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Fletcher et al.

[54] **FLEXIBLE TELECOMMUNICATIONS SYSTEM ARCHITECTURE**

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[73] Assignee: **DSC/Celcore, Inc.**, Plano, Tex.

[21] Appl. No.: **09/026,320**

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[51] **Int. Cl.**[7] **H04Q 7/20**

[52] **U.S. Cl.** **455/403**

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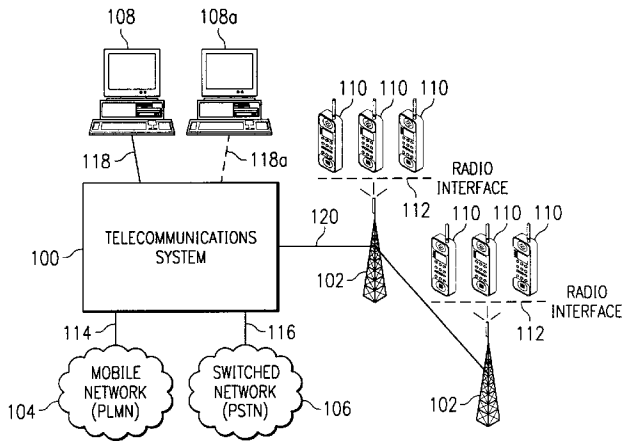
Primary Examiner—Daniel T. Pihulic

Attorney, Agent, or Firm—John G. Flaim

[57] **ABSTRACT**

A flexible architecture for a telecommunications system is disclosed herein. Such architecture provides for different software layers, which include one or more software entities, based on a logical grouping of like or similar functions. For example, a call processing software layer, a resource software layer and a network management software layer may be provided to carry out particular operations. Further, the network management software layer may be divided into a client layer, which presents operations, administration and maintenance related information to a user for adaptation by the user, and a server layer, which stores and accesses operations, administration and maintenance related information. Object request broker technology is utilized to allow a software entity of one software layer to invoke operations associated with another software entity provided by another software layer.

37 Claims, 6 Drawing Sheets



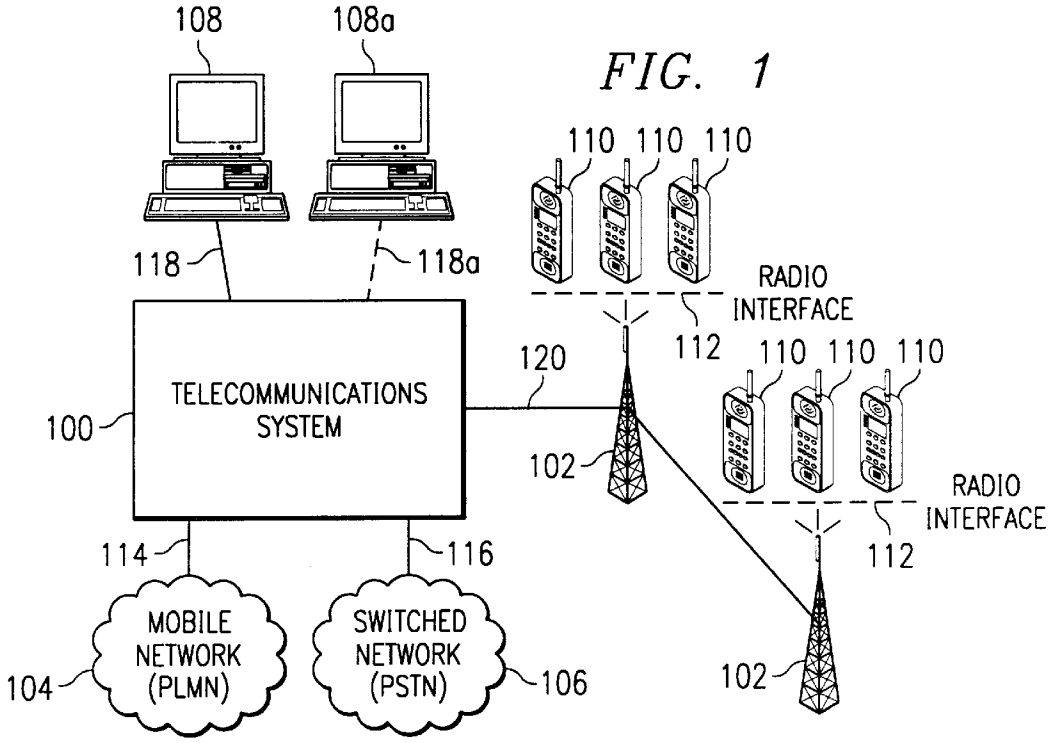

108
108a
118
118a
TELECOMMUNICATIONS SYSTEM
100
110 110 110
RADIO INTERFACE
112
120
102
110 110 110
RADIO INTERFACE
112
102
114
116
MOBILE NETWORK (PLMN)
104
SWITCHED NETWORK (PSTN)
106

FIG. 1

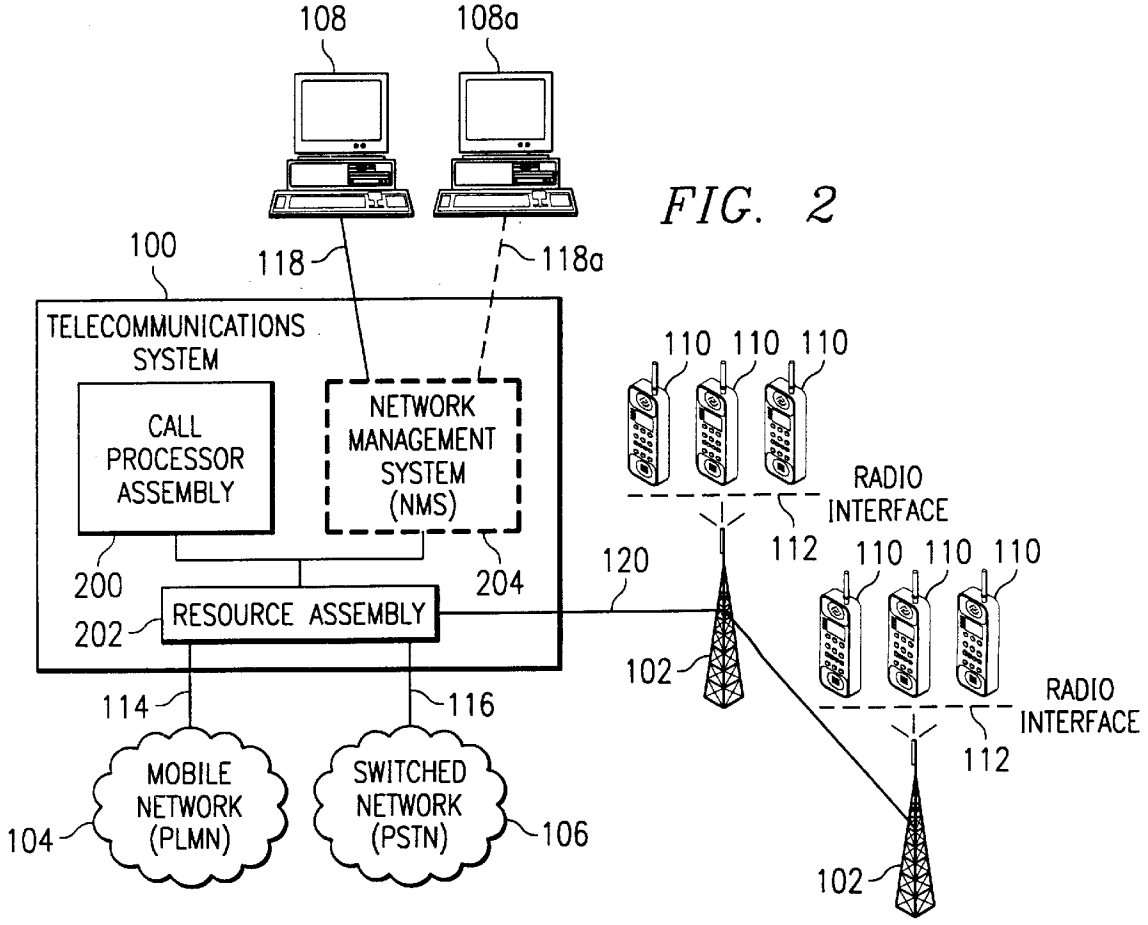
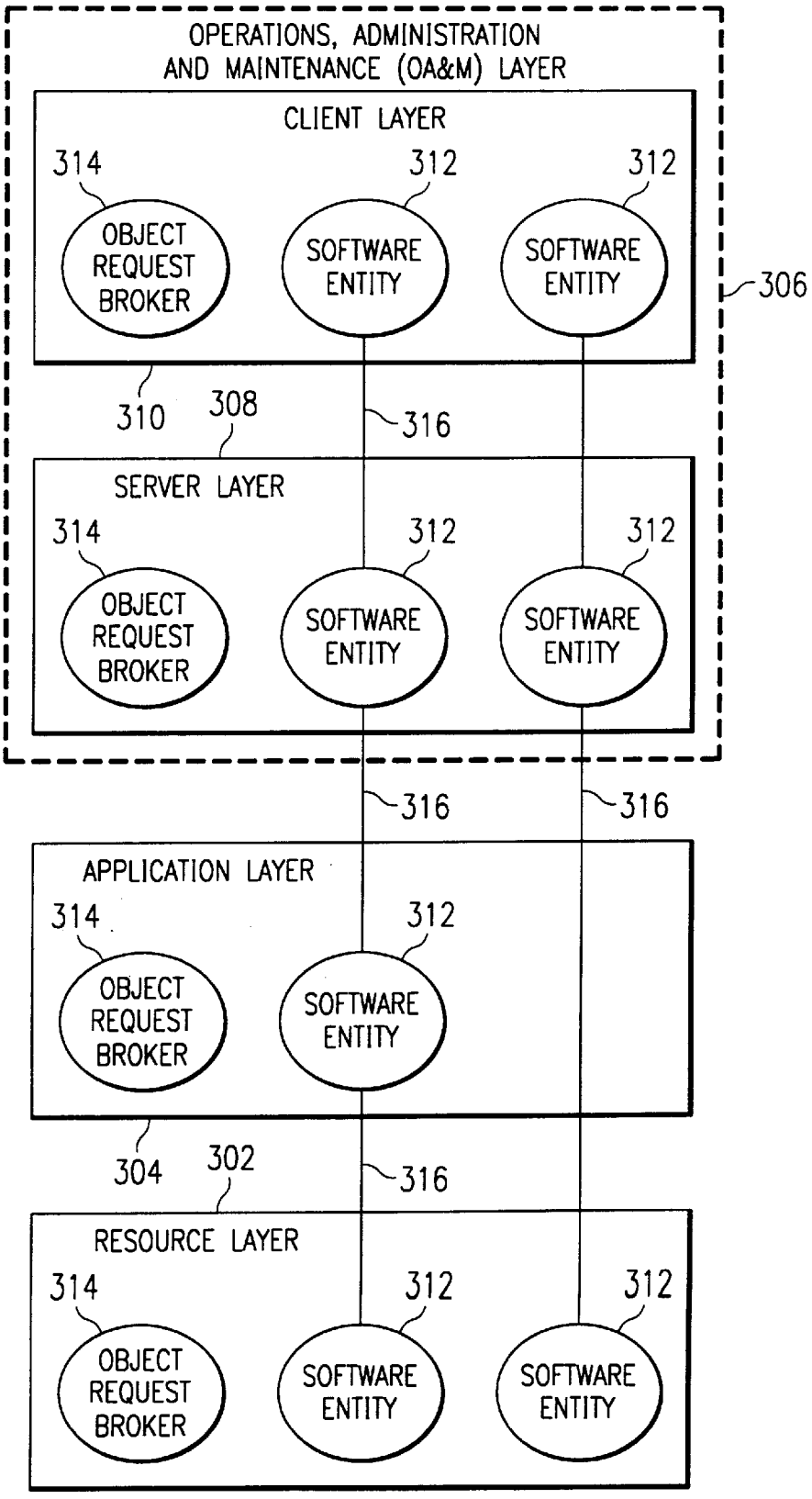

108
108a
118
118a
100
TELECOMMUNICATIONS SYSTEM
CALL PROCESSOR ASSEMBLY
NETWORK MANAGEMENT SYSTEM (NMS)
200
204
202
RESOURCE ASSEMBLY
110 110 110
RADIO INTERFACE
112
120
102
110 110 110
RADIO INTERFACE
112
102
114
116
MOBILE NETWORK (PLMN)
104
SWITCHED NETWORK (PSTN)
106

