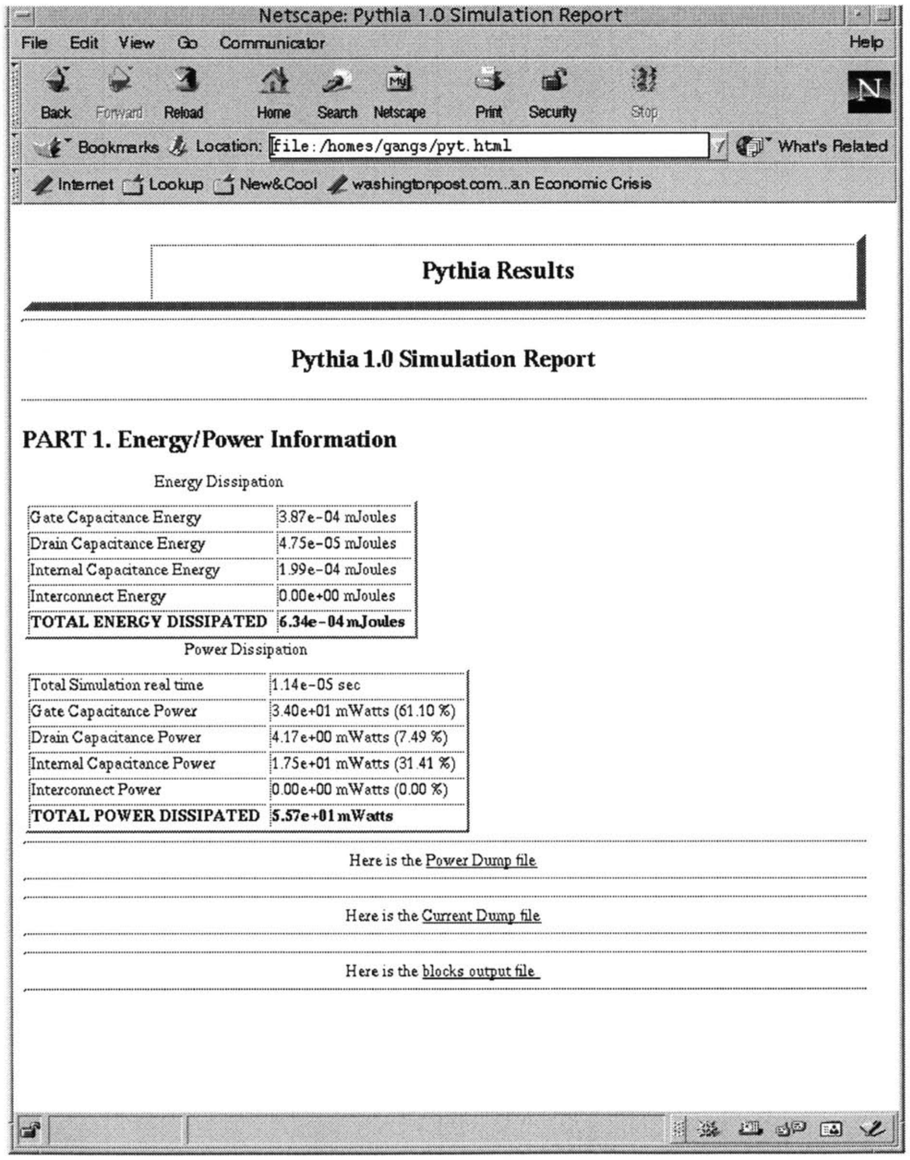
Figure A-5: The Schematic of the IDCT chip submitted to Pythia



Web Tools: Pythia – Verilog Power Estimator

```
//* WEBTOP Verilog Netlister *
//* Copyright: Massachusetts Inst. Of Tech *

//*** TopLevel Cell: idct ***
'timescale 1ns/ 100ps
module idct( clkout,dataout,start_block_out,clkin,dctin,resetin,start_blockin );
   output  clkout;
   output[9:0]  dataout;
   output  start_block_out;
   input  clkin;
   input[11:0]  dctin;
   input  resetin;
   input  start_blockin;

   wire  clkbuf;
   wire[9:0]  b70;
   wire  clk_tram;
   wire[2:0]  pos;
   wire  start_block_s1;
   wire[14:0]  b40;
```

Figure A-6: The verilog netlist of IDCT chip


Netscape: Pythia 1.0 Simulation Report
File Edit View Go Communicator Help
Back Forward Reload Home Search Netscape Print Security Stop
Bookmarks Location: file:/homes/gangs/pyt.html What's Related
Internet Lookup New&Cool washingtonpost.com...an Economic Crisis

Pythia Results

Pythia 1.0 Simulation Report

PART 1. Energy/Power Information

Energy Dissipation

| | |
|---|---|
| Gate Capacitance Energy | 3.87e-04 mJoules |
| Drain Capacitance Energy | 4.75e-05 mJoules |
| Internal Capacitance Energy | 1.99e-04 mJoules |
| Interconnect Energy | 0.00e+00 mJoules |
| **TOTAL ENERGY DISSIPATED** | **6.34e-04 mJoules** |

Power Dissipation

| | |
|---|---|
| Total Simulation real time | 1.14e-05 sec |
| Gate Capacitance Power | 3.40e+01 mWatts (61.10 %) |
| Drain Capacitance Power | 4.17e+00 mWatts (7.49 %) |
| Internal Capacitance Power | 1.75e+01 mWatts (31.41 %) |
| Interconnect Power | 0.00e+00 mWatts (0.00 %) |
| **TOTAL POWER DISSIPATED** | **5.57e+01 mWatts** |

Here is the Power Dump file

Here is the Current Dump file

Here is the blocks output file

Figure A-7: The Pythia output on submitting the netlist from WebTop

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