



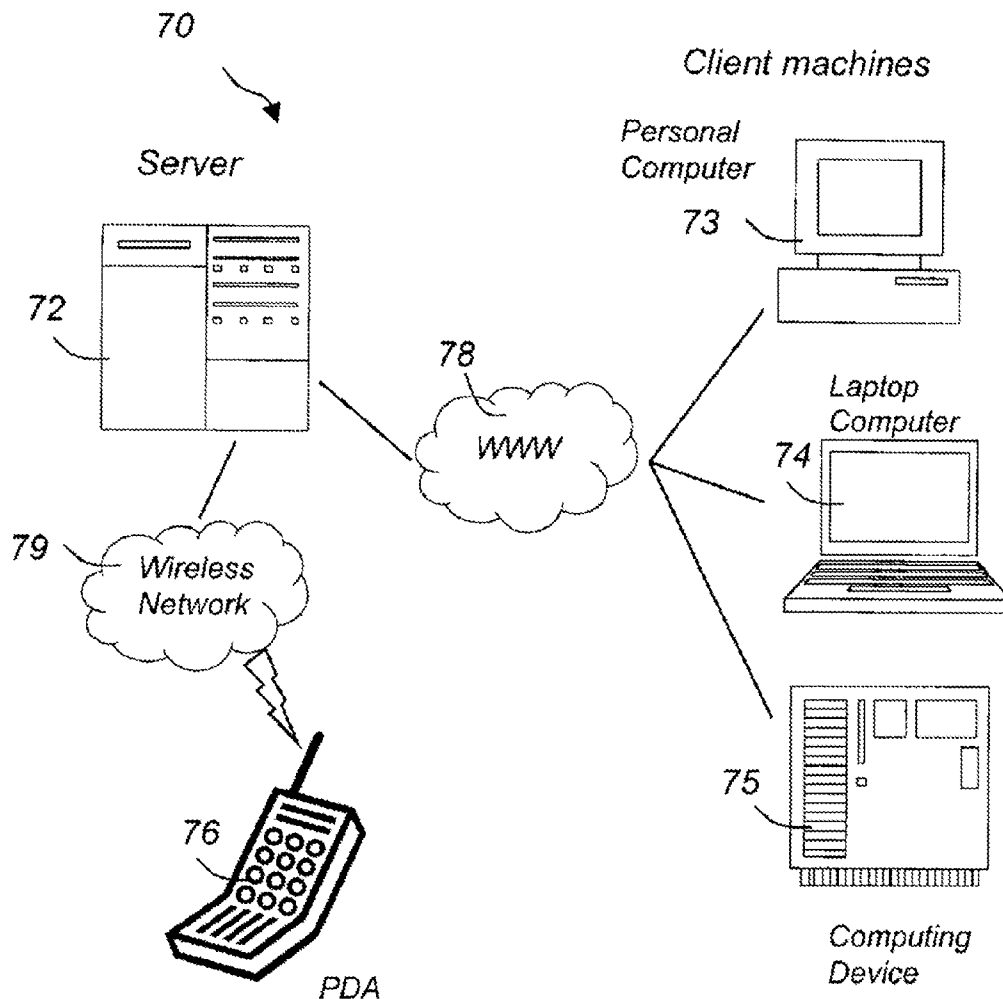
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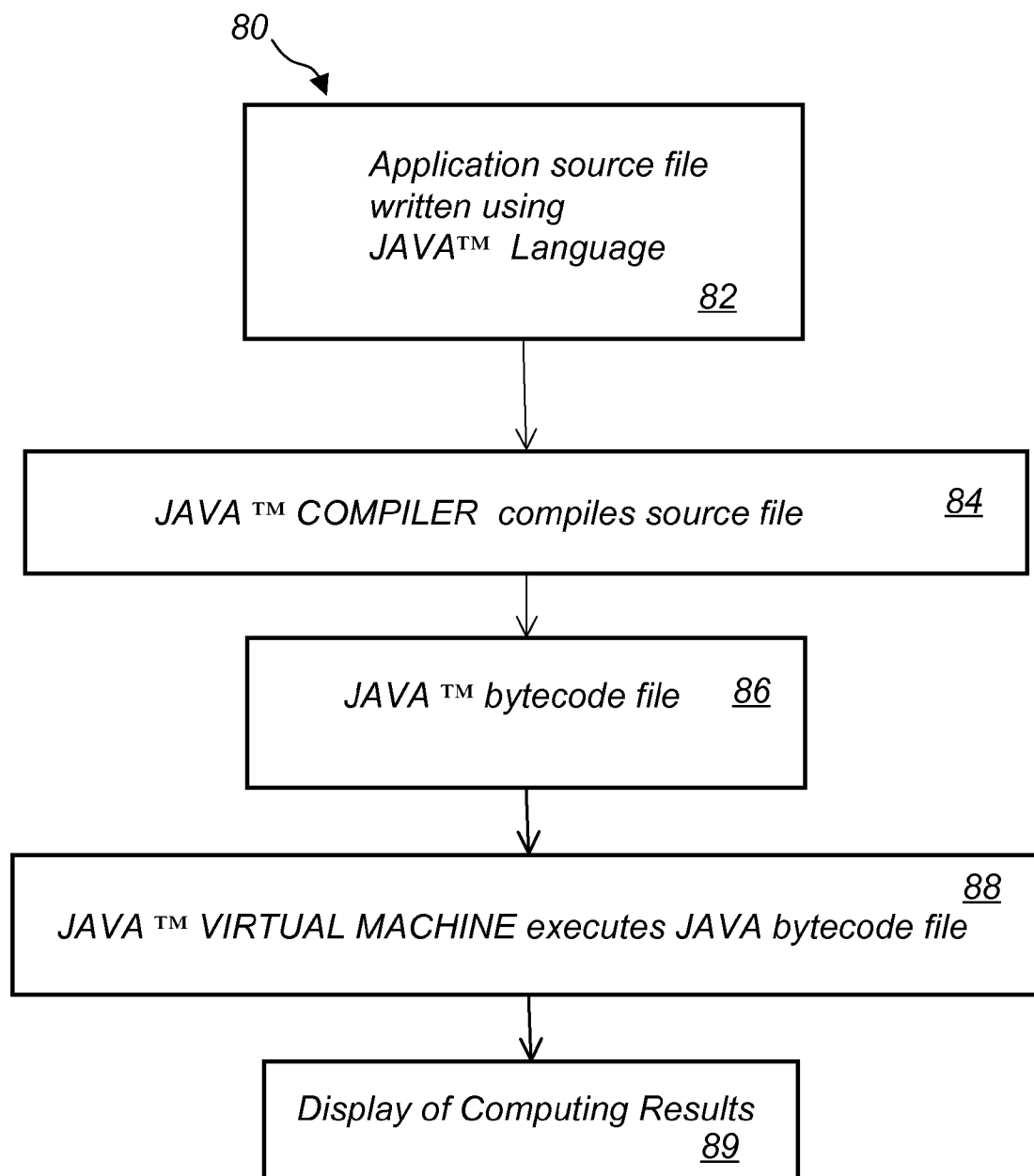
(19) **United States**(12) **Patent Application Publication**  
**WEI**(10) **Pub. No.: US 2009/0007160 A1**(43) **Pub. Date: Jan. 1, 2009**(54) **SYSTEM AND METHOD FOR  
NETWORK-BASED COMPUTING****Publication Classification**(75) Inventor: **COACH K. WEI, BOSTON, MA  
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Correspondence Address:

**AKC PATENTS  
215 GROVE ST.  
NEWTON, MA 02466 (US)**(73) Assignee: **NEXAWEB TECHNOLOGIES,  
INC., Burlington, MA (US)**(21) Appl. No.: **12/209,826**(22) Filed: **Sep. 12, 2008****Related U.S. Application Data**(63) Continuation of application No. 10/754,782, filed on  
Jan. 9, 2004.(57) **ABSTRACT**

A network-based computing system that automates, simplifies, and optimizes the compilation, deployment, and execution of an application by any type of a client machine connected to a server via any type of a network connection. The system includes a client runtime environment, a server runtime environment and an object-oriented markup-business logic binding mechanism. The client runtime environment manages client side code and screen definitions. The server runtime environment dynamical compiles code to ensure client platform compatibility. The system delivers network applications on demand, by separating them into lightweight modules and delivering these modules.