FIG. 2

FIG. 3A


OPERATIONS, ADMINISTRATION AND MAINTENANCE (OA&M) LAYER
CLIENT LAYER
314
312
312
OBJECT REQUEST BROKER
SOFTWARE ENTITY
SOFTWARE ENTITY
306
310
308
316
SERVER LAYER
314
312
312
OBJECT REQUEST BROKER
SOFTWARE ENTITY
SOFTWARE ENTITY
316
316
APPLICATION LAYER
314
312
OBJECT REQUEST BROKER
SOFTWARE ENTITY
304
302
316
RESOURCE LAYER
314
312
312
OBJECT REQUEST BROKER
SOFTWARE ENTITY
SOFTWARE ENTITY

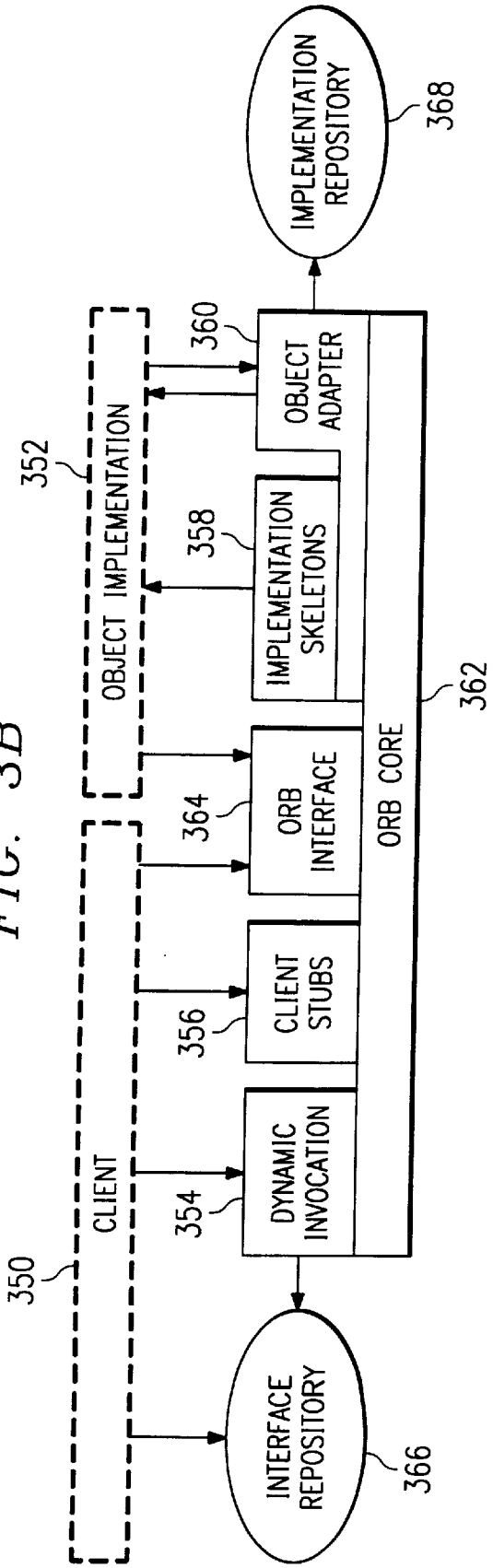

IMPLEMENTATION REPOSITORY
368
OBJECT ADAPTER
360
IMPLEMENTATION SKELETONS
358
ORB INTERFACE
364
CLIENT STUBS
356
DYNAMIC INVOCATION
354
ORB CORE
362
OBJECT IMPLEMENTATION
352
CLIENT
350
INTERFACE REPOSITORY
366

FIG. 3B

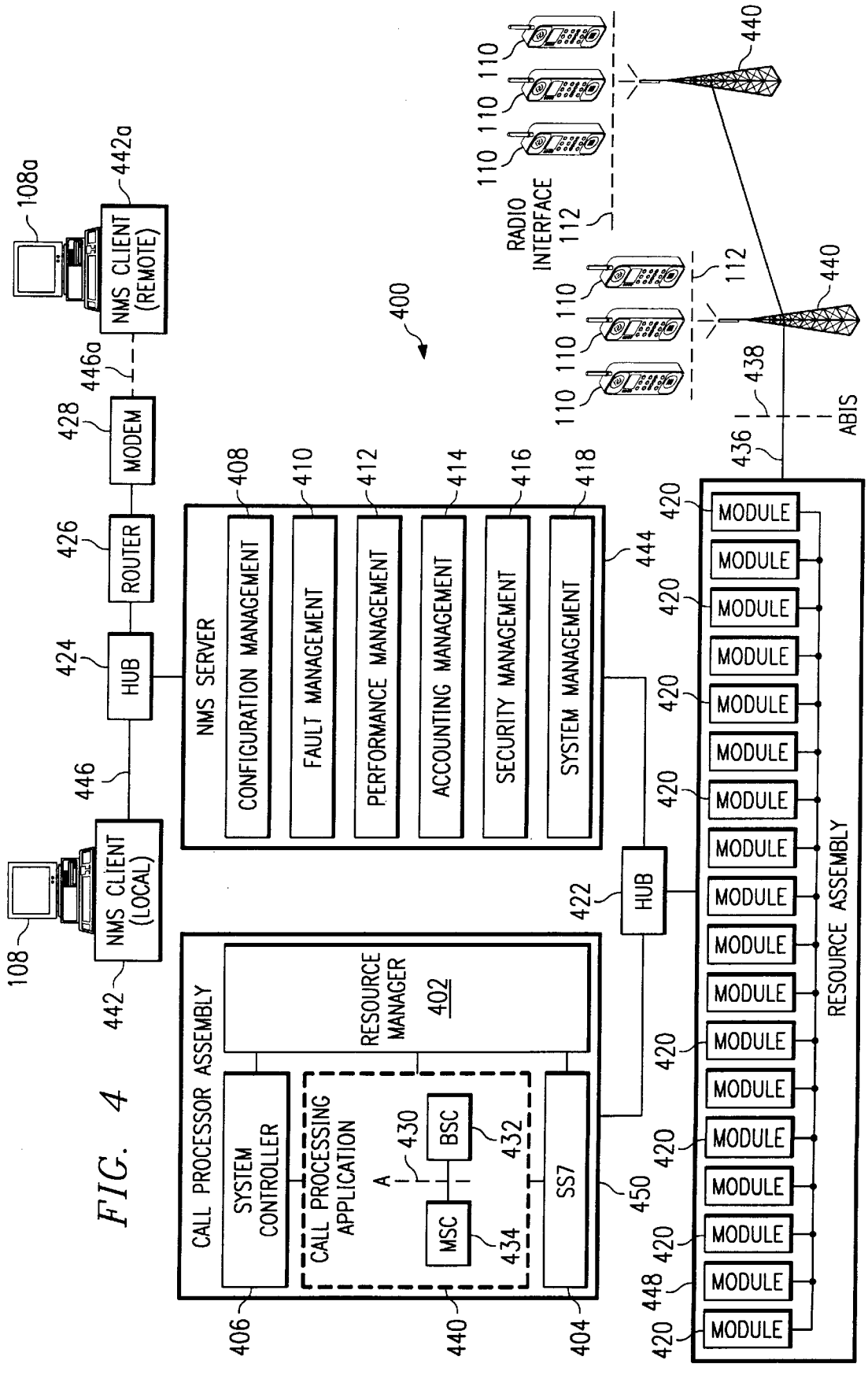

400
108
108a
NMS CLIENT (LOCAL)
NMS CLIENT (REMOTE)
442
442a
446
446a
HUB
ROUTER
MODEM
424
426
428
NMS SERVER
CONFIGURATION MANAGEMENT
FAULT MANAGEMENT
PERFORMANCE MANAGEMENT
ACCOUNTING MANAGEMENT
SECURITY MANAGEMENT
SYSTEM MANAGEMENT
408
410
412
414
416
418
444
HUB
422
CALL PROCESSOR ASSEMBLY
SYSTEM CONTROLLER
CALL PROCESSING APPLICATION
RESOURCE MANAGER 402
A
430
BSC
432
MSC
434
SS7
406
440
404
450
RESOURCE ASSEMBLY
MODULE
420
448
RADIO INTERFACE 112
110
440
438
ABIS
436

FIG. 4

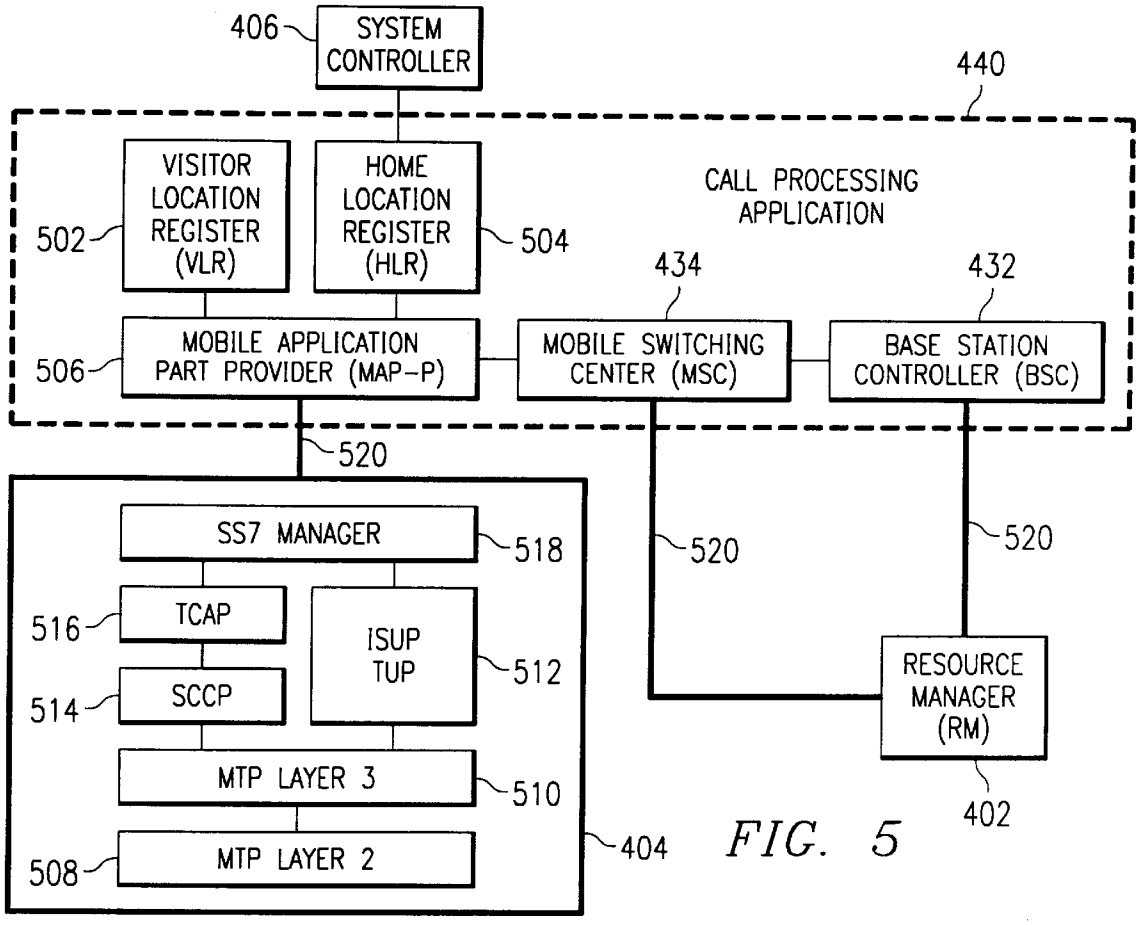

406
SYSTEM CONTROLLER
440
VISITOR LOCATION REGISTER (VLR)
502
HOME LOCATION REGISTER (HLR)
504
CALL PROCESSING APPLICATION
434
432
MOBILE APPLICATION PART PROVIDER (MAP-P)
506
MOBILE SWITCHING CENTER (MSC)
BASE STATION CONTROLLER (BSC)
520
SS7 MANAGER
518
TCAP
516
ISUP TUP
512
SCCP
514
MTP LAYER 3
510
MTP LAYER 2
508
404
RESOURCE MANAGER (RM)
402

