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(54) **RESOURCE MANAGEMENT SUB-SYSTEM OF A TELECOMMUNICATIONS SWITCHING SYSTEM**

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(51) **Int. Cl.**[7] **H04L 12/28**

(52) **U.S. Cl.** **370/419**

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

0123456-A2 1/2000 (EP) 100/100

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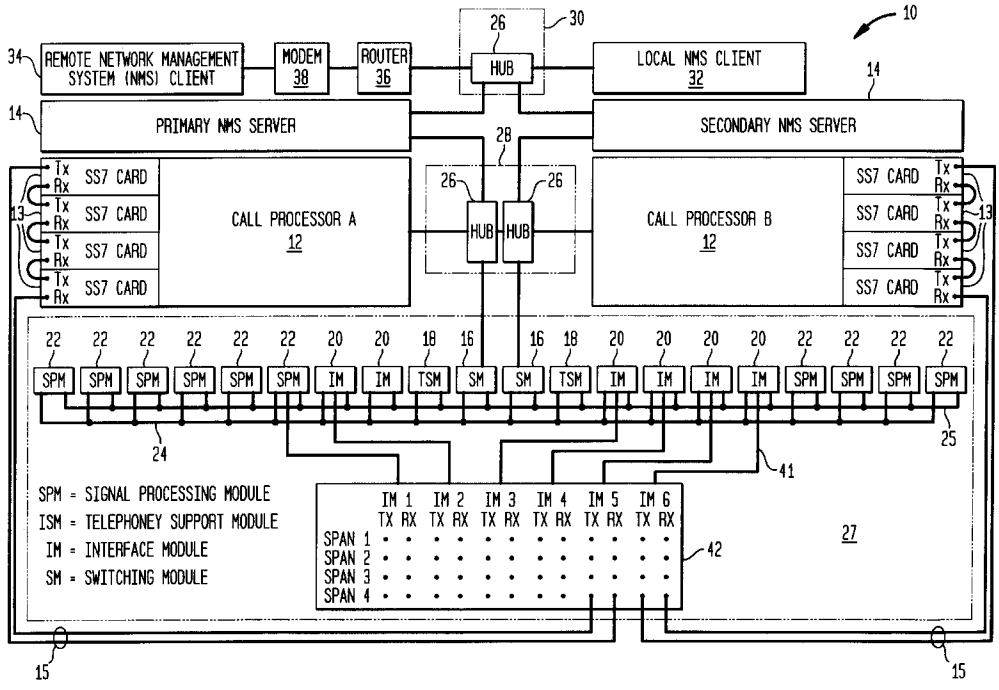
(57) **ABSTRACT**

A telecommunications switching system with a hardware resource manager system. The resource manager interfaces with higher-level system functions such as call processing, OA&M, NMS and system control functions and with lower-level hardware functions embodied in an input/output sub-system (IOSS) containing various hardware resources for interfacing the switching system to other entities. The resource manager controls all interactions between the IOSS hardware and the higher-level functions and hides the hardware specifics of the IOSS, giving the higher-level functions a hardware-independent view of the IOSS resources. As a result, the higher-level functions can operate without modification with a wide variety of IOSS hardware configurations. The resource manager manages the physical interfaces and IOSS resources and is aware of the complete configuration of the IOSS, including all channel addressing information and the state of each IOSS resource. The interfaces between the resource management sub-system and the higher-level functions utilize distributed objects. The resource manager uses the configuration and state information from the IOSS to model each hardware component and communications channel as a managed object, which managed objects are used in the object-oriented interfaces with the higher-level functions of the switching system. Resource characteristics and statuses are available to the higher-level functions as attributes of the resource models. Method calls are provided to manipulate the objects for such operations as loading, testing and controlling the states of the various modeled hardware resources.

3 Claims, 6 Drawing Sheets



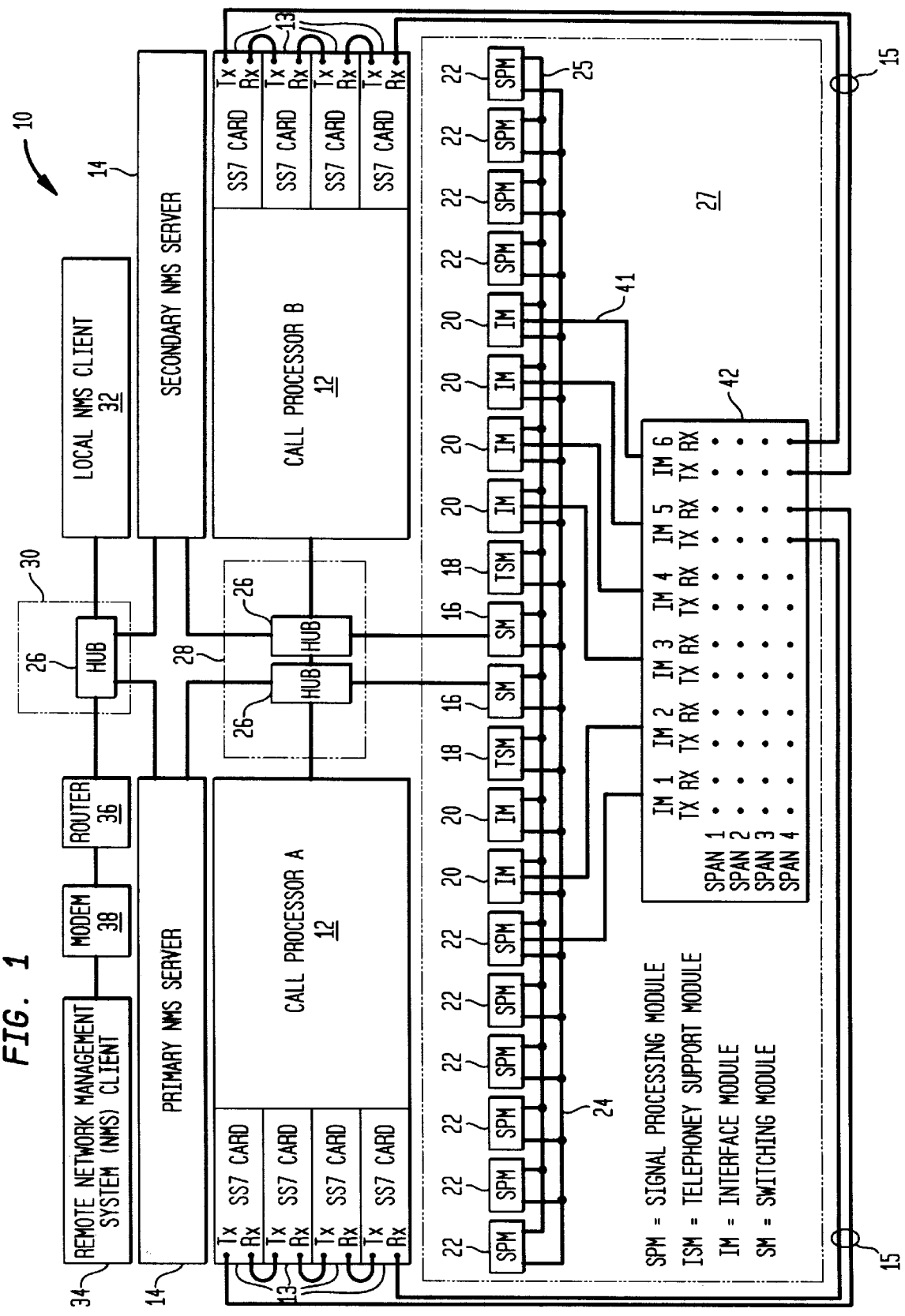

10
14
LOCAL NMS CLIENT 32
SECONDARY NMS SERVER
CALL PROCESSOR B 12
SS7 CARD
Tx
Rx
13
30
26
HUB
28
ROUTER 36
MODEM 38
REMOTE NETWORK MANAGEMENT SYSTEM (NMS) CLIENT
34
PRIMARY NMS SERVER
CALL PROCESSOR A 12
SPM
TSM
SM
IM
22
20
18
16
24
25
27
41
42
IM 1 IM 2 IM 3 IM 4 IM 5 IM 6
TX RX TX RX TX RX TX RX TX RX TX RX
SPAN 1
SPAN 2
SPAN 3
SPAN 4
15
SPM = SIGNAL PROCESSING MODULE
TSM = TELEPHONEY SUPPORT MODULE
IM = INTERFACE MODULE
SM = SWITCHING MODULE