**FIG. 1**  
**(Prior Art)**

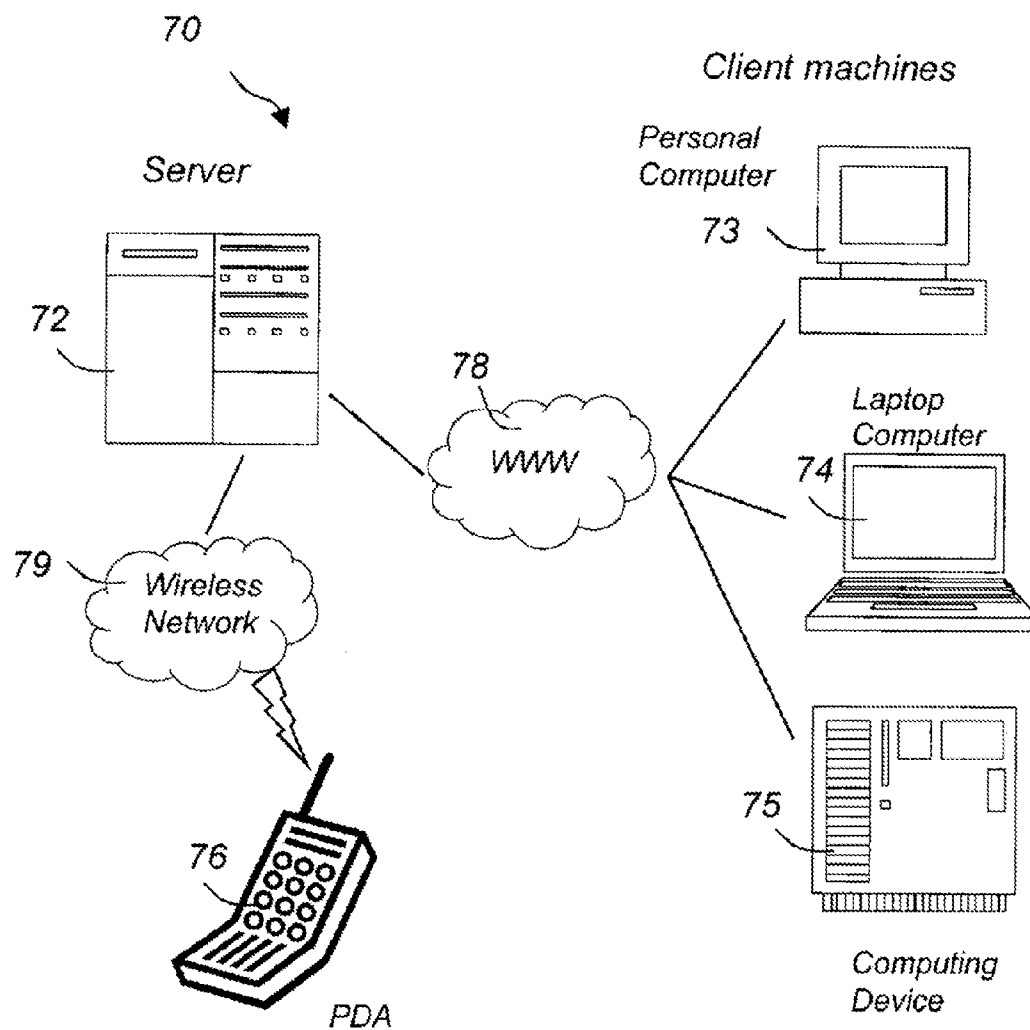


FIG. 2

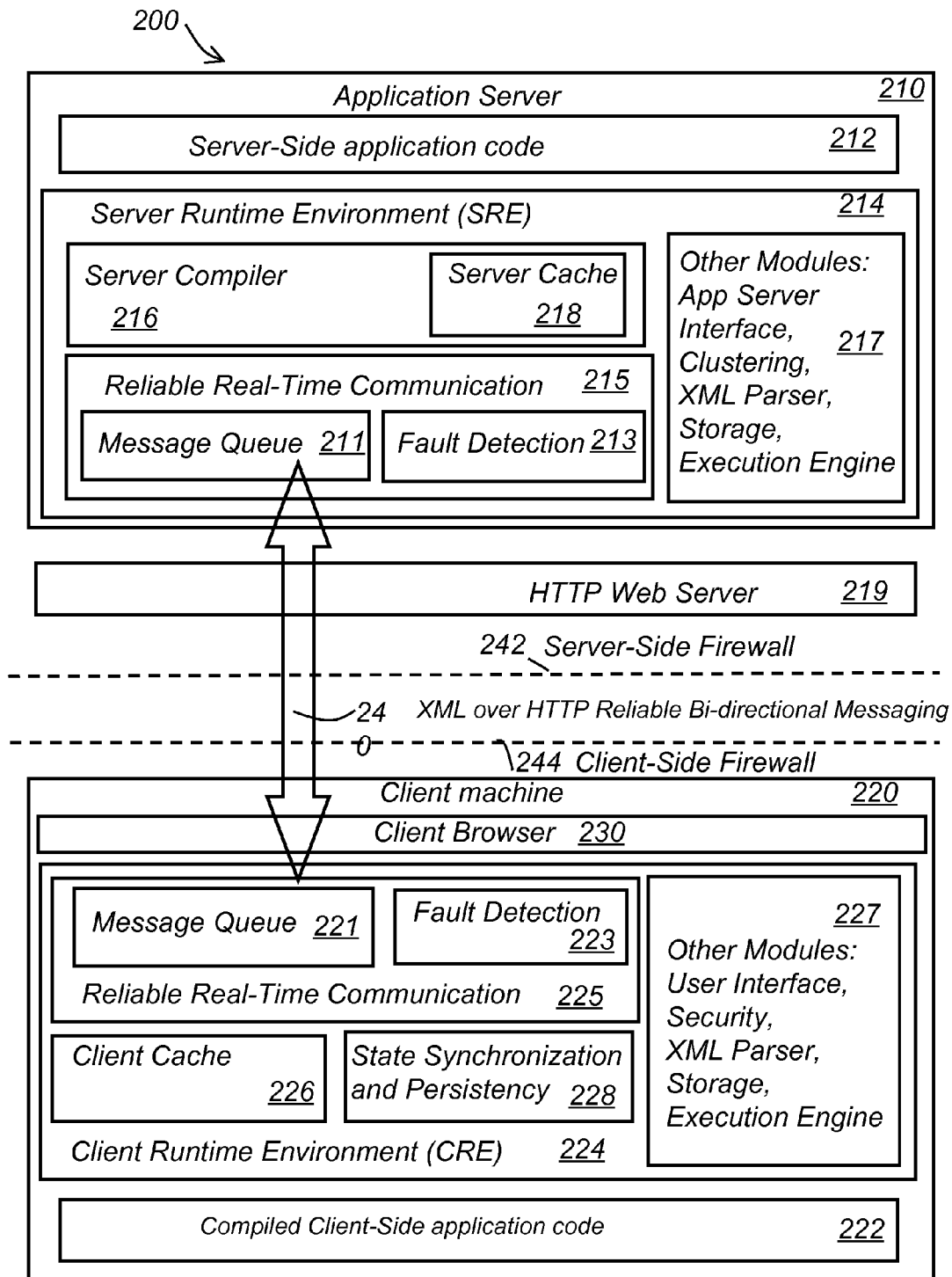


FIG. 3

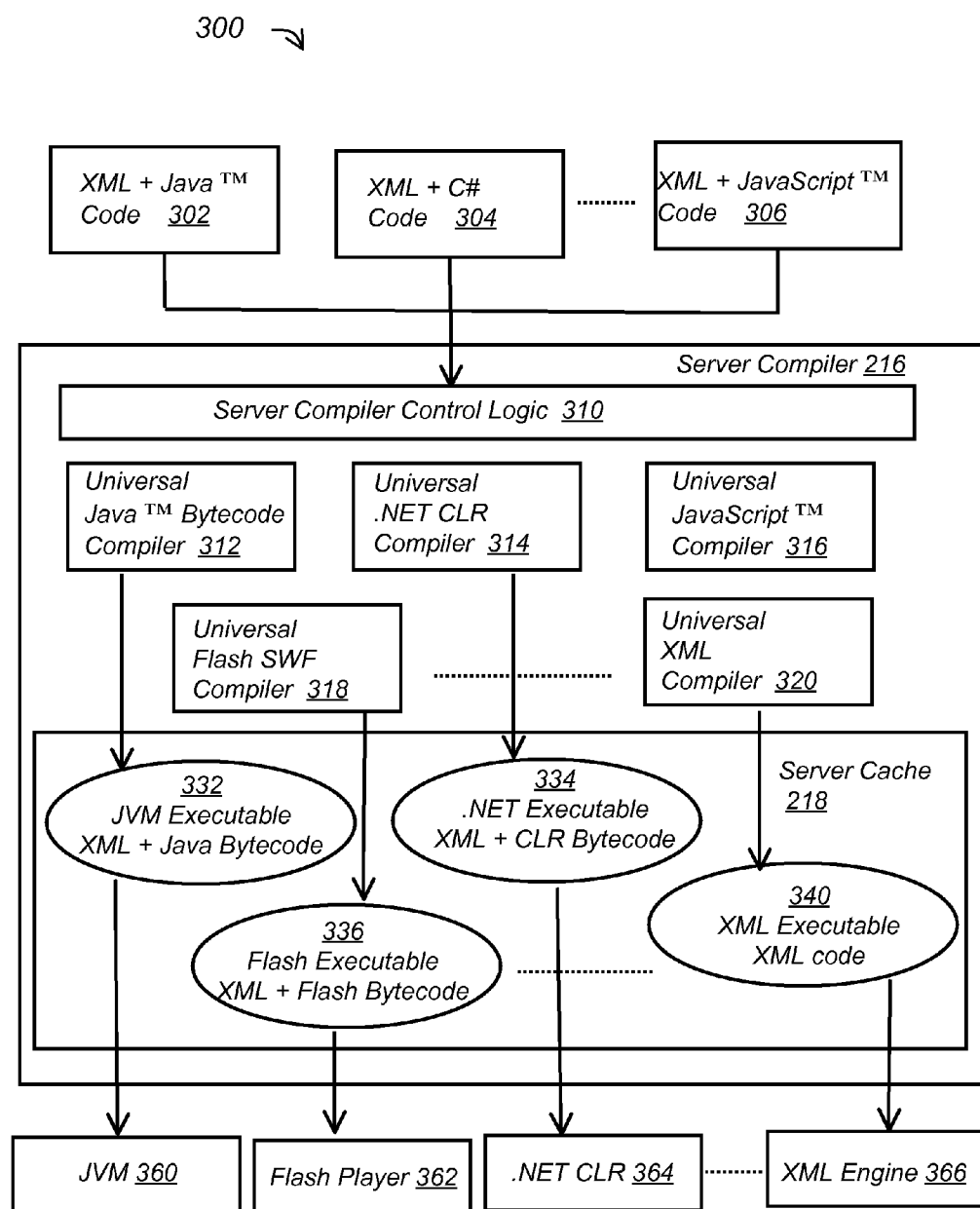


FIG. 4

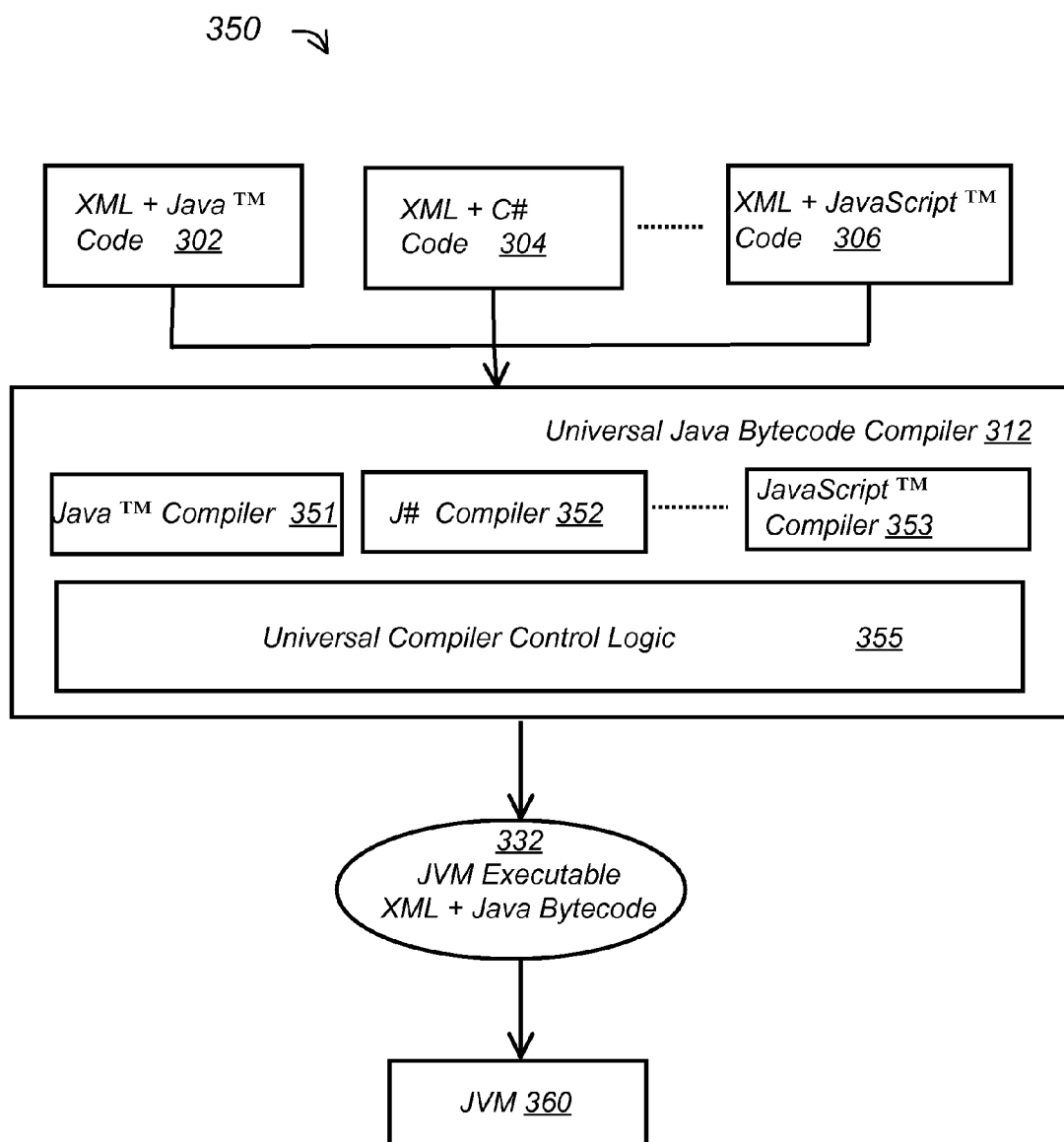


FIG. 4A

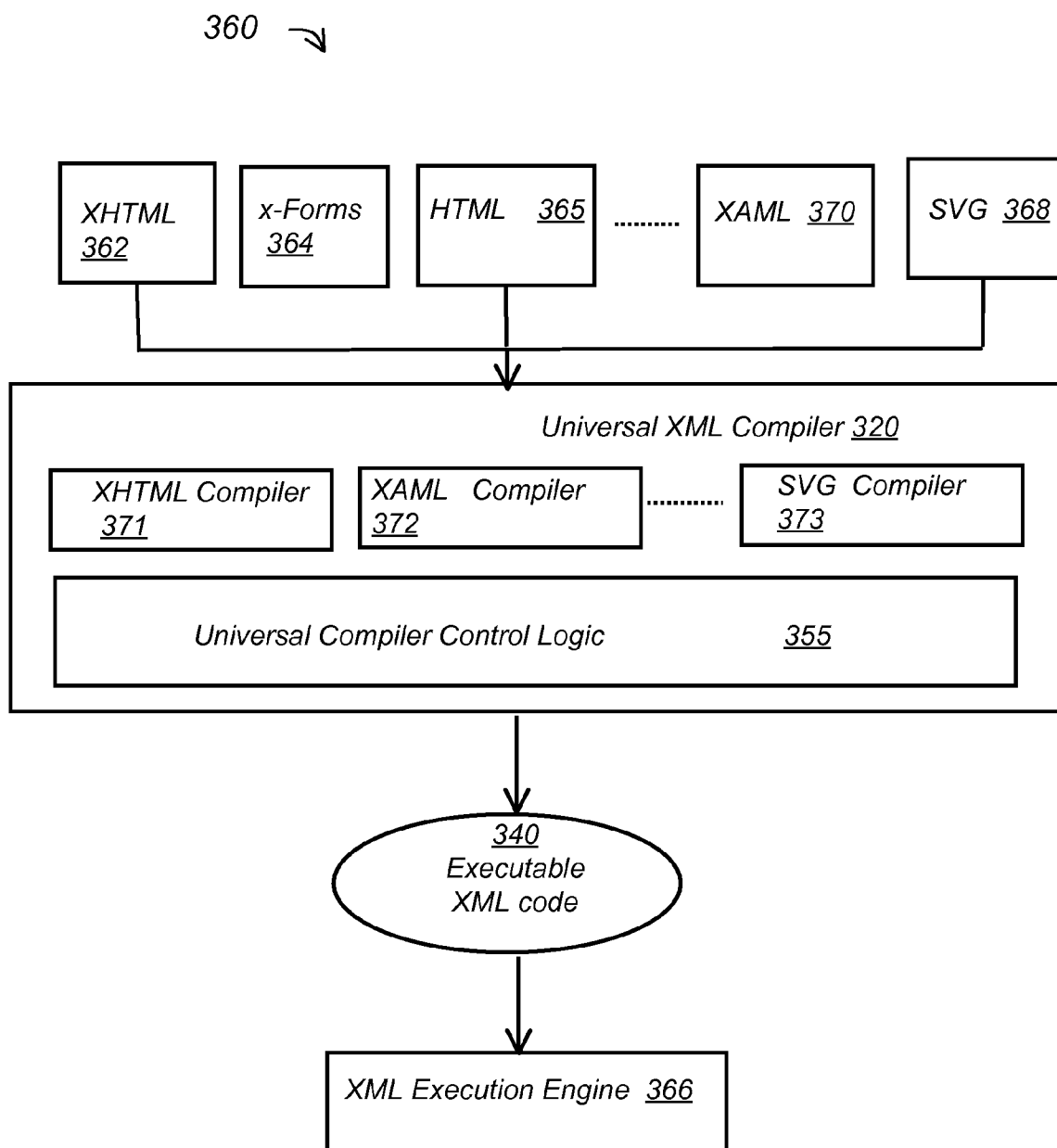


FIG. 4B

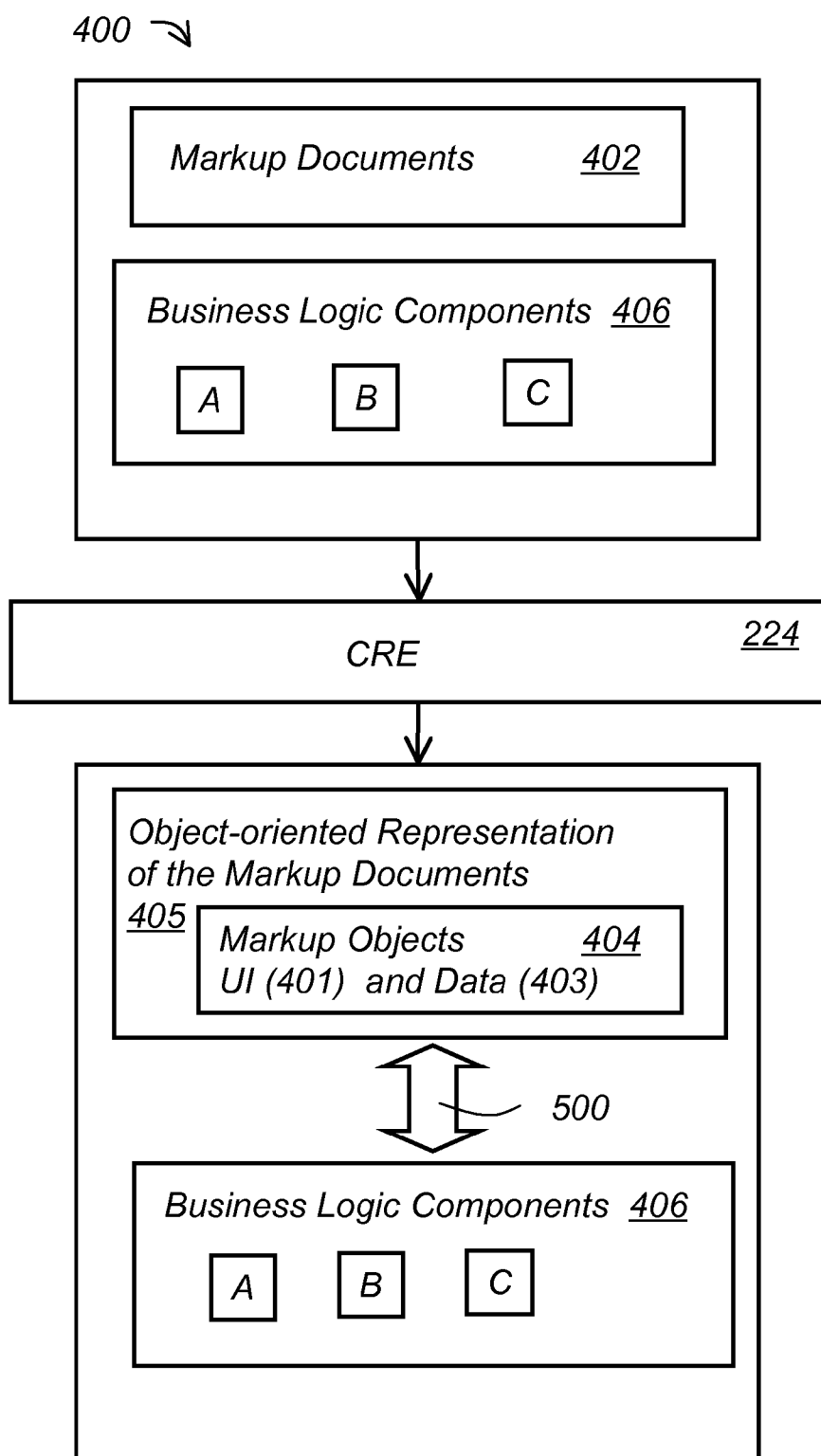


FIG. 5



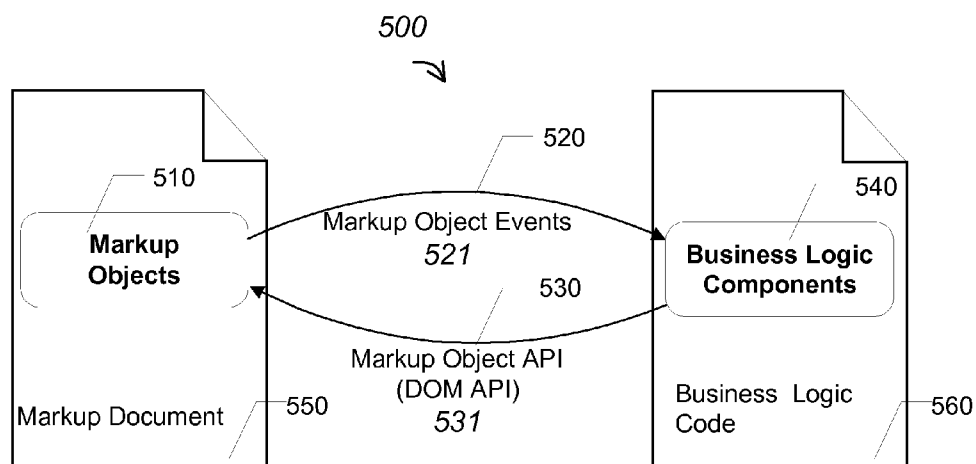
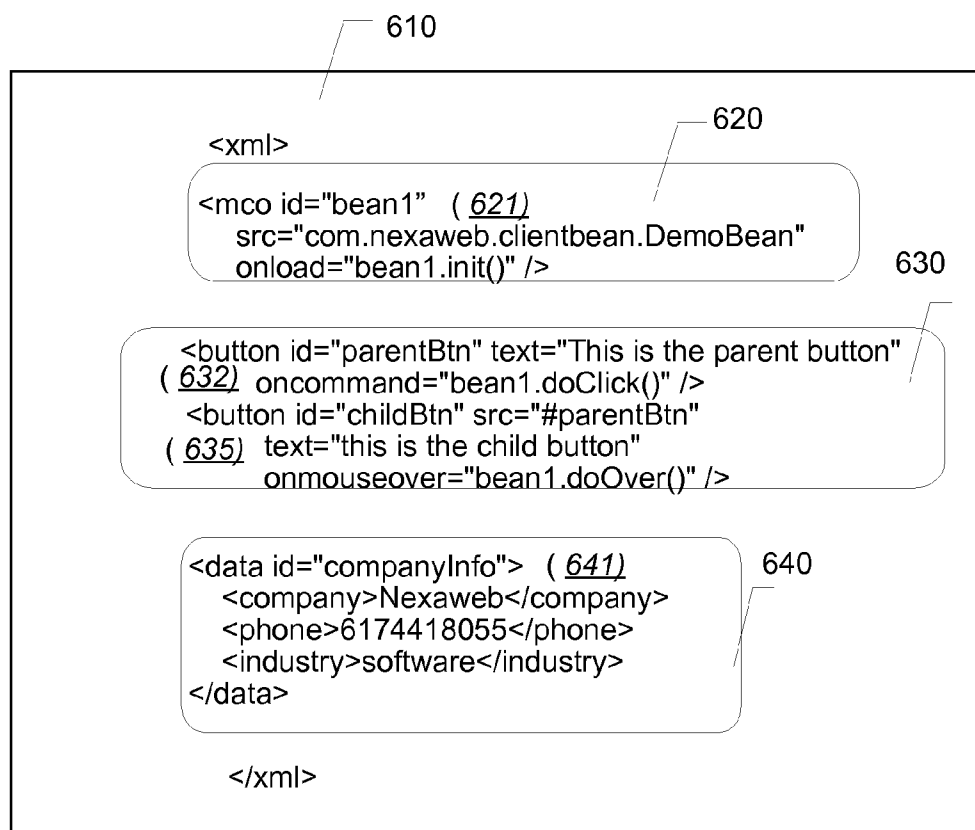


FIG. 6

600 ↘



Markup Objects Defined in A Markup Document  
(UI + Data +Behavior)

**FIG. 7A**

600 ↘

```
package com.nexaweb.clientbean;

import com.nexaweb.domapi.*;
import java.util.*;

/**
 *This is a demo client business logic component written using Java.
 * It illustrates Markup Document to OOP binding.
 */
public class DemoBean
{
    public void init() {
        System.out.println("initializing bean="+this);
    }

    public void doClick() {
        XmlSession ac = XmlSession.instance(this);
        ClientEvent ce=ac.getClientEvent();
        Element eventSource=ac.getXmlElement(ce.getParameter("ctrlid"));
        if(eventSource!=null) {
            eventSource.setAttribute("text","You clicked button "+ eventSource);
        }
    }

    public void doOver() {
        XmlSession ac = XmlSession.instance(this);
        ClientEvent ce=ac.getClientEvent();
        Element data=ac.getXmlElement("companyInfo");
        if(data!=null) {
            alert("CompanyInfo: "+ data);
        }
    }
}
```