FIG. 5

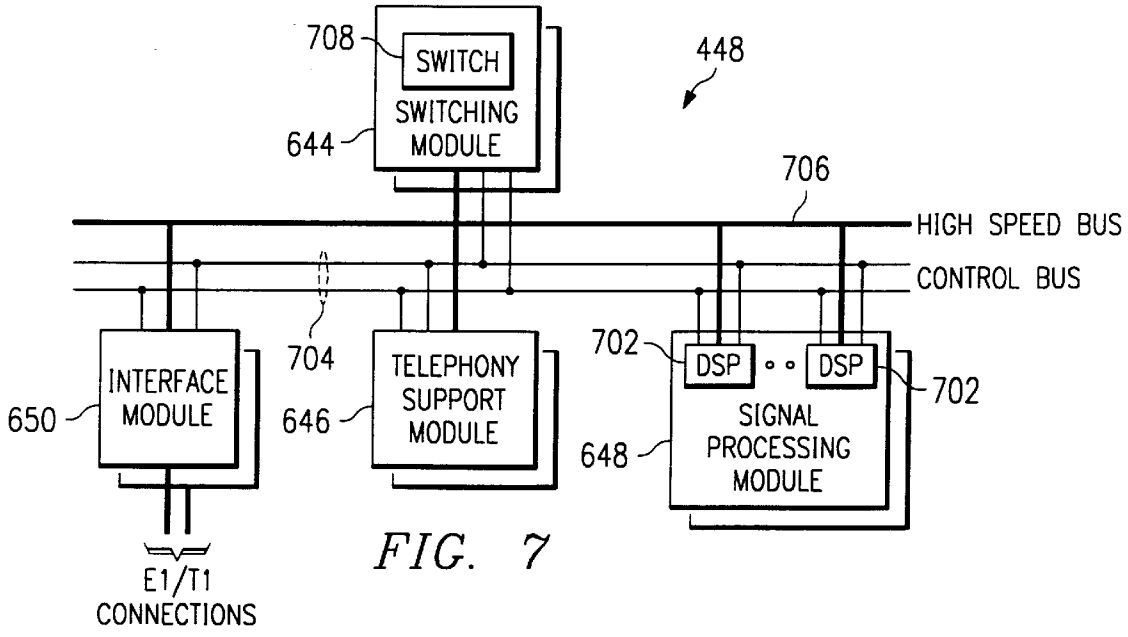
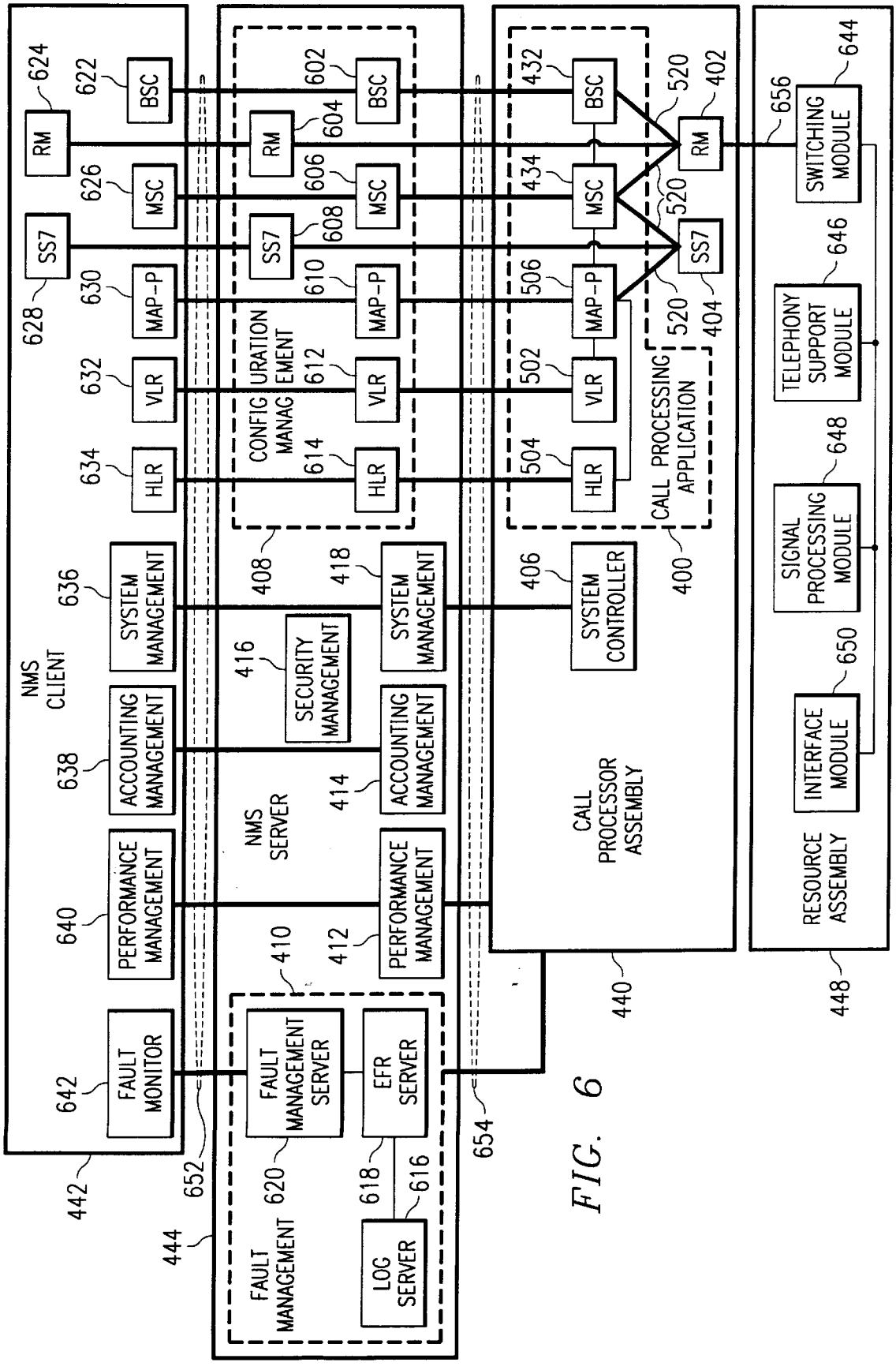

708
SWITCH
SWITCHING MODULE
644
448
706
HIGH SPEED BUS
CONTROL BUS
704
INTERFACE MODULE
650
TELEPHONY SUPPORT MODULE
646
702
DSP
DSP
SIGNAL PROCESSING MODULE
648
E1/T1 CONNECTIONS

FIG. 7


NMS CLIENT
NMS SERVER
CALL PROCESSOR ASSEMBLY
RESOURCE ASSEMBLY
FAULT MANAGEMENT
CONFIG URATION MANAG EMENT
CALL PROCESSING APPLICATION
SYSTEM MANAGEMENT
ACCOUNTING MANAGEMENT
PERFORMANCE MANAGEMENT
SECURITY MANAGEMENT
FAULT MONITOR
FAULT MANAGEMENT SERVER
EFR SERVER
LOG SERVER
SYSTEM CONTROLLER
SIGNAL PROCESSING MODULE
INTERFACE MODULE
SWITCHING MODULE
TELEPHONY SUPPORT MODULE
RM
BSC
MSC
SS7
MAP-P
VLR
HLR
400
402
404
406
408
410
412
414
416
418
432
434
440
442
444
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502
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FIG. 6

FLEXIBLE TELECOMMUNICATIONS SYSTEM ARCHITECTURE

CLAIM OF PRIORITY

The instant patent application claims priority from the U.S. provisional patent application designated with Ser. No. 60/060,107, entitled "Cellular Communication System," naming Anthony G. Fletcher and Scott D. Hoffpauir as inventors, and which was filed on Sep. 26, 1997.

RELATED PATENT APPLICATIONS

The instant patent application is directly related to the following patent applications: (a) the U.S. patent application Ser. No. 09/025,870 designated by DSC Case No. 834-00 and Attorney Docket No. 24194000.180, entitled "Integrated Telecommunications System," naming Anthony G. Fletcher and Scott D. Hoffpauir as inventors, and which was filed concurrently with the instant patent application; (b) the U.S. patent application Ser. No. 09/026,190 designated by DSC Case No. 835-00 and Attorney Docket No. 24194000.181, entitled "Resource Management Sub-System of a Telecommunications Switching System," naming Howard L. Andersen and Scott D. Hoffpauir as inventors, and which was filed concurrently with the instant patent application; (c) the U.S. patent application Ser. No. 09/026,810 designated by DSC Case No. 836-00 and Attorney Docket No. 24194000.182, entitled "Generic Wireless Telecommunications System," naming Anthony G. Fletcher and Scott D. Hoffpauir as inventors, and which was filed concurrently with the instant patent application; (d) the U.S. patent application Ser. No. 09/026,487 designated by DSC Case No. 833-00 and Attorney Docket No. 24194000.179, entitled "Network Management System Server and Method for Operation," naming Scott D. Hoffpauir as inventor, and which was filed concurrently with the instant patent application; (e) the U.S. patent application Ser. No. 09/026,230 designated by DSC Case No. 852-00 and Attorney Docket No. 24194000.197, entitled "Application Provider and Method for Communication," naming Scott D. Hoffpauir and Steve B. Liao as inventors, and which was filed concurrently with the instant patent application; and (f) U.S. patent application Ser. No. 08/678,254, now U.S. Pat. No. 5,835,486, entitled "Multi-Channel Transcoder Rate Adapter Having Low Delay and Integral Echo Cancellation," naming James M. Davis and James D. Pruett as inventors, and which was filed Jul. 11, 1996.

FIELD OF THE INVENTION

The present invention relates to a telecommunications systems, and more particularly, to a flexible architecture of a telecommunications system that facilitates adaptability and interoperability of elements of a telecommunications systems.

BACKGROUND

Conventional telecommunication systems typically include various hardware platforms and software to carry out its operations. Software is, and continues to, provide for a significant portion of the functionality associated with such systems. Conventional telecommunications systems utilize software that is constructed using structured programming principles, such as C language, to produce large monolithic applications. Those applications typically include thousands of loosely organized lines of executable code.

Conventional telecommunications systems are inflexible and difficult to adapt due to their use of conventional software. Different programming languages and operating systems are often used by different conventional software applications. As a result, it is difficult for one application to use the operations and functions provided by another application. In other words, there is an inadequate ability for applications to effectively communicate and cooperate in a collective manner. Similar operations and functions are therefore duplicated in different applications to avoid the obstacles encountered in accessing another application's operations.

Further, even within a given application, functionality is limited by the monolithic and complex nature of applications, which includes multiple interdependent lines of code. That is, there is a large degree of interdependence among executable code found in conventional applications, i.e., specific functions are intermixed throughout the code and not isolated. As a result, redesigning a particular area of code often leads to undesirable effects on other areas of code. This severely inhibits the ability to modify, by adding new functions or removing or adapting existing functions, conventional software code. It also requires a significant collaborative effort among designers. Significant expenditures of time and resources are thus incurred in designing and redesigning software code found in conventional telecommunications systems. Numerous other undesirable consequences result from the use of conventional software, such as the inability to interface with other systems or devices, an inability to provide a modular system, and difficulties in incorporating newly developed or third party software applications within a system.

SUMMARY OF THE INVENTION

The present invention sets out to, among other things, overcome the aforementioned problems associated with conventional wireless telecommunications systems by providing a flexible architecture in which functional elements within and outside diverse environments and applications can effectively communicate.

One object of the present invention is to provide a telecommunications system, which is operable to carry out complex functions, having a flexible architecture.

Another object of the present invention is to provide an architecture in which like or similar elements are logically grouped together and isolated from other elements while still allowing for elements not in the same grouping to effectively communicate and cooperate with each other.

Yet another object of the present invention is to provide an architecture whereby the functionality of one or more elements is sufficiently isolated so that such elements may be modified or replaced without having an adverse impact on other elements, i.e., a low coupling of elements.

An additional object of the present invention is to provide an architecture for a telecommunications system that accommodates and facilitates the incorporation of additional functionality into the telecommunications system, and that allows for functionality already incorporated to be readily removed from a telecommunications system.

Still another object of the present invention allows for the use of operations provided in one application for different applications.

A further object of the present invention is to provide an architecture in which there is interoperability amongst elements, including the ability for different elements to make use of dissimilar programming languages and operating systems and to operate in association with dissimilar development and deployment environments, such as dissimilar processors and operating systems.

Another object of the present invention is to provide an architecture that facilitates the addition and removal of processors used by one or more elements.

Yet another object of the present invention is to provide an architecture having one or more elements which can be accessed by an external system through defined interfaces.

In accordance with the present invention, an architecture is provided that includes multiple layers of object oriented software. Software layers are provided based on a logical grouping of like or similar functions. For example, some or all of the following software applications or layers may be included within a telecommunications system: a call processing software layer to provide call processing operations; a resource software layer to manage and provide access to telephony resources; and a management software layer to provide operations, administration and maintenance related operations. One or more software entities, which may each comprise one or more software objects, are included in a software layer. Software entities encapsulate operations that can be invoked by a software entity in a different software layer. As such, the present invention organizes and isolates functionality within distinct software layers and software entities yet provides for effective communications and cooperation between such layers and entities.