FIG. 1

FIG. 2

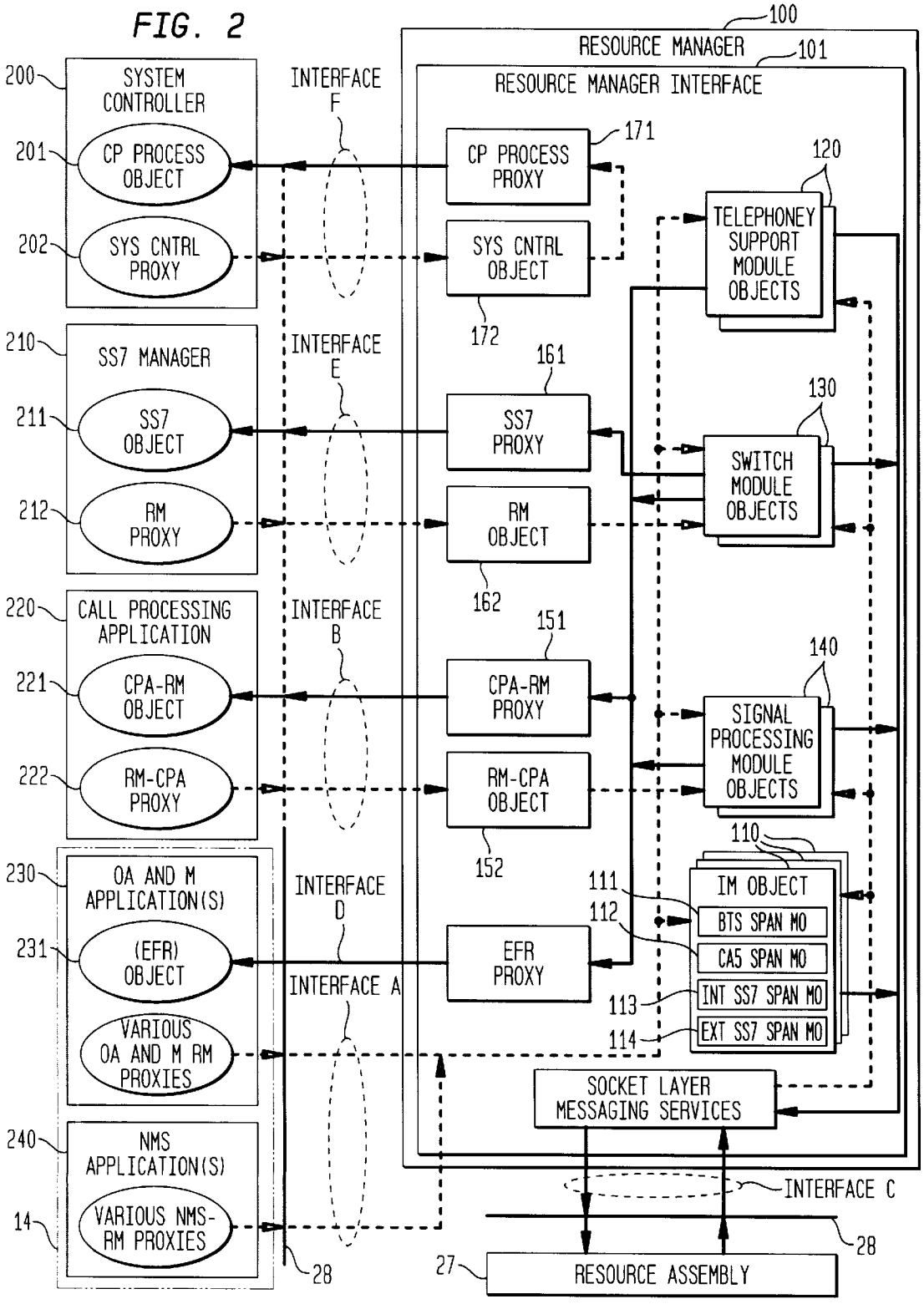
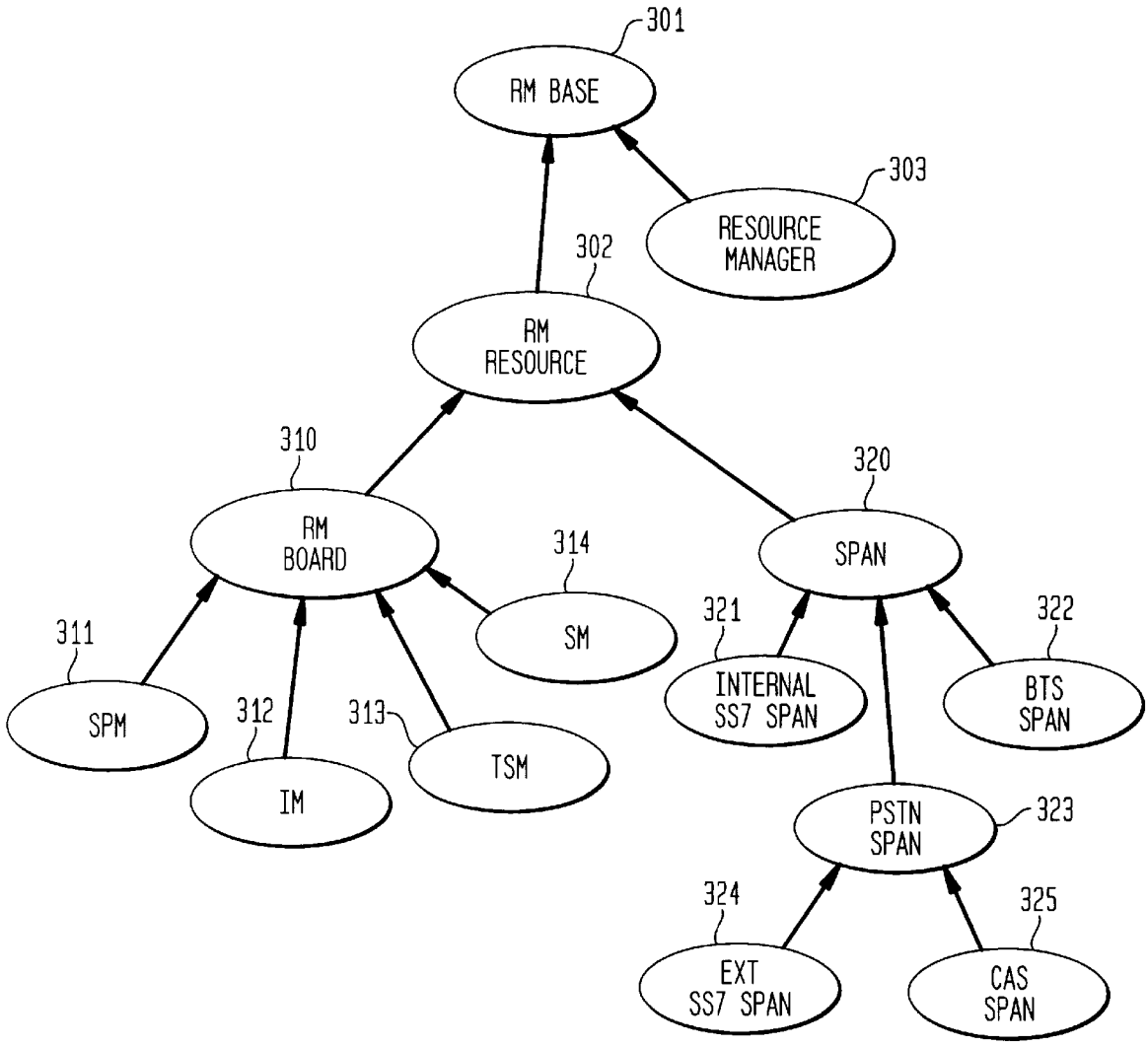