650

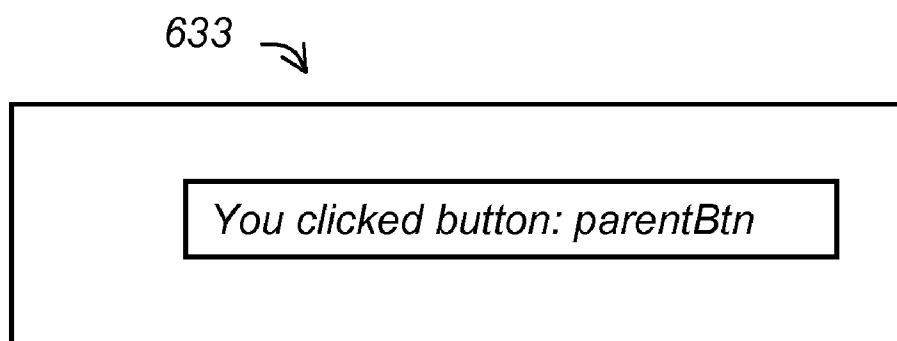
660

670

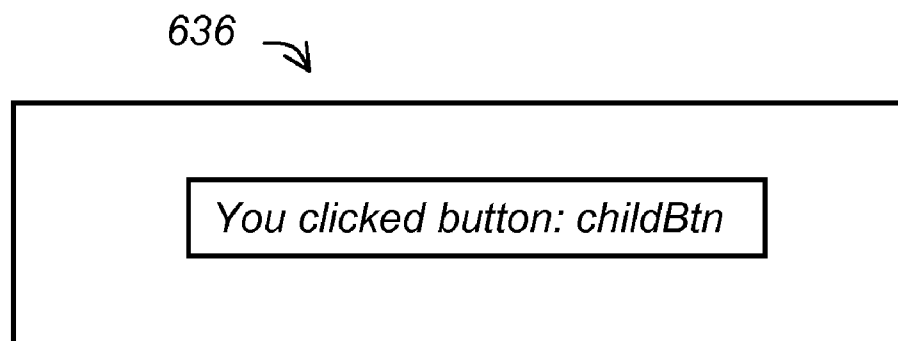
680

Source Code of Business Logic  
Component "bean1"

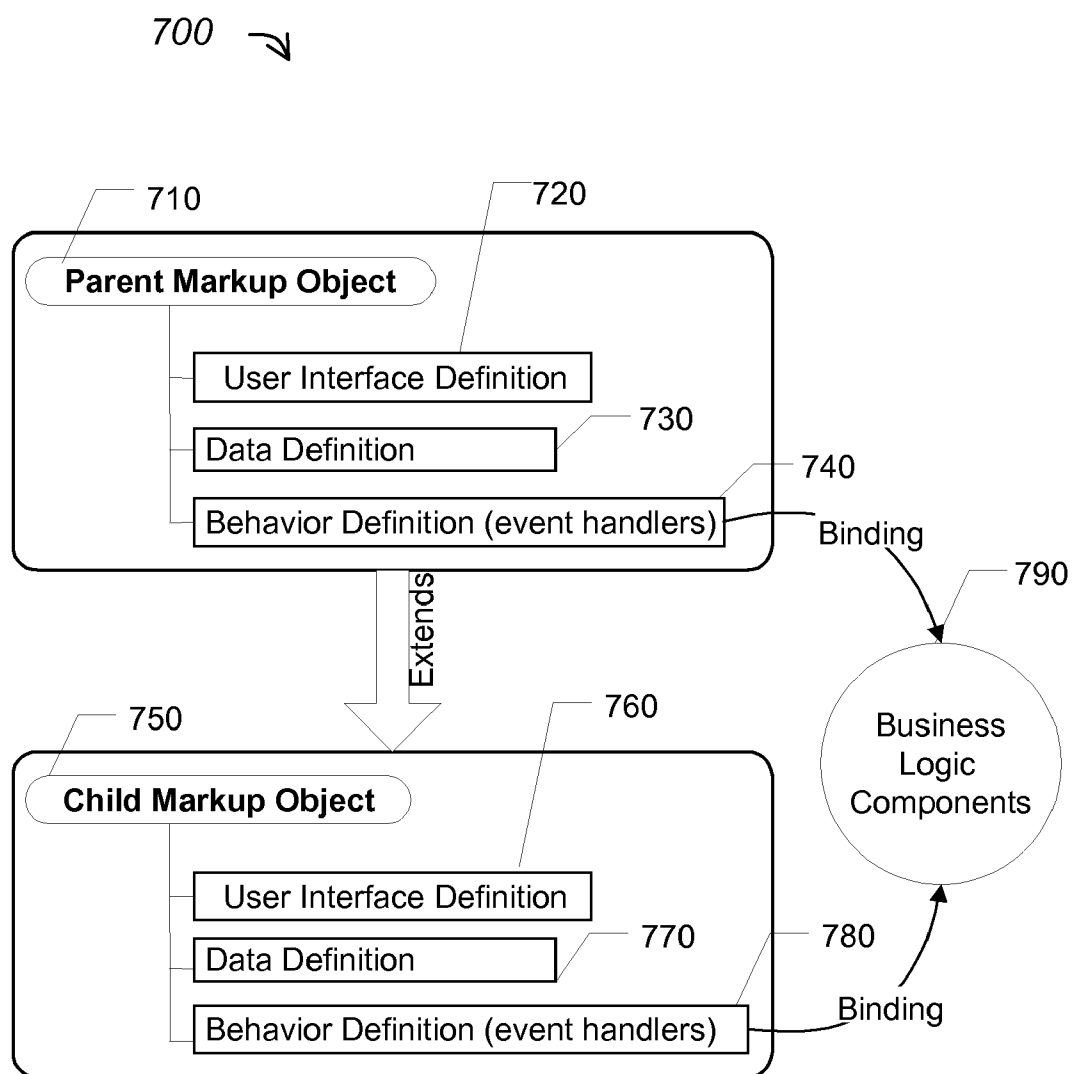
**FIG. 7B**



*FIG. 7C*



*FIG. 7D*



**FIG. 8**

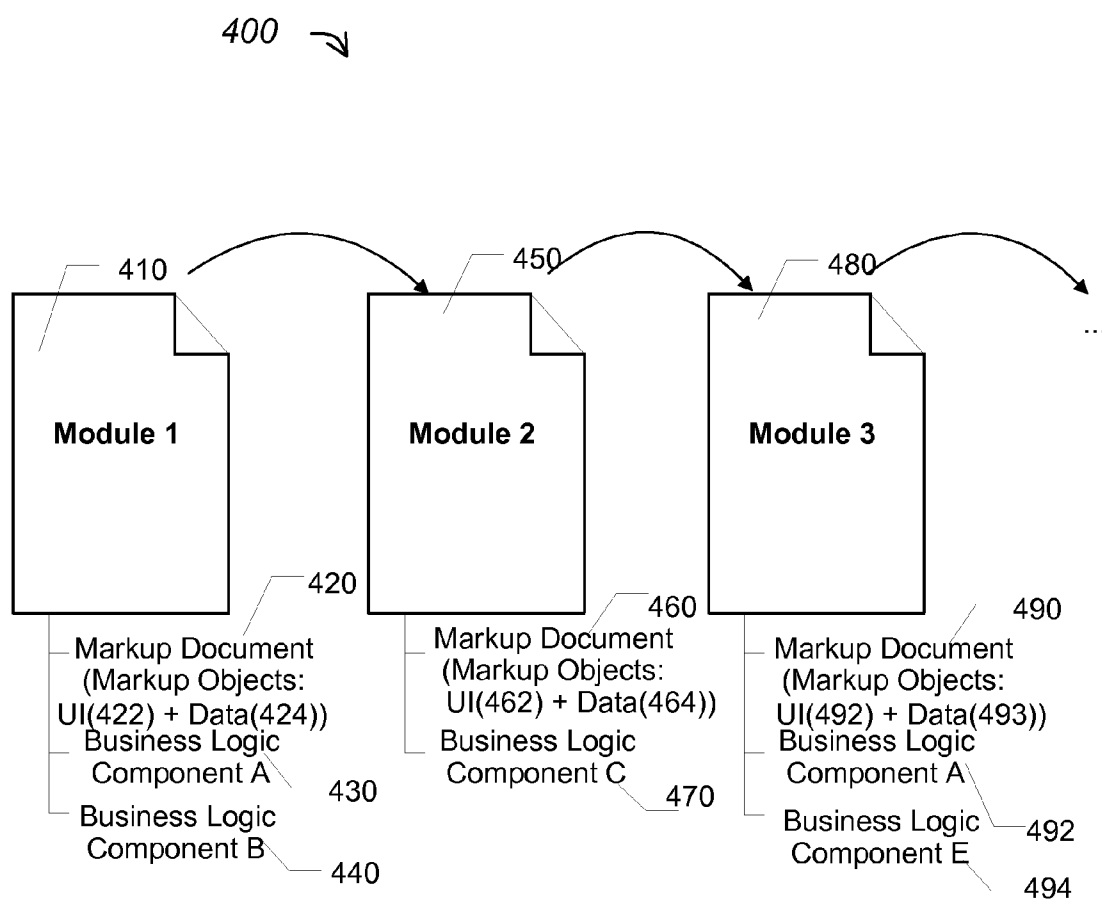
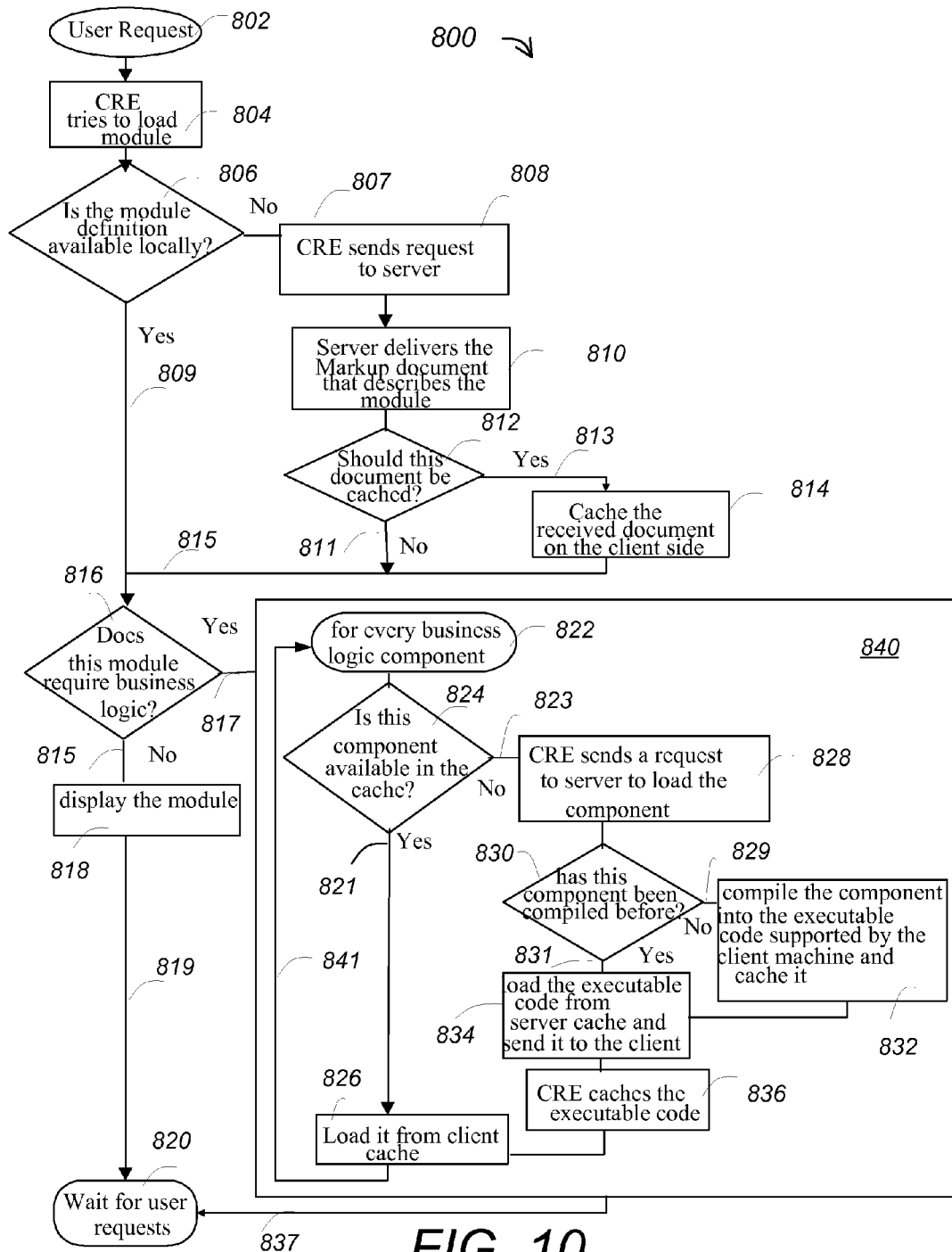