In accordance with one aspect of the present invention, a client layer and server layer may be provided in place of the management layer. The client layer is configured to present operations, administration and maintenance related information concerning to a user for adaptation by the user. In contrast, the server layer is configured to store and access the operations, administration and maintenance related information.

In accordance with another aspect of the present invention, methods and techniques are provided to establish effective communications between software entities in different software layers of a telecommunications system. A software object of one software entity, which is sometimes referred to as an originating object, may issue a request for invocation of a specified operation. A particular operation of an object associated with another entity that resides in a different software layer, sometimes referred to as a target object, may be identified based on the specified operation. Information concerning invocation of the particular operation may also be obtained from which a message to the target object may be composed so as to invoke the particular operation. Following proper invocation, the originating object is provided with a response from the target entity based on the results of the invoked operation.

In accordance with yet another aspect of the present invention, an object request broker element may be provided with respect to a given software layer to facilitate the invocation of operations associated with software entities residing on that layer. An object request broker may, for example, maintain information about the location and addressing of software objects and entities within a given software layer, the operations of those software objects and entities that can be invoked, and information needed to invoke those operations. As such, an originating object may turn to an object request broker to form a connection path with a target object and be apprised of operations of the target object that can be invoked. Further, a proxy may be associated with an originating object and act as a local representative of a target object. As such, it may, for example, send a request to a target object concerning the invocation of an operation and receive a response back from that target object concerning the results of that operation.

The present invention is particularly well suited for use in connection with wireless telecommunications switching systems that are designed in accordance with various technologies and standards, including Global System for Mobile Communications (abbreviated GSM), Personal Communications Services (abbreviated PCS), Code Division Multiple Access (abbreviated CDMA), and Time Division Multiple Access (abbreviated TDMA).

Other and further objects, aspects, features and advantages of the present invention will be apparent from the following detailed description of an exemplary embodiment of the invention, given for the purpose of disclosure and taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may be better understood from the following detailed description of an exemplary embodiment of the present invention with reference to the accompanying drawings, in which:

FIG. **1** is a diagram that illustrates a telecommunications system and certain connections associated with that telecommunications system, in accordance with an exemplary embodiment of the present invention;

FIG. **2** is a diagram that illustrates various assemblies and systems that may be included within a telecommunications system, in accordance with an exemplary embodiment of the present invention;

FIG. **3**A is a diagram that illustrates an architecture of a telecommunications system, in accordance with an exemplary embodiment of the present invention;

FIG. **3**B is a diagram that illustrates an object request broker structure pursuant to the CORBA 2.0 standard, in accordance with an exemplary embodiment of the present invention;

FIG. **4** is a diagram that illustrates a telecommunications system, designed consistent with the GSM standard and in accordance with an exemplary embodiment of the present invention;

FIG. **5** is a diagram that illustrates various elements included within a call processor assembly, designed consistent with the GSM standard and in accordance with an exemplary embodiment of the present invention;

FIG. **6** is a diagram that more specifically illustrates the various elements and resources, and connections provided therebetween, of a telecommunications system, designed consistent with the GSM standard and in accordance with an exemplary embodiment of the present invention; and

FIG. **7** is a diagram that illustrates various modules of a resource assembly, designed consistent with the GSM standard and in accordance with an exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF AN EXEMPLARY EMBODIMENT OF THE PRESENT INVENTION

FIG. **1** illustrates an integrated, wireless telecommunications switching system **100** and certain connections associated with that telecommunications system **100**, in accordance with an exemplary embodiment of the present invention. The telecommunications system **100** is operable to provide speech and data services to multiple subscriber units **110**. Each subscriber unit **110** provides an interface to a human user, such as through use of a microphone, loudspeaker, display or keyboard of a subscriber unit, or provides an interface to terminal equipment, such as an

interface towards a personal computer or facsimile machine, or both. While the subscriber units **110** are illustrated in FIG. **1** as hand held mobile units, it should be appreciated that the implementation of the subscriber units **110** is not so limited. For example, the subscriber units **110** may comprise a fixed antenna assembly connected to a telephone or other interface device. A smart card (not illustrated) may be embodied within a subscriber unit **110** to provide such subscriber unit with subscriber related information and encryption keys.

Communications to and from the subscriber units **110** are established over a radio interface **112** by one or more base stations **102**. Base stations **102** directly communicate with subscriber units **110** over radio frequency signals transmitted from, and received by, the base stations over the radio interface **112**. Base stations **102** may, for example, include radio transmission and reception devices, antenna assemblies, signaling processing logic specific to the radio interface **112** between the base stations and the subscriber units **110**.

A base station **102** is preferably responsible for providing communications to subscriber units **110** located within a particular region, commonly referred to as a service area or cell. One or more base stations **102**, typically in a common area, may be logically grouped into what is commonly referred to as a base station site.

The telecommunications system **100** is connected to the base stations **102** by a link **120**, such as an E1 or T1 telecommunications line, that provides one or more suitable transmission channels. Digital representations of speech or data information are transmitted over the link **120** between the telecommunications system **100** and the base stations **102**, at a predetermined transmission rate.

The telecommunications system **100** is further connected to a mobile network **104** over a link **114** and a switched network **106** over another link **116**. A switched network **106** (for example, the Public Switched Telephone Network or PSTN), typically carries voice and data services to fixed locations. Signals transmitted over the switched network link **116** may therefore include ISUP and R2 type signals. A mobile network **104** (for example, the Public Land Mobile Network or PLMN) typically carries data related to mobile or subscriber units. Signals transmitted over the mobile network link **114** may therefore include SS7 and MAP type signals in addition to R2 and ISUP type trunks.

Configuration of the telecommunications system **100** is preferably accomplished by a graphical user interface associated with a local terminal **108** over a wireline connection **118** or associated with a remote terminal **108***a* over a modem link **118***a*.

FIG. **2** illustrates various assemblies and systems that may be included within the telecommunications system **100**, in accordance with an exemplary embodiment of the present invention.

A resource assembly is preferably included within the telecommunications system **100**. That resource assembly **202** is preferably connected, either directly or indirectly, to base stations **102** over one link **120**, a switched network **106** over another link **116**, and a mobile network **104** over yet another link **114**. Within the telecommunications system **100**, the resource assembly **202** is preferably connected to a call processor assembly **200** as well as a network management system **204**. The resource assembly **202**, in addition to providing an interface to base stations **102**, a switched network **106** and a mobile network **104**, includes resources that are available to be employed by the call processor assembly **200**.

The call processor assembly **200** includes elements that are operable to process calls directed to, or received from, subscriber units **110**, a switched network **106** and a mobile network **104**. The call processor assembly **200** is operable to handle call processing functions needed by the telecommunications system **100**, including call origination, location updating, handovers between cells, trunking and call termination. The call processor assembly **200** may include a general purpose computing platform, such as an Intel Pentium II based computing platform, that includes suitable hardware and/or software systems to support call processing functions. The call processor assembly **200** may use a real-time operating system, such as a QNX operating system, to support the real-time call processing requirements of telecommunications system **100**.

As illustrated in FIG. **2**, the network management system **204** may be embodied within the telecommunications system **100** or external to the telecommunications system **100**. Certain elements of the network management system **204** are preferably provided within the telecommunications system **100** while others are provided externally. It should also be appreciated that while the call processor assembly **200**, resource assembly **202** and network management system **204** are illustrated as distinct assemblies, some or all of the functionality of those entities may nevertheless be integrated into a single assembly consistent with the spirit and scope of the present invention.

In accordance with the present invention, a software architecture including more than one software layer is associated with the telecommunications system **100**. The functions of the telecommunications system **100** are preferably logically divided or partitioned amongst the layers, i.e., each layer preferably includes a distinct logical grouping of like or similar functions. Functions of a software layer are further logically divided among one or more encapsulated software entities. A software entity may comprise one or more encapsulated software objects. A software layer therefore isolates the software entities included in the layer from other layers. A software entity and its associated objects further isolate those functions by encapsulation. This allows for such software layers and software entities to be developed relatively independently of one another. Although providing for isolation by use of software layers and entities, the present invention also provides for communications between the software layers and entities, and in particular, the ability for a software entity found in one software layer to communicate and use operations of another software entity found in a different software layer.

FIG. **3**A illustrates an architecture of the telecommunications system **100**, in accordance with an exemplary embodiment of the present invention.

More than one software layer is provided in accordance with the present invention. As illustrated in FIG. **3**A, three primary software layers **302**–**306** may be provided in accordance with an exemplary embodiment of the present inventions. Such software layers **302**–**306** may, for example, correspond with the resource assembly **202**, call processor assembly **200** and network management system of the telecommunications system **100**. For instance, the telecommunications system **100** may include a resource layer **302**, an application layer **304** and an operations, administration and maintenance (abbreviated OA&M) layer **306**. The resource layer **302** may function to control and administer the operation of hardware modules and components provided within the resource assembly **202**, including management and provision of telephony resources and switching functions provided within the resource assembly **202**. It may

further control and administer communications between the application layer **304** or the OA&M layer **306** and the resource assembly **202**. The application layer **304** provides specific call processing functions, such as switching related functions. As such, the application layer **304** preferably includes one or more functional elements that collectively implement one or more specific particular call processing applications in accordance with one or more standards, such as the GSM standard. An example of a call processing application consistent with the GSM standard is described below in connection with FIG. **5**. Preferably, the application layer **304** isolates those functions that pertain to a particular telecommunications standard so that the application layer **304** can be readily modified to reflect changes in that standard or so that a presently implemented standard can be replaced with another standard, as discussed below in connection with FIG. **5**. The OA&M layer **306** may provide a user interface to receive operations, administration and maintenance related requests and provide services in response to those requests. Such services may include: configuration management services to modify configuration information used by the resource layer **302** and application layer **304**; performance management services to periodically collect and summarize system performance and traffic information; fault management services to detect, log and report failures; accounting management services to create and store billing related records; system management services to monitor and initiate tests and resets of hardware and software; and security management services to control access to the network management system **204**.

The OA&M layer **306** is preferably separated into a client layer **310** and a server layer **308**. Preferably, the client layer **306** provides a user interface and receives requests for the aforementioned services while the server layer **310** provides and manages requests received from the client layer **306**. The client layer **306** is operable to present information, requested by the client layer **306** and provided by the server layer **308**, to a user through a graphical user display. A user can adapt and modify such information. In contrast, the server layer **308** validates and causes the storage of information provided by the client layer **306**, as well as forwards appropriate information to the application layer **304** and resource layer **302**. The server layer **308** also supplies the client layer **306** with appropriate information to display to a user. One or more databases (not illustrated) are accessible by the server layer **308** to store information related to the services, such as configuration information that is used by the application layer **304**. An example of a client layer **310** and a server layer **308** is described below in connection with FIG. **6**.

One or more processors (not illustrated) are associated with each software layer **302–310**. The number and type of processors associated with each software layer **302–310** may be different and should be selected based on the particular requirements of, and benefits derived by, each such layer. Similarly, software layers **302–310** may employ different programming languages and operating systems and should be selected based on the particular requirements of, and benefits derived by, each such layer.

It should be appreciated that the number of software layers **302–310**, as well as the software entities **312** associated with each such layer, is of no consequence with respect to the scope of the present invention. It should further be appreciated that while the various software layers **302–310** need not be co-located, i.e. they may be stored and executed at remote locations and within different products. As such, migration of functionality is accommodated by the present invention. For example, it may become desirable for some or all of the functionality of a given layer **302–310** to be executed by one or more processors not provided within the telecommunications system **100**. Such layer and its associated functionality may therefore, in accordance with the present invention, be readily migrated to hardware platform of an external system. As another example, an existing layer **302–310**, such as the client layer **306**, may be replaced by another application preferred by an operator of a telecommunications product. As yet another example, a particular software entity **312**, such as a home location register **504** discussed below in connection with FIG. **5**, may be inactivated in favor of another provided externally. The present invention therefore provides a great deal of flexibility to continually adapt and modify a telecommunications system **100** as needed or desired.

A software layer **302–310** may include one or more software entities **312**. Software entities, as used herein, comprises one or more software objects that collectively model, for example, a particular component. One example of a software entity **312** is a composite software object. Software objects generally encapsulate one or more operations or methods and associated data to model various functions of, for example, a particular component and variables to reflect information about the characteristics and states of that component. Peer software objects i.e., software objects within the same layer **302–310** or entity, may be coupled by a virtual connection so that they can interact and communicate with one another. For example, one object can invoke or call an operation or method associated with another object. This is ordinarily accomplished by the sending of a message from one object (known as the originating object) requesting that a specified operation or method be carried out by another object (known as the target object). After receiving the request, a target object sends a response to the originating object. One target object may respond to the same message differently from another target object. This result is sometimes referred to as polymorphism. Objects, which include encapsulated methods, interact by exchanging messages. A message typically identifies a target object, a method of the target object and (in some cases) a set of parameters that the method requires to carry out its function. Various commercially available tools and languages may be used to create software objects, such as Smalltalk, C++ and Java. To readily create software objects, a class of objects may be defined. Classes provide a template that defines common methods and variables in a set of related objects. Different objects belonging to a class, commonly referred to as instances of a class, each include particular values for the variables of the class. Classes are specified by a message interface and an implementation of that interface. A message interface specifies, with respect to a given class of objects, those messages to which objects of the given class will respond, whereas an implementation specifies how responses to messages are carried out.