100
RESOURCE MANAGER
101
RESOURCE MANAGER INTERFACE
200
SYSTEM CONTROLLER
201
CP PROCESS OBJECT
202
SYS CNTRL PROXY
INTERFACE F
171
CP PROCESS PROXY
SYS CNTRL OBJECT
172
120
TELEPHONEY SUPPORT MODULE OBJECTS
210
SS7 MANAGER
211
SS7 OBJECT
212
RM PROXY
INTERFACE E
161
SS7 PROXY
RM OBJECT
162
130
SWITCH MODULE OBJECTS
220
CALL PROCESSING APPLICATION
221
CPA-RM OBJECT
222
RM-CPA PROXY
INTERFACE B
151
CPA-RM PROXY
RM-CPA OBJECT
152
140
SIGNAL PROCESSING MODULE OBJECTS
110
230
OA AND M APPLICATION(S)
231
(EFR) OBJECT
VARIOUS OA AND M RM PROXIES
INTERFACE D
INTERFACE A
EFR PROXY
111
112
113
114
IM OBJECT
BTS SPAN MO
CA5 SPAN MO
INT SS7 SPAN MO
EXT SS7 SPAN MO
240
NMS APPLICATION(S)
14
VARIOUS NMS-RM PROXIES
28
SOCKET LAYER MESSAGING SERVICES
INTERFACE C
28
27
RESOURCE ASSEMBLY

FIG. 3


301
RM BASE
303
RESOURCE MANAGER
302
RM RESOURCE
310
RM BOARD
314
SM
320
SPAN
311
SPM
312
IM
313
TSM
321
INTERNAL SS7 SPAN
322
BTS SPAN
PSTN SPAN
323
324
EXT SS7 SPAN
325
CAS SPAN

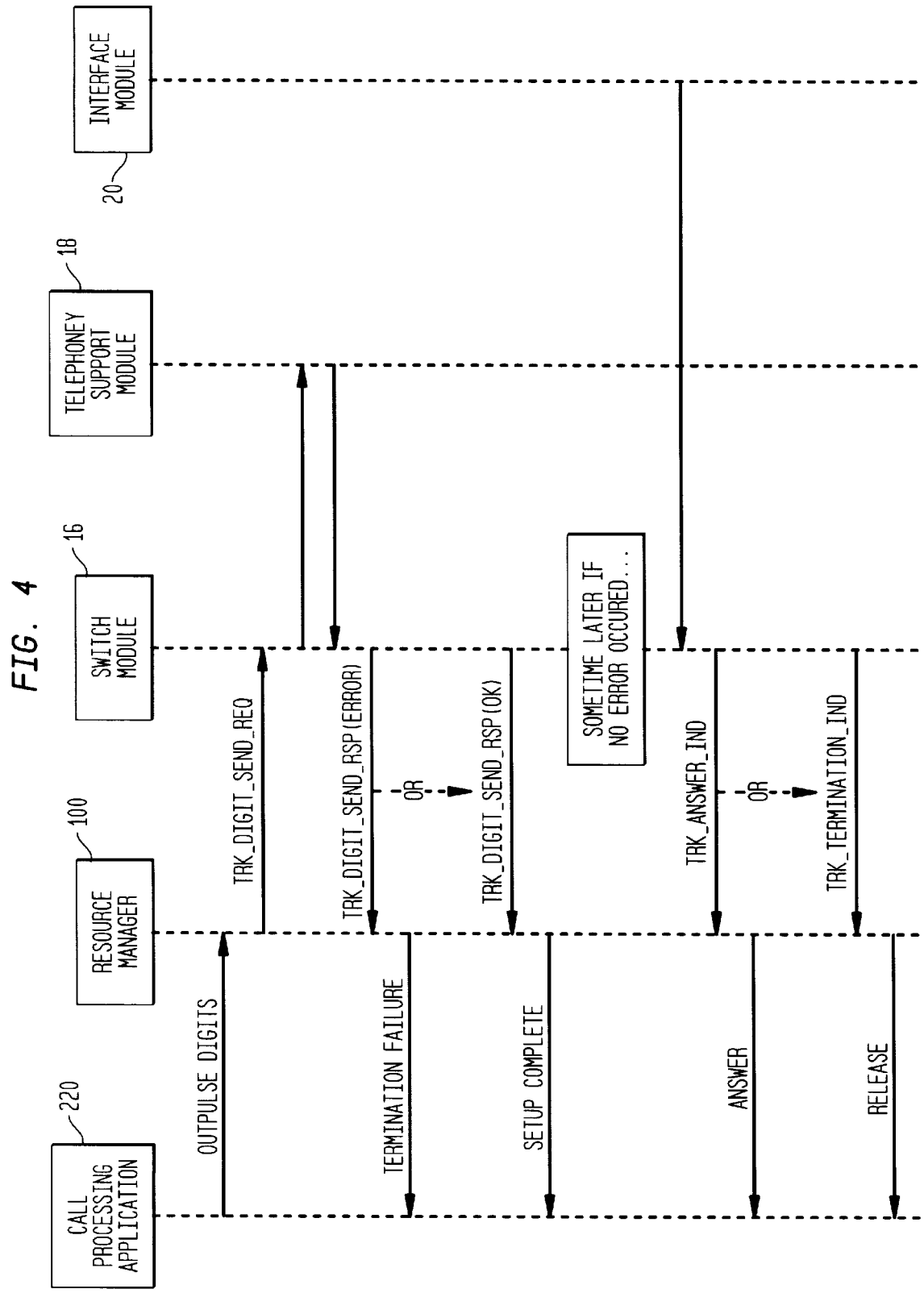
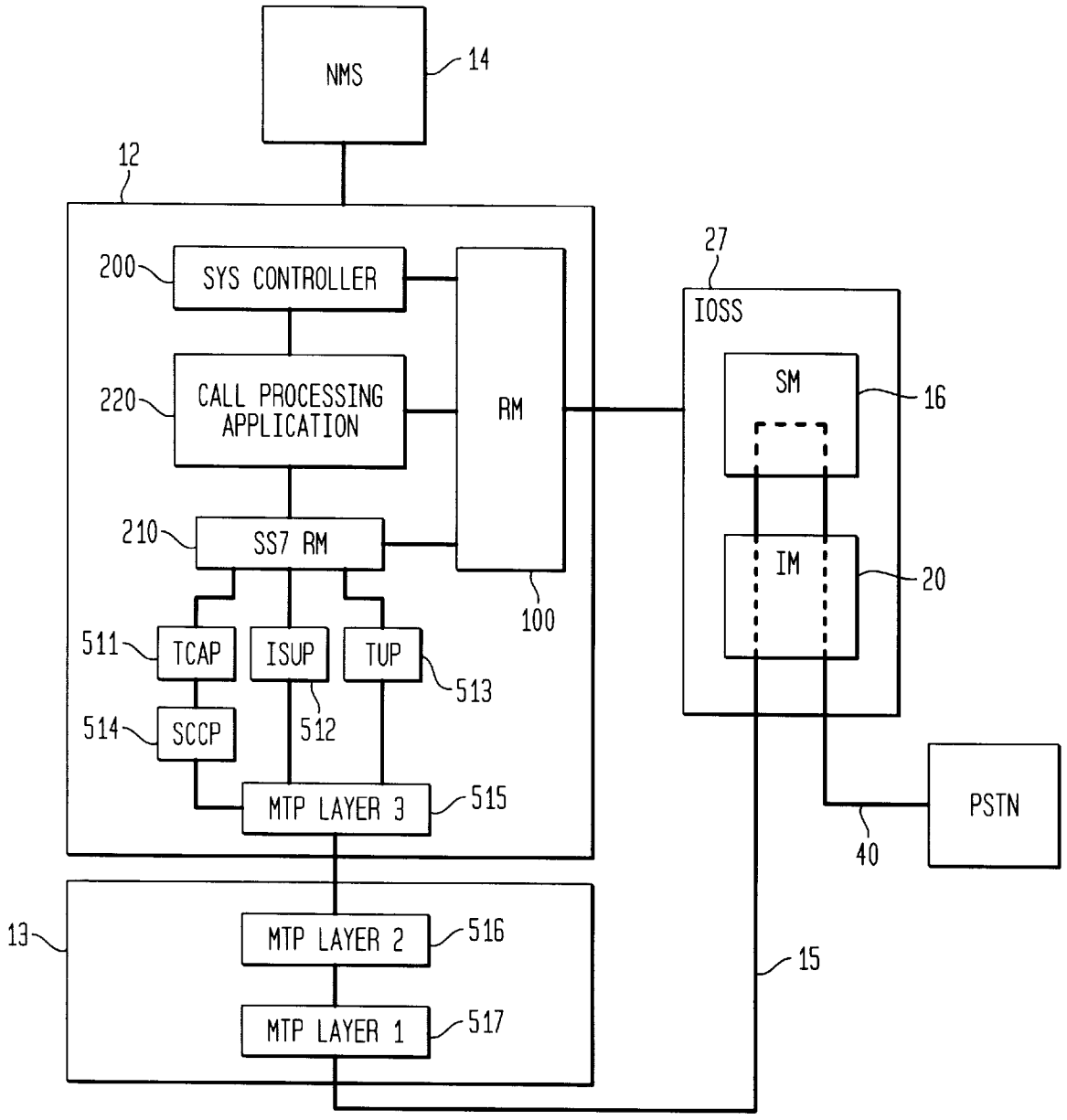