FIG. 9



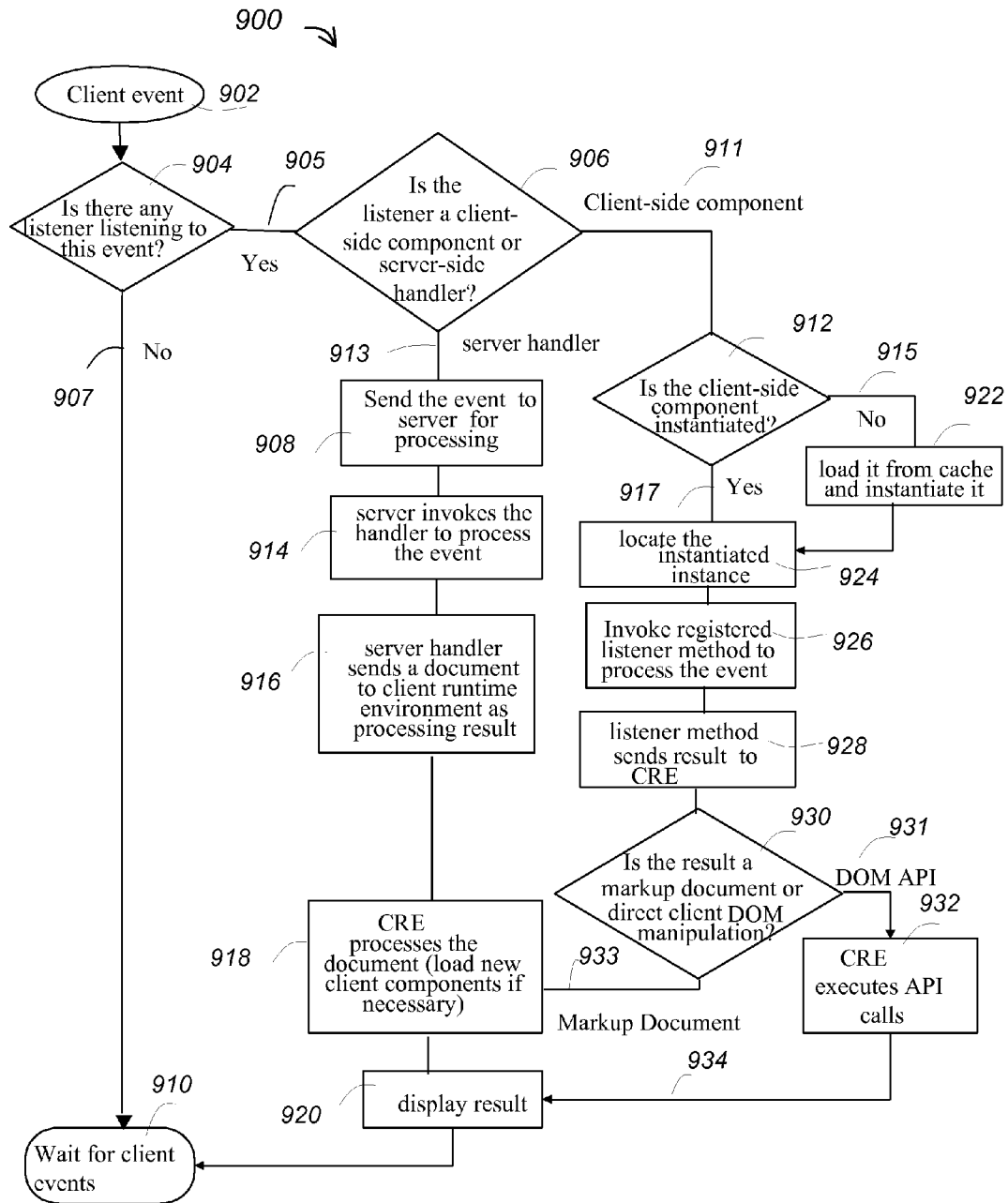


FIG. 11



## SYSTEM AND METHOD FOR NETWORK-BASED COMPUTING

### CROSS REFERENCE TO RELATED CO-PENDING APPLICATIONS

**[0001]** This application is a continuation of U.S. application Ser. No. 10/754,782 filed on Jan. 9, 2004 and entitled "System and Method for Network-Based Computing" which is commonly assigned and the contents of which are expressly incorporated herein by reference.

### FIELD OF THE INVENTION

**[0002]** The present invention relates to a system and a method for network-based computing, and more particularly, to network-based computing that provides network applications that can be automatically deployed, compiled, and executed by any type of a client machine connected to a server via any type of a network connection.

### BACKGROUND OF THE INVENTION

**[0003]** A typical computing system includes hardware and software components. Hardware components include computing devices such as personal computers (PC), mainframe computers, and computing circuits, among others. The basic architecture of a computing device includes a central processing unit (CPU), which executes instructions, and a memory unit, which stores instructions and data. Instructions and data are transmitted from the memory unit to the CPU and the results of the CPU operations are sent back to the memory unit. Software components are application programs, which contain the set of instructions that are executed by the CPU unit. Application programs include among others, system programming software, drawing software, word processing software, spreadsheet evaluation software, enterprise resource management software, customer relationship management software, data analysis software, customer self-help software, network and storage management software, mathematical and scientific software. A computer programmer develops an application program by first coding a set of instructions in a source file using the grammar rules of a programming language. In the example of FIG. 1, a programmer writes a source file using the grammar and syntax of the Java™ programming language **82**. Next, the Java™ source file passes through a Java™ compiler **84** where it gets analyzed and parsed. The parsed file is then used to generate a Java™ bytecode **86**, i.e., a code that is understood by a Java™ Virtual Machine (JVM™). The compiled Java™ bytecode file **86** is then stored in the memory of the computing device. When a user wants to run the particular application program the computing device retrieves the compiled Java™ bytecode file **86** from the memory, the Java™ Virtual Machine **88** executes it, and the computing results are displayed **89**. The compiled Java™ bytecode file **86** may also be stored in a computer readable storage medium such as a compact disk (CD) or a magnetic floppy disk or tape. These computer readable storage media may also be used to distribute and install the application program, i.e., the compiled Java™ bytecode files, in other computing devices. This computing system is sufficient for independent computing devices.

**[0004]** A network-based computing system includes a central server and a plurality of computing devices, i.e., client machines, that are connected with each and to the server via a network. Application programs are stored in the central server

and can be deployed to the client machines via the network. Alternatively, application programs can be installed in the client machines via a manual distribution of computer readable media such as CD or floppy disks containing the compiled application code. Network-based computing is used for large enterprises that have multiple computing devices in multiple locations that interact with each other and with the server via a network connection. An application program in the network-based computing system includes a server program that is stored in the server and a client program that is stored in the memory of a client machine. The server program runs on the server and the client program runs on one of the client machines. Large enterprises utilize network-based computing to run enterprise application such as SAP's Enterprise Resource Planning software and custom internal applications. For example, a financial services company may utilize an internal Investment Portfolio Management application to perform stock analysis. When a portfolio manager wants to do a specific stock analysis, he starts the client program for the Investment Portfolio Management application in the client machine. The client machine loads the multi-megabyte client program, and then receives and processes the portfolio manager's requests. The client machine may also send further requests to the server program via the network to gather any necessary data. Next, the client program receives the necessary data, analyzes the data and presents the result in an appropriate format to the portfolio manager.

**[0005]** Processes associated with network-based computing include application development, application deployment, and application execution, among others. Application development refers to the coding, compiling, and debugging of the server and client programs that can be run by the server and the various configurations and operating systems of the client machines, respectively. Application deployment refers to the distribution and installation of the various client programs in the various client machines. Application execution refers to the execution of the compiled server and client programs by the server and the various client machines of the network, respectively.

**[0006]** The main issues with the application development for a network-based computing system involve around client platform and device configuration incompatibilities. Client platform incompatibilities include different operating systems and different hardware. The operating systems may be various versions of Windows, Mainframe, Macintosh, Unix, Linux, and Palm™. The different hardware may be Pocket PCs, desktops, laptops, workstation, phone systems, personal digital assistants (PDA) and smart television sets. Device configuration includes the specific settings that a given application may require, such as the Dynamic Link Library (DLL) version and registry for typical Windows applications. For companies with thousands of users and client machines, client platform and device configuration incompatibilities result in a significant amount of complexity and increased costs for the development of network applications.

**[0007]** The main issues with the application deployment in a network-based system involve around the distribution of the client program to thousands or even hundreds of thousands of client machines and the confirmation that each client machine always contains the most appropriate version of the application. The following approaches are the most commonly used today for handling code distribution and configuration:

**[0008]** a) CD/Floppy disk distribution and manual installation and configuration: Information System (IS) personnel

install the compiled client program from a CD or floppy disks directly onto the client computer and manually configure the application for each client computer. This manual process is repeated every time the code is upgraded. Considering that an enterprise can have thousands of desktop computers distributed in many different offices, this approach is very inefficient, time consuming and costly.

**[0009]** b) Manual network download, installation and configuration: This approach enables an end user to download and install the client program into his computer over a Local Area Network (LAN), a Wide Area Network (WAN) or the Internet. However, considering that the client program can be easily tens of mega bytes, downloading such a big file and configuring the application can take each user up to several hours to achieve. Considering an enterprise that has thousands of users, the amount of productivity loss due to this manual downloading process can be significant. Furthermore, in cases where the network connection is slow and has limited bandwidth (i.e., dialup or wireless connection), this is simply not a viable option.

**[0010]** The issue with the client program execution is that the current program execution model requires loading almost the entire program into memory before the user is able to run the application. As was mentioned above, client programs are typically multi-megabyte files and loading such big files into memory creates lengthy delays for users. Further, this execution model creates increasing demands on hardware because it requires faster CPU, bigger memory, more storage, and a faster network, all of which translate into costs and performance issues.

**[0011]** Alternative approaches to this static network-based computing system include the Java™ Applet approach and the Hyper Text Markup Language (HTML) web page approach. In the Java™ Applet approach the client component of a network application is written as a Java™ Applet, and the end users can access this application without the need to install it in advance. However, Java™ Applets have severe technical limitations that restrict its practical use to simple application only. For complex enterprise applications, the Java™ Applet not only performs poorly but also can easily have a footprint in excess of 1 MB, which requires lengthy downloading which in turn effectively prevents users from using it over the Internet or WAN. In addition, Java™ Applets require a Java™ Virtual Machine (JVM™) on the client machine. The JVM™ incompatibilities and lack of JVM™ on some machines both add to the failure of wide adoption of Java™ Applets for enterprise applications.