In accordance with the present invention, a given software entity **312** may form a virtual connection **316** with another entity **312**, whether or not such other entity **312** is in the same software layer **302–310** as the given entity or another layer. More specifically, a virtual connection **316** is formed between an originating software object and a target software object of different software entities **312** of different software layers **302–310**. A virtual connection **316** may, for example, be accomplished by sending a message from an originating software object, and receiving a response to such message from a target software object. To accomplish a virtual connection **316** between software entities **316** provided on

distinct software layers **302–306**, object request broker technology is preferably employed in accordance with the present invention. Object request broker technology includes those software products made pursuant to the Common Object Request Broker Architecture (abbreviated CORBA) standard and the Distributed Component Object Model (abbreviated DCOM) technology. By employing object request broker technology within the telecommunications system **100**, a communications and transport mechanism is provided whereby any software entity **312** may effectively communicate with another software entity **312** regardless of the nature and environment associated with each such entity.

Object request broker technology may be considered to provide a message transport mechanism or bus that functions to provide for the formation of virtual connections **316** between software entities **312** of different software layers **302–310**. More specifically, object request broker technology is operable to transport a message from an originating object of a software entity **312** in one software layer **302–310**, to cause delivery of that message to a target object of a software entity **312** in another layer, and then to cause return of a response to the originating object. Use of object request broker technology therefore allows for remote messaging by providing a communications channel between remote entities **312**. In other words, a software entity **312** in a given software layer **302–310** may invoke a method associated with a target object of another software entity **312** that is found in another layer. In this fashion, the target object is not made aware of the mechanisms used to communicate with it. Use of object request broker technology to facilitate communications between two software entities **312** allows for a client-server relationship between such entities wherein the originating object acts as a client and the target object acts as a server. Numerous advantages are thus gained by the use of object request broker technology to provide interoperability among the various entities **312** and software layers **302–310** of the telecommunications system **100**.

One or more elements, referred to and identified herein as object request brokers **314**, are preferably provided with respect to each software layer **302–310**. Preferably, an object request broker **314** is provided for those software entities **312** executed by each processor. An object request broker **314** preferably comprises one or more software objects, and resides together with other software entities **312** of a given software layer **302–310**. It relieves an originating object of the burden of tracking the location of remote objects to which an originating object desires to send a message. Accordingly, an object request broker **314** essentially provides a location service by which target objects can be located by originating objects. Locating a target object is preferably based on a name or numeric identifier associated with the target object, sometimes referred to as an object reference. In operation, an originating object, the object seeking to send a message, initially provides information to the object request broker **314** and requests the location of a target object and/or an operation sought to be invoked by the originating object. In turn, the object request broker **314** provides such location and/or the appropriate interface for the operation sought to be invoked, which allows an originating object to send a message to the target object. Since an originating object typically does not maintain sufficient information to directly send a message to a target object without information provided by an object request broker **314**, the location of the target object is thus transparent to the originating object. Accordingly, an object request broker **314** can be said to facilitate communications between originating and target objects of different software layers **302–310**.

An alternative to providing a centrally located object request broker **314** is distributing those functions that have been described above as being embodied within the object request broker **314** amongst software entities **312** or objects comprising associated with a software entity **312**.

One or more proxies (not illustrated) are preferably provided with respect to an originating entity **312**. A proxy is preferably a software object that acts as a local representative of a software object located in a different software layer **302–310**. As such, a proxy shields an originating object from appreciating that a target object is remotely located. A proxy may represent a remote target object to an originating object of a given software layer **302–310**. By using a proxy, the target object appears to the originating object as a peer object. In operation, a proxy may receive a message or request from an originating object concerning a target object and/or an operation of a target object.

A proxy may be used to provide either a static or dynamic interface to an originating object. Preferably, an originating object requests information from an object request broker **314** concerning the location of a remote target object and/or the interfaces for operations of the target object that can be invoked by the originating object. As a result of such request, a bind is performed whereby a proxy is created within the software entity **312** of the originating object and a direct communication path is formed between the proxy and the target object selected by the object request broker **314**. That proxy preferably includes the various operations of the target object that can be invoked by the originating object. Upon provision of such proxy, the originating object may issue a request to that proxy to invoke one of the identified operations of the target object. In turn, that proxy relays that request to the target object. Alternatively, a proxy may redirect a message or request from an originating object to a target object of the remote software layer **302–310**, provided that the proxy is provided with, and maintains, sufficient information to do so.

A proxy is preferably configured to receive a response from a target object and to transmit that response to the originating object associated with such proxy. By providing a proxy for an originating object, knowledge that a remote target object is not commonly located with the originating object is shielded from **312** the originating object or other software objects within the same software entity **312** or layer **302–310**. Rather, such knowledge is limited to the proxy. A proxy is therefore interchangeable with a remote target object to which it is responsible for conveying and receiving messages. As such, the operations or methods associated with a remote target object may be incorporated within its associated proxies without adversely affecting other software objects or software entities **312** or their associated proxies.

To send a message to a target object, an originating object must know how to address the target entity **312** but not the implementation details associated with the target object, such as the programming language, operating system, processor, tools, network and other aspects associated with a target objects. Addressing a target object, and invoking an operation thereof, calls for knowledge of the specifications of a message interface of the target object. Adherence to the interface specifications allows an originating object to communicate with a target object. An object request broker **314** preferably maintains and provides (or publishes) those interfaces of a target object (sometimes referred to as being published) that can be utilized by originating objects.

An interface to a particular method or operation of a target object—sometimes referred to as a method invocation inter-

face or message interface—is preferably defined and specified by a standard definition language. For example, a method invocation interface may be specified by use of Interface Definition Language (IDL) consistent with the CORBA standard. IDL provides an interface for a given software object, independent of programming language and operating system, to other objects and software entities **312** that are associated with a CORBA architecture. As such, it allows originating and target objects written in different programming languages and associated with different operating systems to communicate and interoperate with one another. Using IDL, a method invocation interface is specified by identifying various data related to an interface of a software object. Such data includes the object's attributes, classes from which the object inherits, exceptions raised by the object, typed events emitted by the object and the methods of the object that can be invoked by other objects, including input and output parameters and data types of those parameters.

A method invocation interface may be either static or dynamic. A static interface is defined at the time that the software entities **312** are compiled, whereas a dynamic interface is defined during run-time. For example, a proxy may provide a static interface by which a virtual connection **316** may be formed between software entities **312**. Consistent with CORBA, an interface repository may be provided to store interface specifications used to construct dynamic interfaces. That interface repository may, for example, dynamically change and be accessed during run-time.

FIG. **3**B illustrates an object request broker structure pursuant to the CORBA 2.0 standard, in accordance with an exemplary embodiment of the present invention.

In accordance with that standard, an originating object is deemed a client **350** while the methods or services of a target or server object sought to be invoked by the client are deemed to be an object implementation **352**. According to CORBA 2.0, certain elements are employed to provide an object request broker environment. One or more client stubs **354** and dynamic invocation elements **356** are utilized by a client **350**. Similarly, one or more implementation skeletons **358** and object adapters **360** are utilized by an object implementation **352**. Further, one or more ORB interfaces **364** are provided for use by clients **350** and object implementations **352**. Such elements are preferably implemented in software and communicate with one another over an ORB core **362**, which may, for example, use CORBA's 2.0 Internet Inter-ORB Protocol (IIOP) services. Other elements, such as one or more interface repositories **366** and implementation repositories **368**, are also employed consistent with CORBA 2.0.

CORBA 2.0 provides for both static and dynamic programming interfaces to be provided between a client **350** (for example, an originating object) and an object implementation **352** (for example, a target object). Specifically, a client **350** may issue requests to remote object implementations **352** through either a client stub **356** or a dynamic invocation interface **354**. Both client stubs **356** as well as interface repositories **366**, which are utilized by dynamic invocation elements **354**, are created through the use of IDL.

Client stubs **356** are provided with respect to a client **350** to provide static interfaces to object implementations **352**. That is, client stubs **356** represent particular methods or operations that may be invoked by a client **350**. Client stubs **356** may be precompiled using IDL and generated by an IDL compiler. Preferably, a distinct client stub **356** is provided for each method or operation invoked with respect to a given client object. Client stubs **356** thus act as proxies for a client **350**, and may reside locally relative to a client **350**. A client stub **356** is preferably operable to encode and decode messages and requests made by a client **350**, including the method and parameters identified in a message or request, into a suitable message format that is directed to an object adapter **360** and then to an implementation skeleton **358**, as discussed more fully below.

Dynamic invocation elements **354** are provided with respect to a client **350** to provide dynamic interfaces to object implementations **352**. Dynamic invocation elements **354** allow for a client **350** to dynamically construct an interface to invoke methods or operations at run-time. This is in contrast to client stubs **356** which provide for a predetermined interface. Dynamic invocation elements **354** are operable to define an interface by accessing an interface repository **366**, generating parameters, issuing remote calls, and obtaining results with respect to an object implementation **352**. An interface repository **366** provides for interface descriptions, supported methods and required parameters with respect to remote object implementations **352** for access and use by dynamic invocation elements **354**. Clients **350** may therefore dynamically access, and object implementations **352** may therefore store and update, information required to uniquely and globally identify a particular interface of a given object implementation **352** so as to allow formation of a virtual connection **316** between the client **350** and that object implementation.

An ORB interface **364** is accessible by both clients **350** and object implementations **352**. An ORB interface **364** is operable to provide a distinct set of services to a client **350**. Those services may include, for example, operations to return an interface type, converting an object reference to a string, as well as various management functions.

Whether a static or dynamic invocation, requests for service are transmitted to an object adapter **360**. An object adapter **360** is interposed between an ORB core **362** and implementation skeletons **358**, and is operable to accept requests for service on behalf of a given server object. An object adapter **360** provides a run-time environment for instantiating server objects, as well as passing requests to server objects and signing identification information to server objects (which are referred to as object references). Further, an object adapter **360** preferably registers the classes of objects it supports and their associated run-time instances with an implementation repository **368**. An implementation repository **368** maintains information provided to it by an object adapter **360**, and is operable to store additional information, such as trace information, audit trails, security and other administrative data.

Implementation skeletons **358** provide the interface through which a method of an object implementation **352** receives a request, which originated either from a client stub **356** or a dynamic invocation element **354**. Object implementations **352** thus receive requests through implementation skeletons **358** without knowledge of the invocation approach, i.e., whether through a static or dynamic interface. Since both static and dynamic invocations have the same message semantics in accordance with CORBA 2.0, messages provided to an object implementation **352** typically do not indicate whether such messages derived from a client stub **356** or a dynamic invocation element **354**. Implementation skeletons **358** correspond with client stubs **356** and dynamic invocation elements **354**. That is, implementation skeletons **358** can provide for either a static interface or dynamic interface to an object implementation **352**. Implementation skeletons **358** may include static skeletons (not

illustrated) and dynamic skeleton invocation elements (also not illustrated). Static skeletons, like client stubs **356** with respect to clients **350**, provide static interfaces to messages exported by an object implementation **352**. These skeletons, like client stubs **356**, are created using an IDL compiler. Dynamic skeleton invocation elements provide a run-time binding mechanism for object implementations **352** that do not have IDL-compiled static skeletons. A dynamic skeleton invocation element thus analyzes the parameter values of an incoming message to determine the target entity and method, and direct the message to the corresponding object implementation **352**. As such, a dynamic skeleton invocation element is the server equivalent of the dynamic invocation element **354**.

While FIG. **3**B and its associated description illustrate and describe a particular implementation that can be used to provide a suitable object request broker environment consistent with the present invention, it should be appreciated and understood that such implementation is exemplary and that other implementations and variations may also be used within the scope and spirit of the present invention.

FIG. **4** illustrates a telecommunications system **400**, designed consistent with the GSM standard and in accordance with an exemplary embodiment of the present invention.

In accordance with the GSM standard, one or more base transceiver stations **440** are provided to communicate with subscriber units **110** over a radio interface **112**. Such base transceiver stations **440** are connected to the resource assembly **448** through a link **436**, which provides one or more suitable transmission channels. Digital representations of speech or data information are transmitted over the link **436** at a predetermined transmission rate. Such link **436** may, for example, be an E1 or T1 telecommunications line.