INTERFACE MODULE
20
TELEPHONEY SUPPORT MODULE
18
SWITCH MODULE
16
RESOURCE MANAGER
100
CALL PROCESSING APPLICATION
220
TRK_DIGIT_SEND_REQ
OUTPULSE DIGITS
TRK_DIGIT_SEND_RSP(ERROR)
OR
TRK_DIGIT_SEND_RSP(OK)
TERMINATION FAILURE
SETUP COMPLETE
SOMETIME LATER IF NO ERROR OCCURED...
TRK_ANSWER_IND
OR
TRK_TERMINATION_IND
ANSWER
RELEASE

FIG. 4

FIG. 5


NMS
14
12
200
SYS CONTROLLER
220
CALL PROCESSING APPLICATION
210
SS7 RM
RM
100
511
TCAP
ISUP
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514
SCCP
512
MTP LAYER 3
515
13
MTP LAYER 2
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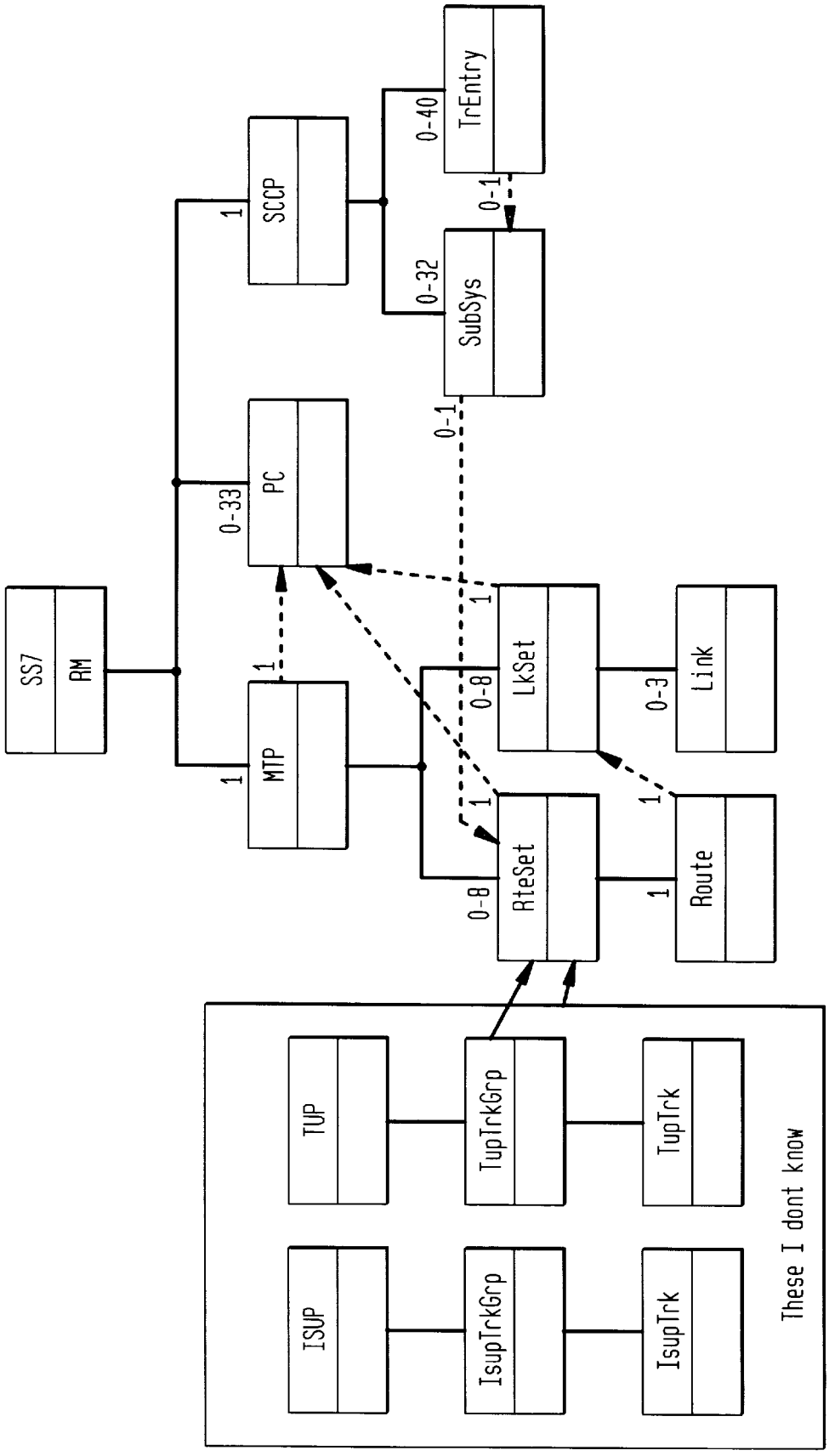
MTP LAYER 1
517
27
IOSS
SM
16
IM
20
PSTN
40
15

FIG. 6


SS7
RM
SCCP
TrEntry
SubSys
PC
MTP
LkSet
Link
RteSet
Route
TUP
TupTrkGrp
TupTrk
ISUP
IsupTrkGrp
IsupTrk
These I dont know
1
0-40
0-1
0-32
0-33
0-8
0-3

RESOURCE MANAGEMENT SUB-SYSTEM OF A TELECOMMUNICATIONS SWITCHING SYSTEM

CLAIM OF PRIORITY

The instant patent application claims priority from U.S. Provisional Patent Application Serial No. 60/060,107, entitled CELLULAR COMMUNICATION SYSTEM, filed on Sep. 26, 1997 and U.S. Provisional Patent Application Serial No. 60/071,151, entitled COMMUNICATION SYSTEM SWITCHING SYSTEM RESOURCE MANAGER, filed Jan. 12, 1998.