**[0012]** In the HTML web page approach companies use HTML for publishing simple application screens. In this approach, the entire application is running on the server. Each screen is formatted into an HTML web page and displayed in a web browser. Some simple client-side logic can be added to the HTML page using technologies, such as JavaScript™. However, this approach is limited to applications that require minimal user interactivity and functionality. Network applications using this approach sacrifice many of the features and functionality associated with client-side computing, such as offline computing, drag&drop, multiple windows, spreadsheet behavior, among others. The “click and refresh” user interaction model associated with web browsing is not suitable for network applications because this model not only consumes significant bandwidth by sending and re-sending redundant information, but it also significantly lowers user productivity by keeping users waiting with every mouse

click. In this scenario, the client-side business logic is also limited because a scripting language, such as JavaScript™, does not scale well to a large team of developers, unlike the more robust Object-oriented programming (OOP) languages like Java™ and C++. As a result, HTML is used only for simple applications. Important applications are still being written as traditional Client/Server applications using OOP languages.

**[0013]** In summary, the current approaches for network-based computing are costly, inefficient and complicated for developers. In order to use an application, users have to go through a lengthy downloading, configuration and loading process. Whenever a new version of the application is available, users have to go through the same process again. Platform incompatibilities often prevent many users from being able to run the application at all. Companies often have to maintain a significant technical support team to manage and deal with application configuration and management. Desktops need to be constantly upgraded to keep up demands from bigger and bigger client programs. For users that are distributed over a wide area network (WAN) or even the general public Internet, where bandwidth is very limited, the current approaches are simply not viable options. Though there are alternative approaches, like HTML, which can significantly lower the client footprint and reduce the client incompatibility problem, such approaches are not able to deliver the functionality and performance required for most business applications.

**[0014]** Accordingly, there is a need for a network-based computing system that automates, simplifies, and optimizes the compilation, deployment, and execution of an application by any type of a client machine connected to a server via any type of a network connection.

## SUMMARY OF THE INVENTION

**[0015]** In general, in one aspect, the invention features a computer application program including at least one markup document, at least one business logic component associated with and applied directly to the at least one markup document and an object oriented binding mechanism binding the at least one markup document to the at least business logic component and the reverse.

**[0016]** Implementations of this aspect of the invention may include one or more of the following features. A client runtime environment (CRE) may receive and convert the at least one markup document into an object-oriented representation. The object-oriented representation may include one or more markup objects, one or more user interfaces, and one or more data sets. The at least one business logic component may include one or more methods used as event handlers for a markup object event. The object oriented binding mechanism may include invoking the one or more methods by the one or more markup objects by firing a markup object event. The object oriented binding mechanism may further include accessing and modifying the one or more markup objects by the at least one business logic component via an Application Program Interface (API). The API may be a markup object API or a Document Object Model (DOM) API. The one or more markup objects may include a parent markup object and a child markup object and the child markup object may have one or more markup object properties inherited from the parent markup object. The one or more markup object properties may be a user interface definition, a data set definition or an event handler definition. The parent markup object may

have one or more user interface definitions, one or more data definitions and one or more event handlers and the child markup object may inherit the one or more user interface definitions, the one or more data definitions and the one or more event handlers from the parent markup object. The one or more markup objects may include a parent markup object and a child markup object and the child markup object may overwrite one or more markup object properties of the parent markup object and replace them with one or more markup object properties of the child markup object. The at least one markup document may be written in a markup language including among others, XML, XUL, SVG, Xforms, XAML, HTML, HTML related languages, text, or combinations thereof. The one or more business logic components may be written in a programming language including among others, Java™, JavaScript™, J#, C#, C+, C++, Visual Basic, ActionScript, XSL, XQuery, or XPath.

**[0017]** In general, in another aspect, the invention features a network application program having one or more modules wherein each module includes at least one markup document, at least one business logic associate with the at least one markup document and an object oriented binding mechanism binding the at least one markup document to the at least business logic component and the reverse.

**[0018]** In general, in another aspect, the invention features a method of binding a markup document with one or more business logic objects including coding the markup document using a markup language, coding the one or more business logic objects using an object oriented programming language and associating the markup document with the one or more business logic objects. Next, constructing an object oriented representation of the markup document thereby generating one or more markup objects. Next, firing one or more markup object events by the object oriented representation thereby invoking the one or more business logic objects for processing the events and finally manipulating the markup objects by the one or more business logic objects. The business logic objects may manipulate the markup objects via a markup object API or a Document Object Model (DOM) API.

**[0019]** Among the advantages of this invention may be one or more of the following. The computing system enables partitioned delivery and execution of a network application from a central server to any client machine connected to the server via a network connection. The network connection may be a low bandwidth network. The client machines may include any type of computing platforms and devices. The network application includes markup documents, business logic components and an object-oriented binding mechanism binding the markup documents to the business logic components and the reverse. The markup documents may be scripted using any type of a markup language including among others, XML, XUL, SVG, Xforms, XML related languages, HTML, HTML related languages, text, and combinations thereof. The business logic components may include source code scripted in any programming language including among others, Java™, JavaScript™, J#, C#, C+, C++, Visual Basic, ActionScript, XSL, XQuery, and XPath. A compiler system converts the source code to any type of executable bytecode. This compiler system configuration provides flexibility in both the programming side of the application and the execution side of the application.

**[0020]** The details of one or more embodiments of the invention are set forth in the accompanying drawings and description below. Other features, objects and advantages of

the invention will be apparent from the following description of the preferred embodiments, the drawings and from the claims.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0021]** FIG. 1 is a block diagram of a prior art process for writing, compiling and executing of an application;

**[0022]** FIG. 2 is an example of a network-based computing system;

**[0023]** FIG. 3 is a block diagram of the software and hardware components of a simple network-based computing system;

**[0024]** FIG. 4 is a schematic diagram of the server compiler of the application server of FIG. 3;

**[0025]** FIG. 4A is a detailed block diagram of the universal Java™ bytecode compiler of FIG. 4;

**[0026]** FIG. 4B is a detailed block diagram of the universal XML compiler of FIG. 4;

**[0027]** FIG. 5 is a block diagram of an object-oriented application according to this invention;

**[0028]** FIG. 6 is a schematic diagram of the markup-business logic binding mechanism of this invention;

**[0029]** FIG. 7A-FIG. 7B are code examples of the markup-business logic binding mechanism;

**[0030]** FIG. 7C is a screen shot of the example of FIG. 7A;

**[0031]** FIG. 7D is another screen shot of the example of FIG. 7A;

**[0032]** FIG. 8 is a schematic diagram of the object-oriented markup object declaration and instantiation;

**[0033]** FIG. 9 is a schematic diagram of the module structure of a network-based application according to this invention;

**[0034]** FIG. 10 is a flow diagram of the process of deploying, compiling and executing a network-based application according to this invention; and

**[0035]** FIG. 11 is a flow diagram of the event handling process of this invention.

#### DETAILED DESCRIPTION OF THE INVENTION

**[0036]** Referring to FIG. 2, a network-based computing system 70 includes a server 72 and client machines 73, 74, 75, and 76. The client machines include a personal computer 73, a laptop computer 74, other computing devices 75, and a wireless communication device 76. Client machines 73, 74 and 75 are connected to the server 72 via a network connection 78. Client machine 76 is connected to the server 72 via a wireless network connection 79. There may be several additional client machines including personal computers, laptop computers, Linux machines, workstations, computing circuits, and wired communications devices, such as telephone and television. Network connection 78 may be the Internet, the World Wide Web (WWW), a Wide Area Network (WAN), a Local Area Network (LAN), a Personal Area Network (PAN) or a telecommunication network. The wireless communication device 76 may be a mobile phone, a personal digital assistant (PDA), a pager, a wireless laptop computer, a personal computer, a television, and programmable versions thereof or combinations thereof. The wireless network 79 may be a wireless wide area network (WWAN), a wireless local area network (WLAN), a wireless personal area network (WPAN) or a private communication network.

**[0037]** Referring to FIG. 3, a block diagram of the software and hardware components of a simple network computing

system **200** includes an application server **210**, a client machine **220**, and a web server **219**. The application server **210** runs behind the web server **219**, and runs server-side application code (or server-side business logic) **212**. The web server **219** delivers markup documents or electronic messages generated by the server side application code **212** to a client web browser **230** residing inside the client machine **220**. Electronic messages are communication messages delivered electronically for information exchange. Markup documents are electronic documents, i.e., files, written using a markup language such as XML or HTML. A markup language is a conventional language for describing the contents of an electronic document that is to be viewed or printed on a computer output device such as a computer monitor. A markup language document can contain text, images, JavaScript™, and hyperlinks, among others. A real time, bidirectional, reliable messaging system **240** transmits messages between the client web browser **230** and the web server **219** over an HTTP web connection. The application server includes in addition to the server side application code **212** a Server Runtime Environment (SRE) **214**. The SRE **214** runs behind the HTTP web server **219** and inside the application server **210**. The SRE **214** includes a server compiler **216**, a server cache **218**, a communications module **215**, and other functional modules **217**. The functional modules **217** include an Application Server Interface, an XML Parser, Clustering, Storage, and an Execution Engine. The application server interface module enables the SRE **214** to run inside the application server **210** and enables applications inside the application server **210** to access the SRE's functionalities. The XML Parser module is responsible for parsing XML documents that come from the various client machines or other information sources such as other backend connections. The parsing results may be stored in the Storage module. The clustering module provides support for clustering the SRE and the execution engine module executes the compiled server-side application code **212**.

[0038] The client machine **220** includes a client runtime environment (CRE) **224** that runs outside the client web browser **230** and client-side application code **222** (or client-side business logic). In other embodiments the CRE runs inside the client web browser **230**. The client side application code **222** includes Extensible Markup Language (XML) documents and procedural code. The client machine **220** is protected by a client side firewall **244** and the web server **219** is protected by a server side firewall **242**. The CRE **224** processes markup documents and executes the client-side application code **222**. The CRE **224** includes a client cache **226**, a communication module **225**, a state synchronization and persistency module **228** and other functional modules **227** such as an XML parser, a user interface, storage, security, and an execution engine. The XML Parser is responsible for parsing XML documents that come from the application server **210**. The parsing results may be stored in the client cache **226** as part of the application's client side state. The user interface module is responsible for displaying the user interface and interacting with the user according to the application's XML description. The execution engine module is capable of running client side application code **222**. The client cache **226** maintains the application's client side state and is updated by the CRE automatically. The synchronization and persistency module **228** is responsible for synchro-

nizing the client cache **226** with the application server **210**, and saving and/or retrieving the client cache **226** from persistent storage.

[0039] The CRE **224** is centrally managed by the SRE **214**. The CRE **224** is automatically downloaded from the application server **210** and installed in the client machine **220** the first time a user access a client application. After the initial installation, the SRE **214** automatically manages the versioning and updating of the CRE **224**. Different CREs **224** are used for the different client platforms. For example, different CREs are used for a Java™ Virtual Machine, a .NET CLR, or a Flash Player. The executable application code formats of these three client platforms are: Java™ bytecode, .NET CLR bytecode and Flash bytecode, respectively. The application code **222** is delivered in three different executable code formats for these three client platforms, accordingly.

[0040] Referring to FIG. 4, the server compiler **216** is a software program that translates source code written in any supported programming language into executable code of any supported executable format. As shown in FIG. 4, the source code is written in a programming language, such as Java™, C#, JavaScript™, and XML, among others. The supported executable formats are Java™ bytecode, .NET CLR bytecode, or Flash bytecode, among others, depending on the client platform. For example, when the client platform is running a Java™ Virtual Machine **360**, all input source files, no matter which language they are being written in, are compiled into Java™ bytecode executable files by the server compiler **216**. Similarly, if the client platform is running a .NET CLR, all source code files are compiled into .NET CLR bytecode.