The interface **438** between base transceiver stations **440** and a base station controller **432** is, pursuant to the GSM standard, known as the Abis interface. The Abis interface **438** provides message flow between a base station controller **432** and base transceiver stations **440**, and also manages message flow between subscriber units **110** and other network elements. The Abis interface **438** is thus interposed between base transceiver stations **440** and the telecommunications system **400** itself. Digital representations of speech or data information are transmitted through the Abis interface **438**, that is, between the telecommunications system **400** and the base transceiver stations **440**, at a predetermined transmission rate. For example, digital representations of speech or data information may be transmitted over the link **120** connecting the base transceiver stations at a rate of 16,0000 bits per second.

The call processor assembly **450** preferably includes a call processing application **440** which includes, among other elements, a base station controller **432** (abbreviated BSC) and a mobile switching center **434** (abbreviated MSC), which is sometimes also referred to as a mobile services switching center. Signaling and voice data is exchanged between the interface between the base station controller **432** and mobile station controller **434**, known as the A interface **430**.

The base station controller **432** is responsible for management of the base transceiver stations **440** and their radio interfaces **112**, including the allocation and release of radio channels associated with a given radio interface **112** and management of handovers from one base transceiver station **112** to another base transceiver station **112**. The base station controller **432** manages the base transceiver stations **440** and their radio interfaces **112** through the allocation, release and handover of radio transmission channels. The base station controller **432** may carry out various procedures that relate to call connection tasks. For example, the base station controller **432** may be responsible for system information broadcasting, subscriber paging, immediate traffic channel assignment, subsequent traffic channel assignment, call handover, radio connection and release, connection failure detection and reporting, and power capability indication reporting. The base station controller **432** may also be responsible for management of both the Abis interface **438** and the A interface **430**.

The mobile switching center **434** coordinates the allocation and routing of calls involving the subscriber units **110** of the telecommunications system **400** by, among other things, receiving dialed digits, interpreting call processing tones and providing routing paths. For example, the mobile switching center **434** is operable to process a service request from a subscriber unit **110**, and route a corresponding call to the designated switched network **106**, a mobile network **104** or to another subscriber unit **110**. Similarly, the mobile switching center **434** is operable to process a service request from a mobile network **104** or switched network **106**, and route a corresponding call to a designated subscriber unit **110**. The mobile switching center **434** is primarily responsible for mobility management, call control and trunking, such as coordinating the setting-up and termination of calls to and from subscriber units **110**. Additionally, it provides all of the functionality needed to handle mobile subscribers units **100** through location updating, handover and call delivery.

The interface between the base station controller **432** and the mobile switching center **434** is, pursuant to the GSM standard, known as the A interface **430**. The A interface **430** provides the link for managing traffic channels/transcoders, and also provides the mobile switching center **434** with access to base transceiver stations **112** for message flow with the subscriber units **110**. The Base Station Subsystem Management Application Part (abbreviated BSSMAP) protocol may be employed to transmit connection-related messages and paging messages between the mobile switching center **434** and base station controller **432**. Preferably, the base station controller **432** and the mobile switching center **434** are implemented as distinct entities, such as separate software objects that communicate with one another so that the A interface **430** is logically discernible.

In addition to the call processing application **440**, the call processor assembly **450** preferably includes several other elements, namely, a resource manager **402**, a SS7 element **404** and a system controller **406**. While the resource manager **402** is preferably included in the call processor assembly **450**, it may also be included in the resource assembly **448** within the scope of the present invention.

Management and allocation of resources provided by the resource assembly **448** with respect to the call processor assembly **450** is carried out by the resource manager **402**. That is, the resource manager **402** acts as the bridge between the call processing application **440** and the resource assembly **448** by enabling different elements of the call processing application **440** to interface with resources of the resource assembly **448**. Preferably, the resource manager **402** also provides an interface to resources of the resource assembly **448** for the SS7 element **404** as well as remote elements, such as the system controller **406** and various elements of the network management system **204**.

The resource manager **402** is preferably implemented in software as a software entity that comprises one or more

software objects. It preferably interfaces with other software entities **312** through the use of object request broker technology. In accordance with an exemplary embodiment, the resource manager **402** provides a proxy for other software entities **312** in which the resource manager **402** may seek to invoke a method or operation. Similarly, a proxy may be associated with a software entity **312** other than the resource manager **402** which may seek to invoke a method or operation associated with the resource manager **402**. An interface is preferably defined between each such proxy to establish acceptable messages and responses that can be exchanged over the defined interface so as to allow a virtual connection to be formed therebetween. The SS7 element **404** provides the logic needed to provide SS7 signaling functionality for SS7 connectivity to a switched network **106**. It is responsible for performing various functions and interfaces associated with the various parts and protocols that are included within SS7 signals. Further details of the resource manager **402** and the SS7 element **404** are provided in the U.S. patent application Ser. No. 09/026,190 designated by DSC Case No. 835-00 and Attorney Docket No. 24194000.181, entitled "Resource Management Sub-System of a Telecommunications Switching System," naming Howard L. Andersen and Scott D. Hoffpauir as inventors, filed concurrently with the instant patent application, and which is incorporated by reference herein for all purposes.

The system controller **406** is responsible for ensuring that the call processor assembly **450** is operating properly by periodically testing elements of the call processor assembly **450**. A successful test of an element of the call processor assembly **450** may comprise, for example, observing a predetermined response from the element after sending a predetermined message to the element. This is sometimes referred to as "pinging" an element.

The NMS server **444** includes several elements for configuring and managing elements of the call processor assembly **450** and resources of the resource assembly **448**. Specifically, the NMS server **444** includes the following elements: configuration management **408**, fault management **410**, performance management **412**, accounting management **414**, security management **416**, and system management **418**. Those elements are operable to provide operations, administration and maintenance related services, and preferably include one or more logical servers.

The configuration management element **408** includes one or more servers to provide services necessary to administer the configurable attributes of the main functional elements associated with the call processing application **440**, the resource manager **402** and the SS7 element **404**. As such, the configuration management element **408** is operable to modify configuration information associated with the call processing application **440**, such as administration of subscriber databases, as well as the configuration of specific elements of the call processing application, such as the base station controller **432** and mobile switching center **434**. Servers of the configuration management element **408** preferably contain software objects that retain attribute information so as to allow an operator to configure the corresponding functional component of the call processing application **440**, the resource manager and the SS7 element **404**. The fault management element **410** provides for the detection, logging and reporting of alarms, errors, and selected events from the call processor assembly **450** and the resource assembly **448**. The performance management element **412** provides for the periodic collection and analysis of system performance and traffic information from the resource assembly **448** and call processing application **440**. The accounting management element **414** attends to the creation and storage of billing records for calls originated or terminated to a subscriber unit **110**, as well as calls forwarded to or from a subscriber unit **110**. Such billing records are in the form of a call data record. The security management element **416** provides for discriminatory access to operation, administration and maintenance operations based on the given operator of the network management system **204**. Various security levels are defined that determine the operations that are available to a given operator. The system management element **418** supports the start-up and recovery functions of the telecommunications system **400**. It is operable to initiate tests to assess the operation of various elements and resources, and to cause the reset of such elements and resources in the event of incorrect operation.

Multiple modules **420** are provided within the resource assembly **448**. Preferably, such modules are replaceable line cards that are interconnected to one another over a backplane. Particular resources are preferably provided on distinct modules **420**. Alternatively, particular resources are distributed over such modules **420**.

Preferably, an ethernet hub **422** allows the call processor assembly **450**, the resource assembly **448** and the NMS server **444** to communicate with one another. Another ethernet hub **424** is provided to allow the NMS server **444** to communicate with both the local NMS client **442** and the remote NMS client **442***a*. That ethernet hub **424** connects to the local NMS client **442** over a wireline connection **446**. That hub **424** also connects to a router **426** that further connects to a modem **428**, which, in turn, connects to the remote NMS client **442***a* over the modem link **446***a*. Further details of the NMS client **442** and NMS server **444** are set forth in U.S. utility patent application designated as DSC Case No. 833-00 and Attorney Docket No. 24194000.179, entitled "Network Management System Server and Method for Operation," naming Scott D. Hoffpauir as inventor, which was filed concurrently with the instant patent application, and which is incorporated by reference herein for all purposes.

While the telecommunications system **400** of FIG. **4** is designed and constructed pursuant to the technical and functional specifications provided for in the current GSM standard, it should be appreciated and understood that the present invention should not be understood or construed to be so limited. Rather, the present invention is equally applicable to use with technologies and applications other than GSM, including, among others, PCS, CDMA and TDMA technologies, as well as those associated with wireline systems, such as tandem switching systems.

FIG. **5** illustrates various elements included within the call processor assembly **450**, designed consistent with the GSM standard and in accordance with an exemplary embodiment of the present invention.

In addition to the base station controller **432** and mobile switching center **434**, the call processing application **440** provides other elements that take part in processing calls directed to, or initiated by, the subscriber units **110**. Specifically, the call processing application **440** includes a visitor location register **502** (abbreviated VLR), a home location register **504** (abbreviated HLR) and a mobile application part provider **506** (abbreviated MAP-P). Such elements are preferably implemented as distinct software entities.

Both the home location register **504** and the visitor location register **502** provide a database function for sub-

scriber related information. Such subscriber related information includes subscription information for such subscribers, such as the service options to be provided to each subscriber (for example, voice mail, call waiting, call forwarding, etc.), preferences and option selections supplied by the subscribers (for example, call forwarding numbers or criteria), and the location of those subscribers. The home location register **504** provides that database function for certain set of subscribers, namely, those subscribers enrolled for service with the operator of the telecommunications system **400** or otherwise associated with the telecommunications system **400**. In contrast, the visitor location register **502** provides a database function for those subscribers known to be situated in the area serviced by the telecommunications system **400** and its associated base transceiver stations **440**. Those subscribers would therefore include roaming subscribers, i.e., subscribers associated with another service provider or telecommunications system for which subscriber related information is maintained externally but not in the home location register **504** of the telecommunications system **400**. To obtain subscriber related information about a roaming subscriber, the visitor location register **502** of a telecommunications system **400** would therefore have to access the home location register of another operator or telecommunications system. Such access would, in turn, provide that external home location register with knowledge of the location of the roaming subscriber.

It is preferable to form distinct elements for the various elements provided for in the call processing application **440**. By providing distinct elements, such as software entities, functionality is encapsulated and isolated from other elements, which allows for such elements to be readily modified, removed or interfaced with other elements.

SS7 type signaling is provided to the telecommunications system **400** as a transport mechanism for mobile application part dialogues and out-of-band signaling with other switches. That signaling includes several parts, each having a distinct protocol. Specifically, SS7 signals include: (a) a lower layer Message Transfer Part (abbreviated MTP), which applies to call related or non-call related signaling; (b) a Signaling Connection Control Part (abbreviated SCCP) and a Transaction Capabilities Application Part (abbreviated TCAP), which apply to non-call related signaling and (c) TUP and ISUP, which apply to call related signaling. The SS7 element **404** includes elements that correspond with the aforementioned parts, namely, a MTP Layer 2 element **508**, a MTP Layer 3 element **510**, and ISUP/TUP element **512**, a SCCP element **514** and a TCAP element **516**. Through these elements, the SS7 element **404** provides functionality related to each of those elements **508–516**, including global title translations and terrestrial and satellite links.

The SS7 manager **518** provides for management and cooperation with respect to the other elements of the SS7 element **404** and other elements of the call processor assembly **450**, such as the resource manager **402**, the mobile application part provider **506** and the mobile switching center **434**.

The mobile application part provider **506** is the logical link between the visitor location register **502** and home a location register **504**. As such, it is directly associated with the visitor location register **502** and the home location register **504** and provides the dialogues through which they communicate with each other and with other elements. The mobile application part provider **506** provides a protocol based on the services provided by the SS7 element **404** for non-call related signaling (specifically, TCAP) for use by other elements. The specific nature of the protocol provided by the mobile application part provider **506** is dependent on the identity of such elements, which is sometimes referred to as the MAP protocol interface. For example, messages between the visitor location register **502** and an external home location register utilize one MAP protocol interface while messages between the home location register **504** and an external visitor location register utilize another MAP protocol interface. Preferably, authentication functions are integrated within the home location register **504** to provide authentication information to the home location register **504** for validating subscribers requesting service from the telecommunications system **400**. Further details of mobile application part provider **506** are set forth in the U.S. patent application Ser. No. 09/026,230 designated by DSC Case No. 852-00 and Attorney Docket No. 24194000.197, entitled "Application Provider and Method for Communication," naming Scott D. Hoffpauir and Steve B. Liao as inventors, which was filed concurrently with the instant patent application, and which is incorporated by reference herein for all purposes.