FIELD OF THE INVENTION

The present invention relates to telecommunications systems, and more particularly to the management and control of resources in a telecommunications switching system.

BACKGROUND INFORMATION

A conventional telecommunications switching system comprises a variety of hardware and software components. Typical hardware components include a switching device, for routing calls into and out of the system; trunk interface devices, for interfacing the system to incoming and outgoing trunks (e.g., E1 or T1); signal generating devices for generating various call progress signals, DTMF tones, etc.; digital signal processors (DSPs) for compressing and decompressing digitally encoded voice signals and/or performing echo cancellation, and a controller for controlling the operation of the overall switching system and for providing call processing (CP) and operations, administration and maintenance (OA&M) functions. The system may also include a network management system (NMS) for such functions as configuration, accounting, fault management and testing.

A conventional wireless telecommunications switching system includes a base station controller (BSC) coupled to multiple base transceiver stations (BTS) over one or more spans, a mobile switching center (MSC), a visitor location register (VLR), a home location register (HLR), an authentication center, an operations, administration and maintenance (OA&M) center for configuring the BSC and an OA&M operation maintenance center-switching component for configuring the HLR and/or the MSC.

The various software components of such switching systems typically reside in the controller and in one or more of the other lower-level hardware components. For example, the switching device may have its own processor, executing low-level code resident in non-volatile memory in the switching device. The controller would typically interact with the other hardware components by sending specific commands or exchanging specific messages over a bus in a well-defined manner.

The software configuration of such conventional switching systems can be characterized as being tightly coupled vertically. In other words, the various layers or components of software are highly interdependent and also highly hardware- or platform-dependent. Modification of one component of software to add functionality would likely require modification of other components. Likewise, modification of the hardware, would likely require extensive modification of software. Furthermore, such software once written for a particular platform, cannot be readily redistributed over multiple, possibly remotely located processors. This makes for an inflexible switching system that cannot be readily modified.

SUMMARY OF THE INVENTION

The present invention is directed to a telecommunications switching system comprising a novel hardware control and interface arrangement.

In accordance with an exemplary embodiment of the present invention, a telecommunications switching system comprises a hardware resource management and interfacing sub-system (or "resource manager"). The resource manager interfaces with higher-level system functions such as call processing, OA&M, NMS and system control functions and with lower-level hardware functions embodied in an input/output sub-system (IOSS) containing various hardware resources for interfacing the switching system to other switching systems, including both wireline and wireless switching systems in the Public Switched Telephone Network (PSTN) and/or the Public Land Mobile Network (PLMN).

The resource manager controls all interactions between the IOSS hardware and the higher-level functions and hides the hardware specifics of the IOSS, giving the higher-level functions a hardware-independent view of the IOSS resources. This capability makes it possible, for example, to completely change out the IOSS hardware platform without necessitating any alteration of the higher-level software thereby providing portability and flexibility to the higher-level functions. The resource manager manages the physical interfaces and IOSS resources, including the switching matrix, tone generators, voice announcements, digit collectors, LAPD links, transcoders, echo cancelers and trunks. The resource manager is aware of the complete configuration of the IOSS, including all channel addressing information and the state of each IOSS resource.

In an exemplary embodiment of the present invention, the interface between the resource manager and the IOSS is a message-based interface carried over an internal system Ethernet, or LAN, through Transmission Control Protocol/Internet Protocol (TCP/IP) sockets. The interfaces between the resource manager and the higher-level functions utilize distributed objects and are based on an Object Request Broker (ORB) scheme. The resource manager uses the configuration and state information from the IOSS to model each hardware component and communications channel as a managed object, which managed objects are used in the object-oriented interfaces with the higher-level functions of the switching system. Resource characteristics and statuses are available to the higher-level functions as attributes of the resource models. In an exemplary interface between OA&M functions and the resource manager, method calls are provided to manipulate the objects for such operations as loading, testing and controlling the states of the various modeled hardware resources. These calls are routed to the appropriate modeled object and the appropriate messaging is exchanged with the IOSS. In another exemplary interface, the call processing function and the resource manager interface via two objects whose method calls initiate such actions as making or breaking switch matrix connections and allocating traffic channels.

The resource management sub-system of the present invention can also be implemented to manage a particular resource or type of resource, as opposed to an entire array of hardware resources. In a further exemplary embodiment, a specialized resource management sub-system is dedicated to a trunk signaling sub-system. In this case, the specialized resource manager interfaces with the main resource manager with a distributed object interface.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an exemplary telecommunications switching system.

FIG. **2** is a block diagram of an exemplary embodiment of a software system with a resource management sub-system in accordance with the present invention.

FIG. **3** is a diagram of an exemplary interface class hierarchy for modeled objects of an interface of the resource management system of the present invention.

FIG. **4** illustrates an exemplary exchange of messages among various components of the exemplary switching system.

FIG. **5** is a block diagram of an exemplary software arrangement including two resource management systems.

FIG. **6** is a block diagram illustrating an object model for an exemplary embodiment of a resource management system.

DETAILED DESCRIPTION

FIG. **1** is a block diagram of an embodiment of an exemplary wireless switching system **10** to be used in accordance with the present invention. The exemplary switching system **10** includes redundant call processors **12**, redundant Network Management System ("NMS") servers **14**, redundant switching modules (SM) **16** as well as various other resource modules **18, 20, 22** that carry out a number of the lower-level tasks to be accomplished by the switching system **10**. (Where redundant resources are provided, only one such resource is active. Any references herein to one of several redundant resources should be understood to be to the active redundant resource.) Resource modules include, for example, a telephony-support module (TSM) **18**, an interface module (IM) **20**, and a signal-processing module (SPM) **22**. The exemplary system of FIG. **1** includes multiple IM **20**, SPM **22** and redundant TSM **18**.

The switching modules **16** and other resource modules **18, 20, 22** communicate with each other through, for example, a control bus **24**. Data is passed between the modules over high-speed data buses **25**, which are preferably time-multiplexed serial data buses. The switching modules **16** preferably communicate with higher-level functional elements (the call processors **12**, for example) within the switching system **10** through communication hubs **26**. In an embodiment of the present invention, logical communication paths are made between the resource modules **18, 20, 22** and the higher-level functional elements via the switching module **16** through, for example, TCP/IP sockets through the communication hubs **26**.

The communication hubs **26** also connect the call processors **12** and the switching modules **16** to the NMS servers **14**. Preferably, there are two distinct LANs **28** and **30** within the switching system **10**. The first LAN **28** connects the redundant call processors **12** to the redundant NMS servers **14** and the redundant switching modules **16** through the redundant communication hubs **26**. The second LAN **30** can connect the redundant NMS servers **14** to local NMS clients **32** and/or remote NMS clients **34**. Connection to remote NMS clients **34** is preferably performed through a router **36** and a modem **38**. Since there is no direct NMS client access to the first LAN **28** on which the call processors **12**, the switching modules **16**, or the resource processors **18, 20, 22** operate, the NMS servers **14** may serve as "firewalls" against unauthorized intrusion into the switching system **10**.