[0041] The server compiler **216** includes a plurality of specific universal compilers including among others, a universal Java™ Bytecode compiler **312**, a universal .NET CLR (Common Language Runtime) compiler **314**, a universal JavaScript™ compiler **316**, a universal Flash SWF compiler **318**, and a universal XML compiler **320**. The server compiler **216** also includes a server compiler control logic **310** that detects the type of the client platform, invokes compiling and caching of a client platform appropriate executable code and delivers the appropriate executable code to the corresponding client platform. When the server compiler **216** receives a request from a certain client machine, the control logic **310** first characterizes the client machine to see which executable format is supported by this client machine. If a compiled executable code of the supported format is available in the server cache **218** and the source file has not changed since last compilation, the server compiler control logic **310** sends the cached executable code to the client machine directly. If the source file has been changed since the last compilation, the control logic **310** prompts the server compiler **216** to retrieve the source file, compile the source file into the appropriate executable code, cache the executable code in the server cache **218** and send the executable code to the client machine.

[0042] Each universal compiler receives an input file written in any programming language, such as Java™, C#, JavaScript™, C++, Visual Basic, and delivers an output file in one executable format specific to a certain client platform. The input files **302**, **304**, **306** and the output files **332**, **334**, **336**, **340** may also include markup documents written in XML.

[0043] Referring to the example of FIG. 4A, the universal Java™ bytecode compiler **312** receives source code files written in programming languages such as Java™ **302**, C# **304**,

JavaScript™ **306**, among others, and delivers a Java™ Virtual Machine executable Java™ bytecode file **332**. The universal Java™ bytecode compiler **312** includes a plurality of custom developed language compilers, such as JavaScript™ compiler **353**, a plurality of commercially available language specific compilers, such as Java™ compiler **351**, J# compiler **352**, C# compiler, among others, and a control logic **355**. Java™ compiler **351** is commercially available from Sun Microsystems of Santa Clara, Calif., J# compiler **352** is commercially available from Microsoft of Redmond Wash. The JavaScript™ compiler **353** is custom developed by Nexaweb and compiles JavaScript™ files into Java™ bytecode. Similarly, the universal .NET CLR compiler **314**, the universal JavaScript™ compiler **316**, and the universal Flash SWF compiler **318**, receive input files written in any programming language and deliver bytecode files executable by a .NET CLR engine, a JavaScript™ engine, and a Flash player, respectively. The control logic **355** module includes rules for handling the various programming language codes and processes the input files. When an input file is received, control logic module **355** checks which language the source code file is being written in and selects the appropriate language specific compiler to compile the source code file into executable code in the desired executable format. For example, control logic **355** of the Universal Java™ bytecode compiler **312** would select the JavaScript™ compiler **353** to compile JavaScript™ source files and Java™ compiler **351** to compile Java™ source files.

[0044] Referring to FIG. 4B, the universal XML compiler **320** receives files written using various markup languages such as, XHTML™ (**362**), x-Forms (**364**), HTML (**365**), XAML (**370**), SVG (**368**), and delivers XML code (**340**) executable by an XML execution engine (**366**). The universal XML compiler **320** includes a plurality of markup language specific compilers, such as XHTML™ compiler **371**, XAML compiler **372**, SVG compiler **373**, among others, and a control logic **355**. The control logic **355** is responsible for selecting and invoking a markup language specific compiler to compile a source file written in the specific markup language. The language specific compiler takes the markup document and converts it into a new markup document in the executable format required by the execution engine. For example, if the execution engine is a SVG rendering engine that knows how to render SVG and the source code file is written using XAML, the XAML compiler takes the XAML input and converts it into SVG format. This compilation process can be achieved using an XML Stylesheet Transformation (XSLT), or some other lexical analysis and transformation.

[0045] The compiled bytecode files **332**, **334**, **336**, **340** may be stored in the server cache **218**, shown in FIG. 4. When the CRE **224** of a client machine **220** requests a specific file, the SRE **214** determines the particular executable format of the CRE **224** and checks if this particular format has already been compiled and is stored in the server cache **218**. If the particular compiled bytecode exist in the server cache **218** and the code has not been modified since the last time it was compiled the SRE **214** downloads the executable file to the CRE **220** and stores it in the client cache **226**. Otherwise, the SRE **214** will invoke the server compiler **216**, and first compile the requested code in the particular executable format and then download it to the CRE **224** and store it in the client cache **226**.

[0046] This invention utilizes object-oriented programming methodology to develop object-oriented application

programs. Object-oriented application programs typically model a problem using an “object model” that defines classes of objects representing elements of the problem. A class of objects is defined in terms of the relationship of the class to other classes, the data and properties (or attributes) associated with objects in the class, and the operations (or tasks) that can be performed on objects in the class. During execution of an object-oriented application program, instances of the classes in the object model, referred to as “objects,” are produced and manipulated. Computation on these “objects” is performed by calling on “methods” defined in business logic components associated with these “objects”. For example, in an accounting management program, the various accounts are defined as the program objects. Each object, i.e., account, has attributes including account name, account number, amount deposited in the account, among others. Tasks associated with these account objects may be “get account number”, “set account name”, “set account amount”, among others. Objects interact with each other and with the business logic code via events or messages. An object may fire an event (or send a message) in order to modify its own properties, or state. Events are received and processed by the subprograms or business logic components associated with these objects. Object-oriented programming languages are well known in the art and are described in “Programming languages” Chapter 11, p 435-483, edited by Robert W. Sebesta.

[0047] Referring to FIG. 5, the object-oriented application code **400** includes one or more markup documents **402** and one or more business logic components **406**. The markup documents **402** are files written using an XML markup language. The business logic components **406** include instructions for performing tasks upon the program objects. These instructions are formulated as source code files written in a programming language, such as Java™, JavaScript™, C#, Visual Basic (VB), J#, among others. The business logic components **406** are also program objects. The Client Runtime Environment (CRE) **224** receives the markup documents **402** and converts them into object-oriented representations, i.e., markup objects **404**. The markup objects **404** may be user interfaces (UI) **401** or data **403**. Each markup object **404** may have events associated with it. For example, in the case of a UI markup object that has input fields or buttons, an event may include highlighting the button or input field, entering text in the field, or clicking the button, among others. The event is received and processed by the business logic component, so that the state of the object is modified. In the example of the user interface with the input fields, where text is entered in the input fields, the business logic component modifies the UI to display the entered text. The object oriented representations of the markup documents **405** and business logic components **406** are bound via a markup-business logic binding mechanism **500**.

[0048] Referring to FIG. 6, the markup-business logic binding **500** includes the process of binding the markup objects to the business logic components (**520**) and the process of binding the business logic components to the markup objects (**530**). In the markup object to business logic component binding **520**, markup objects **510** defined in markup document **550** invoke business logic components **540** by firing markup object events **521**. The business logic components **540**, include definitions of methods that are used as the event handlers for the markup object events. Upon firing of an event, the CRE invokes the associated method in the corresponding business logic component, passes necessary infor-

mation about the event to the method and executes the method. In the previous example of the user interface markup object that has several input fields, firing an event may be entering a user's phone number in the appropriate input field. The business logic component receives this markup object event, validates it and formats the phone number for display.

**[0049]** In the business component to markup objects binding **530**, business logic components **540** can access and modify the markup objects **510** via a markup object Application Program Interface (API), or a Document Object Model (DOM) API, **531**. In one embodiment, the CRE **224** parses and stores the markup document **550** into a DOM, and exposes this DOM as a set of API that can be invoked by business logic components **540**. Business logic components **540** invoke this DOM API to programmatically manipulate the markup document **550** stored in the DOM. This feedback mechanism via the markup object API **531** may be "a form validation" process or an internal calculation that will result in modifying the markup objects **510**. In an example of a "form validation" process the user enters in the UI a phone number that has three digits. The business logic component recognizes that a three digit phone number is not valid, rejects the input, displays an error in the UI and requests a valid phone number.

**[0050]** This two-way binding mechanism **500** enables the clear separation of business logic, presentation and data. The HTML and JavaScript™ interaction models in web browsers share a similar architecture. However, the present invention differs from these prior art models because it allows for object-oriented binding. The markup documents are converted into object oriented representations (markup objects) and the business logic components become program objects as well. The object-oriented binding is then a binding between these objects, i.e., the markup objects and the program objects. In the prior art example, the business logic is written as scripts, which are not object oriented, and the binding is a binding between program methods to HTML objects. This object-oriented binding of this invention allows for the development of complex applications and provides programming language and execution format independence. In other words, the business logic code may be written in any programming language including Java™, JavaScript™, C#, J#, VB, and C+, and the markup documents may be written in any markup language including XML, text, and HTML, among others. If the programming language is not object oriented, the source code can be compiled by the universal compiler into an object oriented executable code. Several XML specifications may be used including XUL (XML User Interface Language), SVG (Scalable Vector Graphics) and XForms. The combination of these XML languages creates a rich environment that supports all functionalities of all network applications including typical Windows graphical user interface, forms, 2D graphics and animation.

**[0051]** A code example **600** of the markup-business logic binding mechanism **500** is shown in FIG. 7A and FIG. 7B. A markup document **610** is written using XML. The markup document **610** defines a client-side logic object "bean1" **621**, a parent button "parentBtn" **632**, a child button "childBtn" **635**, and a data object "companyInfo" **641**. The client-side logic object "bean1" **621** defines a client-side programming object whose source code is "com.nexaweb.clientbean.DemoBean", effectively associating the business logic component **650** with this markup document **610**. The source code for business logic component **650** is written using the Java™

programming language and defines a Java™ class with three different methods, including "init" **660**, "doClick" **670**, and "doOver" **680**. The markup document to business logic binding **520** is achieved by using the three methods **660**, **670**, **680** of the business logic component **650** as the event handlers for events fired by the three markup objects **621**, **632**, and **635**, respectively. Method **660** processes the "onload" event for markup object **621**, method **670** processes the "oncommand" event for the parent button **633**, and method **680** processes the "onmouseover" event for the child button **635**. Whenever such an event happens, the CRE invokes the corresponding method in the business logic component to process it. An example of the business logic to markup binding **530** is shown in the implementation of the three methods **660**, **670**, **680** in the business logic component **650**. For example, using the DOM API exposed by the CRE, the "doClick" method **670** inspects the event information, retrieves the event source, which should be the markup object that the user clicked, and sets the "text" attribute of this markup object to be the processed result. For example by clicking on the parent button object **632** the text "You clicked button: parentBtn" appears on the UI screen **633**, as shown in FIG. 7C. Similarly, by clicking on the child button object **635** the text "You clicked button: childBtn" appears on the UI screen **636**, as shown in FIG. 7D.

**[0052]** FIG. 8 shows how this invention allows object-oriented markup object inheritance. This process greatly simplifies the creation and management of markup documents and increases the flexibility of markup documents. The parent markup object **710** includes a user interface definition **720**, an object specific data definition **730** and object behavior (or event handler) definition **740**. The child markup object **750** includes a user interface definition **760**, an object specific data definition **770** and object behavior (or event handler) definition **780**. The child markup object **750** inherits all these UI, data and behavior definitions **760**, **770** and **780**, respectively, from the parent markup object **710**. The child markup object **750** can also optionally overwrite the corresponding parent definitions and add new definitions. This object-oriented approach allows for inheriting and changing not only object attributes, but also allows for entire different object behavior by replacing the parent object's event handler definition with child specific event handlers. Referring back to the code example of FIG. 7A, the "childBtn" **635** inherits all definitions (UI, data and behavior) from the "parentBtn" **632**. However, markup object specific data are changed, i.e., the "id" is changed from "parentBtn" to "childBtn". Similarly the user interface definition is changed, i.e., the value of "text" attribute is changed so that the text "You clicked button: childBtn" is displayed instead of "You clicked button: parentBtn". The "childBtn" inherits the object behavior from "parentBtn" so that the "oncommand" event will invoke the "bean1.doClick ()" method **670** for the child markup object, as well. The child markup object **750** also modifies the behavior definition of the parent markup object **710** by binding the "bean1.doOver ()" method **680** to the "onmouseover" event so that the "onmouseover" event will invoke the "bean1.doOver ()" method **680** for the parent markup object, as well.