The call processing application **440** is preferably implemented as a distinct software layer, such as an application layer **304** that is discussed above in connection with FIG. **3**A. Further, each of the elements **432–434**, **502–506** of the call processing application **440** are preferably implemented as distinct software entities. As such, virtual connections **520** are preferably formed between the base station controller **432** and the resource manager **448**, as well as between a mobile switching center **434** and the resource manager **448** by employing object request broker technology and associated techniques. Likewise, virtual connections **520** are also preferably formed between the mobile application part provider **506** and the SS7 element **404**.

Wireless telecommunications systems may employ various types of radio interface technology, such as, for example, TDMA, CDMA or FDMA technologies. TDMA technology allows for several subscriber units **110** to communicate simultaneously over a single radio carrier frequency by dividing a signal into time slots, which can be dedicated or dynamically assigned. Accordingly, TDMA systems have narrowband voice or traffic radio channels but can have wideband radio signals. Digital techniques are employed at base stations and in subscriber units **110** to subdivide time on each channel into timeslots. Like the above described GSM telecommunications system **400**, systems that employ TDMA technology typically include, for example, a home location register, a visitor location register and a mobile switching center. Such TDMA systems may also include a radio controller. Several standards have been created with respect to wireless telecommunications TDMA systems employing TDMA technology. Such standards include Interim Standard 54 (abbreviated IS-54) and Interim Standard 136 (abbreviated IS-136) by the Telecommunications Industry Association and the Electronic Industries Association, as well as the Global System for Mobile Communication (GSM) standard. Variants of the GSM standard, which also use TDMA technology, include the PCS-1900 standard for North America and the DSC-1800 standard. CDMA technologies typically divide the radio spectrum into wideband digital radio signals with each signal waveform carrying several different coded channels. Coded channels are each identified by a unique pseudo-random noise code. Digital receivers separate the channels by matching signals with the proper pseudo-random noise code sequence. Like the above described GSM telecommunications system **400**, telecommunications systems that employ CDMA technology typically include, for example, a

home location register, a visitor location register and a mobile switching center. Several standards presently exist with respect to wireless telecommunications systems that employ CDMA technology, such as, for example, Interim Standard 95 (abbreviated IS-95), Interim Standard 41 (abbreviated IS-41) and Interim Standard 634 (abbreviated IS-634) by the Telecommunications Industry Association and Electronic Industries Association.

Operations carried out by the call processing application **440** preferably include substantially all of the functionality that is unique and specifically associated with a particular standard, such as the GSM standard. In doing so, and by implementing the call processor application **440** as a distinct software layer **302–310** having distinct software entities **312**, such unique functionality is isolated and can be readily modified by adapting the software entities **312** found in the call processing application **440**. Further, a given standard specific call processing application **440** can be readily replaced by another standard specific application.

For instance, a call processing application designed consistent with the GSM standard can be modified to provide, or replaced with, a call processing application consistent with the CDMA standard. Such modifications or replacements are facilitated by the provision of software entities **312** for the various elements that comprise the call processing application **440**. As a specific example, consider the call processing application **440** of FIG. **4**, which is designed consistent with the GSM standard and in accordance with an exemplary embodiment of the present invention. That call processing application **440** can readily be reconfigured to be consistent with the CDMA technologies and standards. Such modifications would require, for example, that the mobile application part provider **506**, visitor location register **502** and home location register **504** be reconfigured to be consistent with the protocol specified by the IS-41 standard, and that the base station controller **432** be reconfigured to be consistent with the protocol specified by IS-634 standard, and certain other modifications. Corresponding changes would also likely be required with respect to configuration management element **408** and its associated client elements. No substantial modifications would be required to the resource assembly **202** or the software associated with it, such as the resource manager **448**. Defined interfaces between the software entities **312** of the call processing application **440** and other software layers, which may be provided by an object request broker **314**, would require only minor modifications.

FIG. **6** more specifically illustrates various elements of the NMS client **442** and NMS server **444** and resources of the resource assembly **448**, designed consistent with the GSM standard and in accordance with an exemplary embodiment of the present invention.

As illustrated in FIG. **6**, the resource assembly **448** preferably includes a switching module **644**, a telephony support module **646**, a signal processing module **648** and an interface module **650**. Each of those modules preferably include software and communicate with the resource manager **402** of the call processor assembly **450**. As discussed more fully with respect to FIG. **7**, each of those modules **644–650** preferably include specific resources that can be employed by the call processor assembly **450**. Alternatively, specific resources may be distributed amongst the various modules **420**. It should therefore be recognized and appreciated that the allocation of resources within the resource assembly **448** is not pertinent to the scope of the present invention.

The software architecture of the telecommunications system **400** is preferably based on object oriented software engineering technology, and the use of managed objects provided within the network management system **204**. Managed objects are provided to support system logical attributes and administrative functions. Managed objects model the various functional, hardware, and interface components and subcomponents associated with the telecommunications system **400**. Such software may also model the functional procedures performed by physical components. Managed objects can be created, modified, and deleted by an operator.

Preferably, the NMS server **444** includes a set of elements, which contain managed objects, that communicate with corresponding set of elements of the NMS client **442**. Operators of the NMS client **442** can cause the retrieval and display of a managed object of the NMS server **444**, which can then be modified by the operator. Elements of the NMS server **444** and NMS client **422**, which are discussed more fully below, are preferably implemented as software entities.

There is provided elements resident within the NMS server **444** and the NMS client **442** that correspond to those functional elements provided in the call processing application **440**, as well as the resource manager **402** and the SS7 element **404**. Namely, the configuration management element **408** of the NMS server **444** preferably includes a BSC server **602**, a RM server **604**, a MSC server **606**, a SS7 server **608**, a MAP-P server **610**, a VLR server **612** and a HLR server **614**. Similarly, the NMS client **442** preferably includes a BSC client **622**, a RM client **624**, a MSC client **626**, a SS7 client **628**, a MAP-P client **630**, a VLR client **632** and a HLR client **634**. Such NMS client elements **622–634** are operable to provide a graphical user interface to, and receive configuration information from, an operator with respect to the associated elements of the call processor assembly **450**. Such NMS server elements **602–614** are responsible for validating and storing the configuration information from such NMS client elements **622–634** for use by elements of the call processor assembly **450**.

For example, an operator can make changes to reflect the addition or removal of hardware components or modifications to their operational parameters, changes to reflect the addition or removal of subscribers and to subscriber service profiles, and modify translation tables of the mobile switching center **434**. Changes made by an operator are sent to the appropriate server elements of the NMS server **444** which, in turn, update local data base, notify all peer elements of the call processing application **408** of those changes, and report the completion status of the change request to the operator.

The system management server **418** of the NMS server **442** supports the start-up and recovery functions of the telecommunications system. Preferably, it is responsible for the sequential, automatic start-up of other NMS server elements by reading system start-up files and periodically polling such elements to verify their operational status and automatically restarting failed elements. It periodically requests that functional elements of the telecommunications system **400** update their stored configuration files to support system recovery. This ensures the availability of start-up files that will allow the system processors to restart at a known configuration state following a shutdown or reset. The system management client **636** of the NMS client **442** provides an operator with a list of elements residing in the telecommunications system **400**, the software version and status of such elements. The operator is also provided with the ability to start, stop or query the status of individual servers through that client element **636**.

The security management server **416** is preferably responsible for validating operator log-in information and restrict-

ing access to certain operations based on the operator's access class. It may also be responsible for management of user identification, passwords, and access levels.

An accounting management server **414** and a corresponding accounting management client **638** are preferably respectively provided within the NMS client **442** and NMS server **444**. Billing records, in the form of call data records, are reported from the accounting management server **414**, which stores those records on a database associated with the NMS server **444**. Such billing records may also be transferred from the accounting management server **414** to the accounting management client **638** for storage with an associated memory.

A performance management server **412** and a corresponding performance management client **640** are preferably respectively provided in the NMS client **442** and the NMS server **444**. The performance management server element **412** polls the call processing application **440** for function-specific performance measurements, and generates reports and statistics based on those measurements. Such reports and statistics may be presented for display by the performance management client **640**.

Alarms and fault-related events are routed from an event filtering and reporting (abbreviated EFR) server **618** to the NMS client **442** for display and to the log server **616** for storage and later processing. The NMS client **442** includes a filtering and reporting mechanism, the fault monitor **642**, that allows an operator to tailor alarm, event, and state change reporting to meet specific needs.

The fault monitor **642** includes browsers that provide one or more operators with current alarm, event, alarm and state change information and maintains a consistent view of network alarm conditions. Real-time notifications are forwarded to the fault monitor from the EFR server **618**. An operator has the ability to filter these notifications (messages) based on their type and severity level.

The EFR server **618** provides common services that support various elements of the NMS client. The EFR server **618** receives real-time event notifications, such as alarms, test results and billing records, generated by the call processor assembly **450** and resource assembly and other elements of the NMS server **444**. The EFR server **618** is operable to filter them, and then route them to certain destinations within the telecommunications system **400**.

The log control server **616** is responsible for logging functions. As such, it receives various alarm, event, and state change notifications from the EFR server **618** and stores the information to a database associated with the NMS client **442**.

The call processing application **440**, the NMS client **442** and the NMS server **444** are preferably implemented as distinct software layers. Further, the NMS client elements **622–634**, performance management server **412**, accounting management server **414**, security management server **416**, system management server **418**, system controller **406**, SS7 element **404**, resource manager **448**, elements provided in the call processing application **440**, as well as the configuration management **408** and fault management **410** elements, are preferably implemented as software entities. As such, virtual connections **652** are preferably formed between the software entities of the NMS client **442** and corresponding software entities of the NMS server **444** by employing object request broker technology and associated techniques. Similarly, virtual connections **654** are preferably formed between software entities of the configuration management element **408** and corresponding software entities of the call processing application **440**, between the system management **418** and system controller **406** elements, as well as between the EFR server **618** and performance management server **412** and various software entities of the call processor assembly **450**. Virtual connections **656** are also preferably formed between the resource manager **448** and various software entities of the resource assembly **448**.

FIG. **7** illustrates various modules **420** of the resource assembly **448**, designed consistent with the GSM standard and in accordance with an exemplary embodiment of the present invention. In accordance with an exemplary embodiment, one or more switching modules **644**, interface modules **650**, telephony support modules **646** and signal processing modules **648** are provided within a resource assembly **448**. The interface modules **650**, signal processing modules **648** and telephony support modules **646** are coupled through one or more of the switching modules **644**. Control information is provided by a switching module **644** to other modules over the redundant control bus **704**. Data is provided by a switching module **644** to other modules over a high speed bus **706**.

A switching module **644** may be implemented in software, hardware or a suitable combination of software and hardware. A switching module **644** preferably performs switching operations, clock operations, and local communications between resources of the resource assembly **448** of the telecommunications system **400**. These operations may be performed using pulse code modulation switching and data transfer techniques, Link Access Protocol on the D Channel (abbreviated LAP-D) communications and ethernet interface communications.

A switch **708** preferably resides within a switching module **644** to perform the switching functions and operations. That switch **708** may be a timeslot switch having a memory timeslot matrix to make required timeslot cross-connections within the telecommunications system **400**. The switch **708** functions to set up and tear down both simplex and duplex connections between two specified channels, which may represent a call or other useful connections. For example, the switch **708** may cause a channel to connect a channel (provided by, for example, a base transceiver station **440** or a switched network **106**) to a call progress tone or a voice announcement. Further, the switch **708** should be operable to set up system defined connections upon power up and reset as well as connections for the testing of timeslots when not in use. Timeslots are preferably provided to the timeslot switch via the high speed bus **706**.

A switching module **644** may also, for example, include suitable digital data processing devices, a processor, random access memory and other devices. Preferably, each switching module **644** runs a suitable operating system, and include one or more pulse code modulation bus interfaces, one or more High Level Data Link Controller (abbreviated HDLC) control bus interfaces, one or more ethernet interfaces, and an arbitration bus interface to other switching modules **644**.

A telephony support module **646** may be implemented in software, hardware or a suitable combination of software and hardware. A telephony support module **646** may, for example, provide tone generation, digit transceiver functions, and digitized announcements for the telecommunications system **400**. Telephony support modules **646** may also provide call setup functions, such as digit collection and out-pulsing, and call completion functions, such as digitized announcement generation and call supervisory tone generation. A telephony support module **646** may, for example,

include suitable telecommunications data processing equipment, such as a processor, random access memory, one or more redundant High Level Data Link Controller bus interfaces, one or more pulse code modulation buses, and an arbitration bus for establishing active telephony support module **646** status. Preferably, a single telephony support module **646** provides all required functionality for the telecommunications system **400**, and one or more additional telephony support modules **646** are used to provide redundancy in the event of component failure.