With further reference to FIG. **1**, the interface modules **20** connect externally to telecommunication spans **40** (not shown), which are, for example, industry-standard T1 or E1 spans, each carrying a number of information channels as specified by the particular standard. These information channels may be traffic channels or control channels, as will be discussed below. Connection to the spans are made through span signal paths **41** from the interface modules to a span connector panel **42**, which is the point at which the telecommunication spans **40** physically connect to the switching platform **10**. The connector panel **42** provides connectivity to and from span interfaces on the interface modules **20**, with each interface module **20** having four span interfaces SPAN1–SPAN4. In the exemplary embodiment of FIG. **1**, there are six interface modules **20**, designated IM1–IM6.

The switching system **10** of the present invention couples to one or more base transceiver stations (BTSs) via one or more E1/T1 spans (referred to herein as "BTS spans").

The switching system **10** couples to the PSTN (not shown) via one or more E1/T1 spans (referred to herein as "PSTN spans"). The PSTN spans can include spans which follow the Signaling System No. 7 (SS7) signaling protocol as well as spans which carry Channel Associated Signaling (CAS) (referred to herein as "external SS7 spans" and "CAS spans," respectively).

Collectively, the switching modules 16, resource processors 18, 20, 22, control buses **24**, high-speed buses **25**, span signal paths **41**, and span connector panel **42** are referred to as the Input/Output Sub-System (IOSS) or platform **27**. In an exemplary embodiment, the IOSS **27** resides on a single shelf within a telecommunications equipment rack.

The control bus **24** preferably comprises a pair of redundant control buses over which the various resource processors **18, 20, 22** communicate using, for example, High Level Data Link Control (HDLC) channels. (Each of the redundant control buses is also referred to as an HDLC bus.) The high-speed data buses **25** carry various types of data including control and configuration information, signaling information and voice information, which may be encoded using various encoding schemes.

The communication hubs **26** are preferably Ethernet Local Area Network (LAN) communication hubs, although the hubs **26** may be hubs for other local networking protocols such as, for example, Token Ring or StarLAN. The communication hubs **26** and protocols may operate using either wired or wireless connection schemes. Although the resource modules **18, 20, 22** communicate with the higher-level functional elements in the system through the switching module **16**, via TCP/IP sockets, through the communication hubs **26**, other configurations are possible. It is possible in an alternative embodiment, for example, to have individual resource modules **18, 20, 22** directly connected to the call processor **12** and exchanging messages directly. With the present invention, a wide variety of IOSS hardware arrangements are possible without affecting the higher-level functions.

The exemplary switching system of FIG. **1** is based on one or more switching systems disclosed in U.S. patent application Ser. No. 09/026,360 (Docket No. 24194000.173), filed on Feb. 19, 1998, entitled FLEXIBLE TELECOMMUNICATIONS SYSTEM and incorporated herein by reference in its entirety, in U.S. patent application Ser. No. 09/025,870 (Docket No. 24194000.180), filed on Feb. 19, 1998, entitled INTEGRATED TELECOMMUNICATIONS SYSTEM and incorporated herein by reference in its entirety and in U.S. patent application Ser. No. 09/026,486 (Docket No. 24194000.196), filed on Feb. 19, 1998, entitled SYSTEM AND METHOD FOR FORMING CIRCUIT CONNECTIONS WITHIN A TELECOMMUNICATIONS SWITCHING PLATFORM and incorporated herein by reference in its entirety. Each redundant call processor **12** in the exemplary switching system **10** of FIG.

1 also includes a trunk signaling sub-system. In the exemplary embodiment of FIG. **1**, the trunk signaling sub-system for each call processor **12** includes four SS7 trunk signaling cards **13** and several software components resident on the cards **13** as well as on the call processor. The SS7 signaling sub-system performs Message Transfer Part (MTP) and Signaling Connection Control Part (SCCP) functions and provides Transaction Capabilities Application Part (TCAP), ISDN User Part (ISUP) and Telephone User Part (TUP) user interfaces to the higher-level applications which use the SS7 sub-system.

In the exemplary embodiment of FIG. **1**, the four SS7 cards **13** of each call processor **12** can handle four E1 trunks, one per card. Each group of four SS7 cards **13** is coupled by an E1 span **15** to the span connector panel **42** of the IOSS **27**. Each of SPAN**4** of IM**5** and SPAN**4** of IM**6** is coupled to one of the two groups of SS7 trunk cards **13** on the redundant call processors **12**. The spans **15** are also referred to herein as "internal SS7 spans" as they are internal to the switching system **10**. This is in distinction to spans with SS7 signaling which are coupled to the system **10** externally, which are referred to as "external SS7 spans."

The SS7 trunk signaling sub-system of the present invention will be described in greater detail below.

With reference to FIG. **2**, an exemplary software architecture of the switching system **10** of the present invention will now be described.

A central component in the software architecture depicted in FIG. **2** is the resource manager (RM) **100**. The RM **100** is one of several processes running in the active call processor **12**. The primary function of the RM **100** is to provide interfaces between the various other software components of the switching system **10** and the various resources of the resource platform **27**. Another function of the RM **100** is to manage the integrity of the resources of the resource platform **27** while they are in use. The RM **100** also provides an OA&M interface for the configuration of resources and for notifying the NMS server **14** of any alarms or state changes that may occur with respect to the resources.

While the RM **100** interacts with the IOSS **27** in a message-based environment, the RM **100** interfaces with the higher-level functions in a distributed object-oriented environment. The RM **100** acts the interface between the two different environments. Objects modeling hardware and software components reside within the RM **100** and are used to model the IOSS **27**, with its various hardware resources, as well as the RM **100** itself, to the higher-level functions such as the CP and NMS functions. These objects will be described below in greater detail.

The interfaces in which the RM **100** is involved and the various hardware and software components with which the RM **100** interfaces will now be described in greater detail with reference to FIG. **2**. As shown in FIG. **2**, the RM **100** is involved in six interfaces, designated A–F.

Interface A is an interface between the RM **100** and NMS applications **240** and OA&M applications **230** running on the NMS server **14**. At the physical level, interface A is carried over the LAN **28** coupling the call processor **12** and the NMS server **14**. At the software level, interface A provides an object model of the IOSS platform **27** to the NMS server **14** and to any NMS clients **32**, **34** requiring OA&M control of the IOSS **27**.

Interface A follows an object model in which the various physical components and resources of the IOSS **27** are modeled as managed objects (MOs). This object model appears as various CORBA (Common Object Request Broker Architecture)-compliant Object Request Broker (ORB) interfaces, with one ORB interface for every "Managed Object" (MO) in the system. As a CORBA object, each MO's interface is specified in a text file in a standardized syntax known as the CORBA Interface Definition Language (IDL). An IDL interface definition sets forth all of the operations (methods), parameters (attributes) and return values supported by the MO.

In the exemplary embodiment disclosed herein, there are nine different types of MOs modeled by the RM **100**. They are: interface module objects **110**, one for each IM **20**; telephony support module objects **120**, one for each redundant TSM **18**; switching module objects **130**, one for each redundant SM **16**; signal processing module objects **140**, one for each SPM **22**; BTS span objects **111**, one for each BTS span; CAS span objects **112**, one for each CAS span; external SS7 span objects, one for each external SS7 span; internal SS7 span objects, one for each internal SS7 span **15**; and a resource manager container object **101**, for the RM **100** itself.