**[0053]** Application programs are typically multi-megabyte files. Loading such big files into memory creates lengthy delays for users and places great demands on the hardware components because it requires faster CPU, bigger memory, more storage, and a faster network, all of which translate into costs and performance issues. The present invention solves

these problems by separating the application code into small independent modules each of which can be downloaded and executed independently. Referring to FIG. 9, application code 400 includes N number of modules, Module 1 (410), Module 2 (450), Module 3 (480), . . . Module N (not shown). Each module includes one or more markup documents and optionally one or more business logic components. In the example of FIG. 9, Module 1 (410) includes a markup document 420 and business logic components A (430) and B (440). Markup document 420 defines two markup objects, i.e., a User Interface (UI) 422 and a Data file 424. Module 2 (450) includes a business logic component C (470) and a markup document 460 defining a User Interface 462 and a Data file 464. Module 3 (480) includes business logic component A (430), business logic component E (494) and a markup document 490 defining a User Interface 492 and a Data file 493. Different modules may share business logic components. For example, Module 3 (480) uses the same business logic component A (430) as Module 1 (410). In this case the system 200 of FIG. 3 uses client-side caching 226, as well as server-side caching 216 to avoid loading the same module or component more than once. Accordingly, although the entire application code 400 is composed of many XML documents and many business logic components, each module may require only one XML document and a few compiled business logic components, therefore resulting in a small footprint for each module. This small footprint of each module enables fast application code downloading. Furthermore, once a module is downloaded in the client machine it is stored in the client caching and it can be reused in the future without requiring a new download. The server also provides for automated updating of the modules that were previously downloaded in the client machine and were stored in the client cache.

[0054] Referring to FIG. 10, the process 800 of running and application through a client machine includes the following steps. When a user wants to use a network application he starts the CRE and enters a request to start the client program (802). The CRE receives the request (804) and checks to see if the initial module is available in the local client cache (806). If the module is not available in the local cache (807), the CRE sends a request to the server (SRE) to download the specific module (808). The server delivers the markup document that describes the specific module to the CRE (810) and the CRE inquires if this markup document needs to be cached (812) by checking the document properties or configuration information. If this markup document needs to be cached (813), the CRE caches it in the local client cache (814) and then proceeds to the next question (815). Similarly, if the markup document does not need to be cached in the local client cache (811), the CRE proceeds to the next question (815). If the module is available in the local cache (809), the CRE skips the downloading process and proceeds to the next question (815), as well. Next, the CRE checks the module properties or configuration information to see if this module requires a business logic component (816). If no business logic component is required (815) the CRE displays the module to the user (818) and then waits for a user input (820). If the module requires a business logic component (817), process (840) takes place. In process (840), the CRE proceeds to check if the business logic component is available in the local cache (824). If the business logic component is available in the local cache (821), it gets loaded from the local cache (826) in the active memory. If the business logic component is not locally available (823), the CRE sends a request to the server to

download the business logic component (828). The server checks if this business logic component has been compiled before for this particular client machine executable format (830), and if it has (831) it downloads the executable code from the server cache to the client cache (834). Next, the CRE stores the executable code in the client machine cache (836) and loads it in the active memory (826). If the business logic component has not been previously compiled for the specific client machine executable format (829), the server first compiles it into an executable code executable by the specific client machine execution engine and stores it in the server cache (832). Next, the server downloads the executable code from the server cache to the client cache (834), where the CRE caches it in the client cache (836) and then loads it in the active memory (826). Finally, both the markup document and the business logic component (837) are present in the active memory and wait for an input from the user (820). If there are more than one business logic components associated with a specific module the process (840) is repeated for each individual business logic component (841). The process 800 is repeated for downloading the next module and the business logic components that are associated with it. Once the CRE receives the markup language document, it immediately processes the document, executes the associated business logic and displays the result to the user. This module-type downloading and execution of a network application has the advantages of being fast and requiring low bandwidth. The storing of the previously downloaded modules and associated business logic in the client-side cache and the server cache and the synchronization of the client-side cache with the server cache allows the client machine to execute the network application offline, even in the case when the network connection is not available.

[0055] Once the appropriate modules are brought in the active memory of the client machine the user interacts directly with the application through client events. Client events include among others, entering text in a screen field, moving the mouse over text or a screen button, clicking the mouse, highlighting a button in the screen, drag & drop, a window is hidden, and new data is available. FIG. 11 depicts how the system handles the client events (900). When a client event happens (902), the CRE checks if there is a listener listening to this event (904). If there is no listener listening to this event (907) the CRE waits for a new client event (910). If there is a listener listening to this event (905), the CRE determines if the listener is a business logic component in the client side or a server-side event handler (906). If the listener is a client-side business logic component (911), the CRE checks if this client-side business logic component is instantiated, i.e., the business logic component has been created and initialized in the memory (912). If the client-side business component is not instantiated (915) the CRE loads it from the cache and instantiates it (922). If the client-side business component is instantiated the CRE locates the instantiated instance (924), and invokes the registered listener method for handling this event (926). The CRE processes the event according to the client-side business component listener method and produces a result (928). Next the CRE checks if the result is a markup document or a direct client DOM manipulation through an API (930). If the result is a markup document 933 the CRE processes the markup document (918) and displays the result (920). If the result is a direct client DOM manipulation through the API (931) the CRE executes the API calls (932) and displays the result (920).



DOM modifications result in changes in the application state which may be changes entered through the user interface or internal data changes. The system then waits for a new client event (910). A client-side listening component may be a client side business logic component, macro statements defined in markup documents, and local URL invocations, among others. A server-side event handler may be a Java™ server page, a web service call, a servlet, and an Active Server Page, among others. In one example, the application state is maintained in an XML Document Object Model (DOM). This DOM is maintained on the client side by the CRE and by the server. When the user interacts with the application, the CRE updates the client side DOM accordingly to reflect the user's inputs. When the application's server-side business logic dictates a change in the state of the application, for example, making a Window invisible, the server automatically updates the server side DOM. Whenever either the client side or the server side DOM is updated, either the CRE or the server send a message to the corresponding party to synchronize its DOM, respectively. When the network is disconnected, the application is still available because business logic code and markup documents have been cached on the client side, and the application state is available on the client side as well. Changes of the application state are maintained in the DOM. When the network connection becomes available, the client runtime and server runtime automatically synchronize the DOM.

[0056] Other embodiments are within the scope of the following claims. For example, instead of downloading one module at a time, the server may package a group of modules together, or all modules together into one deployment module and downloads this deployment module to the client machine. This is particularly useful for the purpose of offline computing where all required offline computing functionality and data can be packaged into one deployment module and downloaded to the client machine at once. After such downloading, the deployment module can run on the client machine without any connectivity until further modules or data are required.

[0057] Several embodiments of the present invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1. A computer application program stored in a computer comprising:

- at least one markup document;
- at least one business logic component associated with and applied directly to said at least one markup document; and
- an object oriented binding mechanism binding said at least one markup document to said at least business logic component.

2. The computer application program of claim 1 wherein a client runtime environment (CRE) receives and converts said at least one markup document into an object-oriented representation comprising one or more markup objects, one or more user interfaces, and one or more data sets.

3. The computer application program of claim 2 wherein said at least one business logic component comprises one or more methods used as event handlers for a markup object event.

4. The computer application program of claim 3 wherein said object oriented binding mechanism comprises invoking

said one or more methods by said one or more markup objects by firing a markup object event.

5. The computer application program of claim 4 wherein said object oriented binding mechanism further comprises accessing and modifying said one or more markup objects by said at least one business logic component via an Application Program Interface(API) and wherein said API comprises one of a markup object API or a Document Object Model (DOM) API.

6. The computer application program of claim 5 wherein said one or more markup objects comprise a parent markup object and a child markup object and wherein said child markup object comprises one or more markup object properties inherited from said parent markup object and wherein said one or more markup object properties comprise one of a user interface definition, a data set definition or an event handler definition.

7. The computer application program of claim 6 wherein said parent markup object comprises one or more user interface definitions, one or more data definitions and one or more event handlers and wherein said child markup object inherits said one or more user interface definitions, said one or more data definitions and said one or more event handlers from said parent markup object.

8. The computer application program of claim 7 wherein said one or more markup objects comprise a parent markup object and a child markup object and wherein said child markup object overwrites one or more markup object properties of said parent markup object and replaces them with one or more markup object properties of said child markup object.

9. The computer application program of claim 1 wherein said at least one markup document is written in a markup language comprising one of XML, XUL, SVG, Xforms™, XAML, HTML, XHTML™, HTML related markup languages, text, or combinations thereof.

10. The computer application program of claim 1 wherein said at least one business logic component is written in a programming language comprising one of Java™, JavaScript™, J#, C#, C+, C++, Visual Basic™, ActionScript, XSL, XQuery, or XPath™.

11. A method for developing a computer application program comprising:

- providing at least one markup document;
- providing at least one business logic component associated with and applied directly to said at least one markup document;
- providing an object oriented binding mechanism binding said at least one markup document to said at least business logic component; and
- storing said computer application into computer memory.

12. The method of claim 11 further comprising receiving and converting said at least one markup document into an object-oriented representation by a client runtime environment (CRE), wherein said object-oriented representation comprises one or more markup objects, one or more user interfaces, and one or more data sets.

13. The method of claim 12 wherein said at least one business logic component comprises one or more methods used as event handlers for a markup object event.

14. The method of claim 13 wherein said object oriented binding mechanism comprises invoking said one or more methods by said one or more markup objects by firing a markup object event.



15. The method of claim 14 wherein said object oriented binding mechanism further comprises accessing and modifying said one or more markup objects by said at least one business logic component via an Application Program Interface(API), wherein said API comprises one of a markup object API or a Document Object Model (DOM) API.

16. The method of claim 15 wherein said one or more markup objects comprise a parent markup object and a child markup object and wherein said child markup object comprises one or more markup object properties inherited from said parent markup object, and wherein said one or more markup object properties comprise one of a user interface definition, a data set definition or an event handler definition.

17. The method of claim 16 wherein said parent markup object comprises one or more user interface definitions, one or more data definitions and one or more event handlers and wherein said child markup object inherits said one or more user interface definitions, said one or more data definitions and said one or more event handlers from said parent markup object.

18. The method of claim 17 wherein said one or more markup objects comprise a parent markup object and a child markup object and wherein said child markup object overwrites one or more markup object properties of said parent markup object and replaces them with one or more markup object properties of said child markup object.

19. The method of claim 11 wherein said at least one markup document is written in a markup language comprising one of XML, XUL, SVG, Xforms™, XAML, HTML, XHTML™, HTML related languages, text, or combinations thereof.

20. The method of claim 11 wherein said at least one business logic component is written in a programming language comprising one of Java™, JavaScript™, J#, C#, C++, C++, Visual Basic™, ActionScript, XSL, XQuery, or XPath™.

21. A network application program stored in a server memory comprising one or more modules wherein each mod-

ule comprises at least one markup document, at least one business logic associate with and applied directly to said at least one markup document and an object oriented binding mechanism binding said at least one markup document to said at least business logic component.

22. The network application program of claim 21 wherein said network application program is deployed in a network computing system by first separating said network application into said one or more modules and then downloading separately each of said one or more modules to one or more client machines.

23. The network application program of claim 22 wherein each of said client machines comprises a client runtime environment (CRE) and said CRE further comprises a storage for caching said downloaded one or more modules.

24. The network application program of claim 23 wherein said CRE executes said downloaded one or more modules independently of each other.

25. The network application program of claim 24 wherein said CRE executes said downloaded one or more modules offline.

26. The network application program of claim 25 wherein said server further comprises a compiler system receiving a plurality of input files, and converting any of said plurality of input files into a plurality of output files, respectively, wherein said plurality of input files comprise said network application written in a plurality of different programming languages, respectively, and said plurality of output files comprise a plurality of corresponding executable codes of said network application, respectively.

27. The network application program of claim 26 wherein each of said one or more client machines comprise an execution engine receiving one of said output files and executing said corresponding executable code.

28. The network application program of claim 27 wherein said server is connected to said one or more client machines via a low bandwidth network connection.

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