An interface module **650** is an interface device that is used to interface a suitable number of telecommunications lines that carry data in a predetermined format, such as an E1 data format, with the telecommunications system **400**. Interface modules **650** provide the physical interface between the telecommunications system **400** and other equipment, a switched network **106** and base transceiver stations **440**. Interface modules **650** also support in-band trunk signaling for DSO data channels that are configured for channel associated signaling, and transmit data to and receive data from a signal processing module **648**. An interface module **650** may be implemented in software, hardware or a suitable combination of software and hardware. For example, an interface module **650** may include suitable data processing equipment, such as a processor, random access memory, up to four E1 ports, redundant High Level Data Link Controller bus interfaces, and pulse code modulation bus interfaces.

A signal processing module **648** is preferably used to provide an interface between a call processor assembly **450** and a signaling system. For example, signaling data may be received from a data transmission channel from the switched network **106**, and may be switched to another data transmission channel, such as an E1 telecommunications channel, from an interface module **650** to a signal processing module **648** by a switching module **644**. A signal processing module **648** is also preferably employed to perform transcoding and rate adaption functions, such as converting from a wireless system speech encoding format to a pulse code modulation data format, as well as other functions, such as echo cancellation functions. For example, signal processing modules **648** may be employed by telecommunications system **400** to convert data from the GSM data format to another format, such as the pulse code modulation data format.

One or more digital signal processors (abbreviated DSP) **702** are preferably provided within the signal processing module **648**. A multi-channel transcoder rate adapter unit **308** is preferably implemented in a digital signal processor **702**. That is, one or more digital signal processors **702** preferably incorporate functions associated with the transcoder rate adapter unit **308**. Such digital signal processors **702** preferably include multiple input and output buffers for storing multiple channel audio data, and perform rate adaption through an interrupt-driven routine that places the appropriate channel data onto both the near-end and far-end transmission lines at the appropriate data rate. With the implementation of rate adaption, such digital signal processors **702** also has further processing power available to perform encoding and decoding of the incoming audio data. In addition to functions associated with the transcoder rate adapter **308**, an echo-cancellation capability may be advantageously provided by the digital signal processors **702** by utilizing the already robust voice activity detection bits produced in transcoding a signal. An example of a single digital signal processor **702** that provides transcoding, rate adaption, and echo-cancellation functions, and using an improved decoding process, is disclosed in U.S. patent application No. 08/678,254, entitled "Multi-Channel Transcoder Rate Adapter Having Low Delay and Integral Echo Cancellation," naming James M. Davis and James D. Pruett as inventors, filed Jul. 11, 1996, and which is incorporated by reference herein for all purposes.

An E1 or T1 transmission line providing a 16,000 bits per second signal, which may carry four traffic channels, may be coupled to an interface module **650**. That signal may, in turn, be connected to a digital signal processor **702** over a high speed bus **706**. A digital signal processor **702** is further connected to a 64,000 bits per second transmission line also capable of carrying, for example, four traffic channels. The 64,000 bits per second transmission line can be, for example, a 64,000 bits per second PCM line. These lines are functionally bi-directional; each transmission line is connected to both an input and output of the digital signal processor **702**. A digital signal processor **702** may be further connected via an address bus, a data bus, and a control bus to at least one random access memory and at least one read only memory device, in a conventional manner. A digital signal processor **702** used in this exemplary embodiment can be, for example, an Analog Devices 2106x digital signal processor chip.

A signal processing module **648** may be implemented in software, hardware or a suitable combination of software and hardware. In addition to one or more digital signal processors **702**, a signal processing module **648** may include suitable data processing equipment, such as a processor, random access memory, four daughter board module ports, redundant High Level Data Link Controller bus interfaces, pulse code modulation matrix bus interfaces and other signal processing application hardware.

In operation, a subscriber unit **110** may attempt to place a call using the telecommunications system **400** by the following procedures. Signaling data and other call control data is received from a base transceiver station **440** in an E1 data format at an interface module **650**. That data is then switched through a switching module **644** to a telephony support module **646**, which performs call setup functions. A call processor assembly **450** receives the signaling data, and determines the call destination. Depending upon the call destination, the call processor assembly **450** sends signaling and call control data to the switched network **106**, another telecommunications system, or a base transceiver station **440** serviced by the telecommunications system **400**. If a telecommunications channel cannot be established, a busy signal, a no answer message, or another appropriate response is generated by the telephony support module **646**, and the call attempt is terminated. If a telecommunications channel can be established, the call processor assembly **450** configures the switching module **644**, telephony support module **646**, interface modules **650**, and signal processing module **648** to process the call data. A similar process is also used to handle incoming telecommunications channels from other telecommunications switches or the switched network **106**, or to de-allocate elements of the telecommunications system **400** after the call is completed.

The present invention is well adapted to carry out the objects and attain the ends and advantages mentioned, as well as others inherent therein. While an exemplary embodiment of the invention have been given for the purposes of disclosure, alternative embodiments, changes and modifications in the details of construction, interconnection and arrangement of parts will readily suggest themselves to those skilled in the art after having the benefit of this disclosure. This invention is not necessarily limited to the specific embodiment and examples illustrated and described above. All embodiments, changes and modifications encompassed within the spirit of the invention are included, and the

scope of the invention is defined by a proper construction of the following claims.

What is claimed is:

1. A software architecture for a wireless telecommunications system comprising:

a call processing software layer, which includes one or more software entities, encapsulating operations concerning the processing of calls directed to or from the telecommunications system; and

a management software layer, which includes one or more software entities, encapsulating operations concerning operations, administration and maintenance related information.

2. The software architecture for a telecommunications system according to claim **1**, wherein at least one of the software entities of the call processing software layer software layer may invoke one or more of the encapsulated operations of the management software layer.

3. The software architecture for a telecommunications system according to claim **1**, wherein at least one of the software entities of the management software layer may invoke one or more of the encapsulated operations of the call processing software layer.

4. The software architecture for a telecommunications system according to claim **1**, wherein the management software layer stores and accesses the operations, administration and maintenance related information on a data base.

5. The software architecture for a telecommunications system according to claim **1**, further comprising a resource software layer, which includes one or more software entities, encapsulating operations that manage and provide access to telephony resources.

6. The software architecture for a telecommunications according to claim **5**, wherein at least one of the software entities of the resource software layer may invoke one or more of the encapsulated operations of either the call processing software layer or the management software layer.

7. The software architecture for a telecommunications system according to claim **5**, wherein the telephony resources include a switch.

8. A telecommunications system comprising:

a call processor assembly including one or more first processors and a call processing application executed by the first processor(s), the call processing application including one or more software entities that encapsulate operations concerning the processing of calls directed to or from the telecommunications system; and

a network management system including a client portion and a server portion, the client portion including one or more second processors and a client application executed by the second processor(s), the client application including one or more software entities that encapsulate operations concerning the presentation of operations, administration and maintenance related information to a user for adaptation by the user, the server portion including one or more third processors and a server application executed by the third processor(s), the server application including one or more software entities that encapsulate operations concerning the storage of and access to the operations, administration and maintenance related information.

9. The telecommunications system according to claim **8**, wherein at least one of the software entities of the call processing application may invoke one or more of the encapsulated operations of the server application.

10. The telecommunications system according to claim **8**, wherein at least one of the software entities of the server application may invoke one or more of the encapsulated operations of the call processing application.

11. The telecommunications system according to claim **8**, wherein at least one of the software entities of the server application may invoke one or more of the encapsulated operations of the client application.

12. The telecommunications system according to claim **8**, wherein at least one of the software entities of the client application may invoke one or more of the encapsulated operations of the server application.

13. The telecommunications system according to claim **8**, wherein the call processor assembly further includes a resource application executed by the first processor(s), the resource application including one or more software entities that encapsulate operations concerning the management and provision of telephony resources.

14. The telecommunications system according to claim **13**, wherein at least one of the software entities of the resource application may invoke one or more operations of either the call processing application or the server application.

15. The telecommunications system according to claim **13**, wherein an object request broker is associated with the call processing application and the resource application to provide information concerning the encapsulated operations of the call processing application and the resource application so as to enable at least one software entity of the server application to invoke one or more of the encapsulated operations of either the call processing application or the resource application.

16. The telecommunications system according to claim **13**, wherein a proxy is associated with at least one software entity of the call processing application or the resource application to provide information concerning the encapsulated operations associated with that software entity so as to enable at least one software entity of the server application to invoke the encapsulated operations associated with that software entity.

17. The telecommunications system according to claim **8**, wherein an object request broker is associated with the call processing application to provide information concerning the encapsulated operations of the call processing application so as to enable at least one software entity of the server application to invoke one or more of the encapsulated operations of the call processing application.

18. The telecommunications system according to claim **8**, wherein a proxy is associated with at least one software entity of the call processing application to provide information concerning the encapsulated operations associated with that software entity so as to enable at least one software entity of the server application to invoke the encapsulated operations associated with that software entity.

19. The telecommunications system according to claim **8**, wherein an object request broker is associated with the server application to provide information concerning the encapsulated operations of the server application so as to enable at least one software entity of either the client application or the call processing application to invoke one or more of the encapsulated operations of the client application.

20. The telecommunications system according to claim **8**, wherein an object request broker is associated with at least one software entity of the server application to provide information concerning the encapsulated operations associated with that software entity so as to enable at least one software entity of either the client application or the call processing application to invoke the encapsulated operations associated with that software entity.

21. The telecommunications system according to claim 8, wherein an object request broker is associated with the client application to provide information concerning the encapsulated operations of the client application so as to enable at least one software entity of the server application to invoke one or more of the encapsulated operations of the server application.

22. The telecommunications system according to claim 8, wherein an object request broker is associated with at least one software entity of the client application to provide information concerning the encapsulated operations associated with that software entity so as to enable at least one software entity of the server application to invoke one or more of the encapsulated operations associated with that software entity.

23. The telecommunications system according to claim 8, wherein the server application provides data to the client application from which the client application causes the generation of a graphical user interface.

24. A software architecture for a telecommunications system comprising:

a call processing software layer, which includes one or more software entities to provide call processing operations, and which further includes a first object request broker that maintains information by which at least one other software layer may invoke certain of those operations;

a resource software layer, which includes one or more software entities configured to manage and provide access to telephony resources, and which further includes a second object request broker that maintains information by which at least one other software layer may invoke certain of those operations;

a management software layer, which includes one or more software entities to provide operations, administration and maintenance related operations, and which further includes a second object request broker that maintains information by which at least one other software layer may invoke certain of those operations.

25. The software architecture for a telecommunications system according to claim 24, wherein the first object request broker is configured to facilitate the invocation of an operation of a particular software entity of the call processing software layer by a given software entity of either the resource software layer or the management software layer.

26. The software architecture for a telecommunications system according to claim 25, wherein a proxy is associated with the given software entity, the proxy being configured to receive a response to the operation invoked by the particular software entity.

27. The software architecture for a telecommunications system according to claim 24, wherein the second object request broker is configured to facilitate the invocation of a particular software entity of the resource software layer by a given software entity of either the call processing software layer or the management software layer.

28. The software architecture for a telecommunications system according to claim 27, wherein a proxy is associated with the given software entity, the proxy being configured to receive a response to the operation invoked by the particular software entity.

29. The software architecture for a telecommunications system according to claim 24, wherein the third object request broker is configured to facilitate the invocation of a particular software entity of the management software layer by a given software entity of either the resource software layer or the call processing software layer.

30. The software architecture for a telecommunications system according to claim 29, wherein a proxy is associated with the given software entity, the proxy being configured to receive a response to the operation invoked by the particular software entity.

31. A method for communicating between applications associated with a telecommunications system comprising:

providing a first software layer having one or more software entities and a second software layer also having one or more software entities;

receiving a request issued from a given software entity of the first software layer to access a particular operation of a particular software entity of the second software layer;

determining an appropriate messaging format to invoke the particular operation;

composing a message based on the appropriate messaging format; and

directing the composed message to the given software entity.

32. The method according to claim 31, wherein determining an appropriate messaging scheme to invoke the particular operation comprises:

defining an interface for the particular operation;

retrieving the defined interface; and

composing a message in accordance with the defined interface that can be directed to the identified software entity.

33. The method according to 31, wherein the interface for the particular operation is predetermined.

34. The method according to 31, wherein the interface for the identified second software entity is dynamically defined upon receiving the request.

35. The method according to claim 31, wherein either the first software layer or the second software layer is configured to provide call processing functions.

36. The method according to claim 31, wherein the one or more software entities of either the first software layer or the second software layer are configured to manage and provide access to telephony resources.

37. The method according to claim 31, wherein the one or more software entities of either the first software layer or the second software layer are configured to provide operations, administration and maintenance related functions.

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