The primary purpose of the ORB MO interfaces is to allow configuration and maintenance control of all MOs modeled by the RM **100**. The various managed object interfaces will be described in greater detail below. Preferably, interface A is a call and return interface, which from the client's point of view looks like a method call on a C++ object.

Interface A is used primarily by the NMS on the NMS server **14**. Through interface A, the NMS can retrieve all managed object references contained within the RM **100**, perform standard operations as well as retrieve standard attributes on all the managed objects in the RM **100**. Interface A also provides any additional operations and attributes necessary for OA&M functions specific to the hardware objects.

Each individual MO preferably adopts those attributes and operations of a managed object that are relevant for that individual object.

As mentioned above, interface A is a CORBA-compliant ORB interface. CORBA ORBs allow for inheritance of interfaces, whereby one interface can be derived from another base interface, effectively inheriting all of the operations and attributes of the base interface. Interface A takes advantage of this feature, as many of the managed objects modeled by the RM **100** share common functionality. Therefore, the various interface classes in the IOSS RM's MOs are derived from a number of base interface classes.

FIG. **3** depicts the interface class hierarchy used in interface A. It is important to note that only the most derived interface classes (i.e., **311–314**, **321**, **322**, **324** and **325**) are concrete. The base classes **300–303**, **310**, **320**, and **323** are all abstract interface classes.

The various managed objects and their corresponding operations and attributes are described below. All objects include "get" method calls for each attribute and all attributes not indicated to be read-only can be modified with a "set" method call. All concrete classes include "get <interface_name>" and if appropriate, "set <interface_name>" operations which allow the client to get all or set all attributes with one call. All concrete class MOs also include "description", "name" and "owner" attributes.

The RM Base class **301** provides operations for getting standard MO state attributes that are implemented in all objects modeled in the RM **100**. Such attributes pertain to the various states that may apply to a modeled resource including its administrative state (LOCKED, UNLOCKED,

or SHUTTING DOWN), usage state (IDLE, ACTIVE, or BUSY), operational state (ENABLED or DISABLED), alarm state (CRITICAL, MAJOR, MINOR, or CLEAR), availability status (AVAILABLE, OFF LINE, NOT INSTALLED, or LOADING) and unknown status (KNOWN or UNKNOWN). In the exemplary embodiment of the RM **100**, these attributes are supported as read-only from the RM Base class **301** interface. It should be understood that these attributes need not all be applicable to all concrete classes of MOs and could mean different things to different concrete classes of MOs.

The RM Resource class **302** interface provides operations and attributes that are common to all MO resources modeled in the RM **100**. Operations that can be carried out on all RM Resource MOs include: test (invokes a test on the resource), end test (stops a previously invoked test), lock (sets the administrative state of the resource MO to LOCKED), unlock (sets the administrative state of the resource MO to UNLOCKED). All RM Resource MOs include a "test types" attribute, a read-only sequence of structures defining the types of tests available on the resource and a short description of each. To determine the list of tests supported by the resource, a client would call get <test types> which would return the sequence of test type structures. An exemplary enumeration of tests includes SPAN LOOPBACK, SPAN REMOTE LOOPBACK, SPAN LOCAL LOOPBACK, and SPAN FRAMER LOOPBACK and can be extended to include more tests as they are made available. The client could then invoke a selected test via the "test" operation. The availability status of the resource MO will change to IN TEST while the test is in progress and will return to the original state upon completion of the test. A state change notification will be sent to the EFR (described below) indicating the test completion and the corresponding results will be packaged with the event. The client can abort the test prematurely by calling the "end test" operation.

The RM Board interface class **310** provides operations and attributes that are common to all MOs in the RM **100** which model physical hardware boards or modules in the IOSS **27** (i.e., IMs, TSMs, SPMs and SMs). Such operations include: upload (upload code from the board's flash memory and save it to a file), load (load code into the board's flash memory) and reset (forces a soft reset of the board if the board's administrative state is LOCKED). Attributes applicable to all RM Board MOs include: shelf and slot (indicate a shelf and slot in the IOSS **27** in which the board is inserted), hardware version (the hardware revision of the board), code versions (a sequence of structures indicating the types of code embedded in the board, their description, their current versions, and their available versions). All of these attributes are read-only.

To determine the current code version details of a board, a client would call get <code versions>, which would return a sequence of code version structures. When a client calls the load operation for a particular board, the corresponding MO will take on an availability status of LOADING, indicating to the client that the board should not be reset or powered down until it has moved to a stable availability status (OFF LINE or AVAILABLE). When loading is complete, the availability status will assume the state it contained before the load method was called and the RM Board MO will send a corresponding state change event via the EFR interface.

The Resource Manager interface class **303** includes the RM managed object **101** which is basically a container object for all of the MOs modeled in the RM **100**. Preferably, it is the only MO interface that clients are allowed to bind to. All other MOs modeled in the RM **100** can be retrieved via a "members" container attribute which contains a sequence of strings representing the markers of all the MOs in the RM **100**.

The following additional attributes are available on the RM MO **101**: CAS span info (a sequence of data structures defining all of the CAS spans configured in the system), BTS span info (a sequence of data structures defining all the BTS spans configured in the system), external SS7 span info (a sequence of data structures defining all of the external SS7 spans configured in the system), internal SS7 span info (a sequence of data structures defining all of the internal SS7 spans configured in the system), slot info (a sequence of data structures defining all of the slots in the system), shelf info (a sequence of data structures defining all of the shelves in the system), operational state (DISABLED, until the startup sequence is complete with at least one SM in the system and ENABLED once startup sequence is complete with the first SM in the system; on changing state from DISABLED to ENABLED, the RM **100** will startup the CPA **220** by sending a startup event on interface B), description ("Resource Manager built on <DATE>"), name ("ResourceManager") and owner ("NONE").

The following methods are available on the RM MO **101**: get slots per shelf (retrieves the number of slots available on a particular shelf of the IOSS **27**), get number of shelves (retrieves the number of shelves currently known to the RM **100**), get slot reference (retrieves a stringified object reference of the RM Board MO modeling the board inserted in the given shelf and slot), get slot description (retrieves a string describing the type of board that can be present in a particular slot on a particular shelf, i.e., "SM", "IM", "TSM" or "SPM"), and update-all-firmware-now.

The update-all-firmware-now method will update the firmware of all boards installed in the IOSS **27** starting with each SM **16**. This method iterates through each slot of the IOSS **27** and through each load type that is needed by that slot and forces a download for each load type which does not match the released version. The upgrade software is obtained by this method from predetermined directories on the Call Processor **12**. This operation will not upgrade boot code, which is done manually with the load command of the RM Board interface class **310**. As such, almost all of the embedded software of the IOSS **27** can be upgraded with this one method.

Upon first interacting with the RM **100**, such as upon startup, a client, such as an OA&M or NMS application should first obtain an object reference by connecting to the RM ORB (its implementation server will have a name, e.g., "RM", on the call processing host). If the operational state attribute is DISABLED at the time connection is attempted, the client should wait until the attribute has changed to ENABLED (this can be detected by waiting for a state change EFR event, described below, or by polling the attribute).

At this point, the client can proceed to determine the physical configuration of the IOSS **27** and the configuration of the RM **100** by one of several ways. In a first such procedure, the client could:

1) call the "get number of shelves" method;
2) for each shelf, determine the available slots by calling the "get the slots per shelf" method;
3) for each slot, retrieve the description of the supported resource type for that slot by calling the "get slot description method";
4) retrieve the contained MOs in the RM MO **101** by "getting" the members attribute; and

5) for each contained MO, get the operational-state and unknown status attributes:
   a) if the MO is ENABLED and KNOWN, then it can be assumed that the board is present, or
   b) if the MO is DISABLED, determine if the board is NOT INSTALLED by getting the availability status attribute; if the availability status is anything else, then it can be assumed that the board is installed but not available for use.

Binding to each board in each slot can slow down performance over a slow network connection. As such, the following alternative procedure for determining the configuration of the RM **100** and of the IOSS resources may be preferable:

1) get the "shelf info" attribute, which provides the number of slots in each shelf of the IOSS **27**;
2) get the "slot info" attribute, which provides all details about each of the slots on each shelf and the state of each slot's contents (e.g., description, operational state, administrative state, alarm status, availability status, etc.); and
3) get the various span information attributes, which will provide all details about the state of all of the spans on each IM **20** in the system (e.g., operational state, administrative state, alarm status, etc.)

In this alternative procedure, all methods are performed on the RM MO **101** itself. As such, there is no need to explicitly bind to each board, thereby enhancing startup performance.

The SM interface class **314** provides attributes and methods for the SM MO **130** which models the SM **16**, which is responsible for all switching tasks in the system **10**. All of the operations available with the SM interface **314** are derived by inheritance, such as the ability to "load" and "reset" the SM **16**. In addition to inherited attributes such as the shelf and slot of the SM, the SM interface also provides the following attributes: clock source1 (selects an IM slot number from which to extract the highest priority clock source), clock source2 (selects an IM slot number from which to extract the second priority clock source), system clock (selects the clock source, e.g., internal, source **1** or source **2**, from which to drive the switching system), description (primary or secondary SM of redundant SMs), name (e.g., SM <Slot#>) and owner (i.e., "Resource Manager"). The clock selection attributes are writeable.

The TSM interface class **313** provides attributes and methods for the TSM MO **120** which models the TSM **18**. All of the operations available with the TSM interface class **313** are derived by inheritance from the RM Board, RM Resource and RM Base classes, as shown in FIG. **3**. In addition to inherited attributes such as the shelf and slot of the TSM **18**, the TSM interface also provides the following attributes: description (primary or secondary TSM of redundant TSMs), name (e.g., PSM <Slot#>) and owner ("Resource Manager").

It should be noted that an additional intermediate interface class RM Redundant Board (not shown) can be inserted in the chart of FIG. **3** as deriving from the RM Board class **310** and with the TSM class **313** and SM class **314** deriving from the RM Redundant Board class. Such an interface class can be used to specify methods and attributes common to redundant boards such as the SM **16** and the TSM **18**.

The SPM interface class **311** specifies attributes and methods for the SPM MOs **140** which model the SPMs **22**. As with the SM and PSM classes, all of the operations available on the SPM interface class are inherited. In addition to inherited attribute types, each SPM MO includes the following attributes: description ("SPM on <shelf#> and <slot#>), name ("SPM <slot#>") and owner ("Resource Manager").

The IM interface class **312** provides attributes and methods for the IM MOs **110** which model the IMs **20** which are responsible for all the E1/T1 span interfacing tasks in the system. Each IM MO **110** is a container and can contain any combination of up to four BTS Span MOs **111**, CAS Span MOs **112**, Internal SS7 Span MOs **113**, or External SS7 Span MOs **114**, depending on how the modeled IM **20** is configured. Each IM MO **110** maintains the configuration for the corresponding IM **20**, remembering which spans were configured and where, and contains attributes and operations for manipulating these objects.

In addition to all of the inherited types of operations, such as "load" and "reset," the IM interface class **312** provides additional operations such as: create/delete CAS Span (creates/deletes a CAS Span on a specified span number), create/delete BTS Span (creates/deletes a BTS Span on a specified span number), create/delete External SS7 Span (creates/deletes an External SS7 Span on a specified span number) and create Internal SS7 Span (creates an internal SS7 span on a specified span number). In addition to the inherited attribute types, MOs of the IM interface class **312** also make available the following attributes: number of spans (the current number of spans for which the corresponding IM is configured), description (e.g., "IM on <shelf#> and <slot#>), name (e.g., "IM <slot#>), owner ("Resource Manager") and members (a sequence of strings representing the markers of all Span MOs contained within the IM MO).

In addition to modeling board-based resources of the IOSS **27**, the RM **100** also models span resources. The Span interface class **320** provides operations and attributes that are common to all spans modeled in the RM **100**. In addition to inherited types of operations, the Span interface class **320** provides a "get channel type" operation which when called returns a CHANNEL TYPE parameter (e.g., traffic channel, trunk, LAPD, external SS7, internal SS7) corresponding to a particular subslot of a particular timeslot of the modeled span. In addition to inherited types of attributes, the Span interface class **320** provides the following attributes: Time Slots (a sequence of structures reflecting the channel configuration of the modeled span) and Span Number (the span number, 1–4, corresponding to the modeled span).

The Internal SS7 Span interface class **321** provides the methods and attributes of all Internal SS7 Span MOs **113** in the RM **100**. The MOs **113** model the behavior of configured internal SS7 spans **15** coupled to any IM **20** of the IOSS **27**. Each Internal SS7 Span MO **113** is logically contained within an IM object **110**, as depicted in FIG. **2**. The Internal SS7 Span interface class **321** is used in routing external SS7 spans to the internal SS7 spans **15**. All operations available with this interface class are inherited. In addition to the inherited types of attributes, the Internal SS7 Span interface class **321** provides the standard concrete class attributes of description ("Internal SS7 Span number <span#> on IM in <Shelf#> and <Slot#>"), name ("Internal SS7 Span <span#>") and owner ("IM <Slot#>").

The BTS Span interface class **322** provides the methods and attributes of all BTS Span MOs **111**, which MOs model the behavior of configured BTS spans coupled to any IM **20** of the system **10**. Each BTS Span MO **111** is logically contained within an IM object **110**. The BTS Span interface class **322** is responsible for all tasks related to communicating with a local BTS. All operations available by this interface are inherited. In addition to the inherited types of attributes, the BTS Span interface class **322** provides the standard concrete class attributes: description ("BTS Span number <span#> on IM in <Shelf#> and <Slot#>"), name ("BTS Span <span#>") and owner ("IM <Slot#>").

The PSTN Span interface class **323** provides methods and attributes that are common to all MOs in the RM **100** which model all configured PSTN spans coupled to an IM **20** of the IOSS **27**. There are two interface classes derived from the PSTN Span class **323**: the External SS7 Span class **324** and the CAS Span class **325**. Each MO of the CAS Span class **325** models the behavior of a configured R2 or CAS span whereas MOs of the External SS7 Span class model the behavior of a configured SS7 Span. The PSTN Span interface class **323** is responsible for all tasks related to communicating with the PSTN. Each PSTN Span MO is logically contained within an IM MO. The PSTN Span interface inherits all of the operations and attributes common to all spans and resources in the system. As with the Span interface class **320**, a client can request a description of all the timeslots on a PSTN Span. All operation types available with the PSTN interface class are inherited. In addition to the inherited attribute types, the PSTN Span interface class **323** provides the following attributes: crc4 (a writeable attribute which specifies the use of CRC4 error correction on the modeled PSTN span) and signaling (reflects the signaling type, CAS for CAS spans or Out-Of-Band (OOB) for SS7 spans, used on the PSTN span).

The CAS Span interface class **325** provides methods and attributes for the CAS Span MOs **112**, which model the behavior of configured CAS spans coupled to any IM **20** of the system **10**. Each CAS Span MO **112** is logically contained within an IM object **110**. The CAS Span interface class **325** is responsible for all tasks related to communicating with a the PSTN over a CAS, or R2, span. All operations available by this interface are inherited. In addition to the inherited types of attributes, the CAS Span interface class **325** provides the description ("CAS Span number <span#> on IM in <Shelf#> and <Slot#>"), name ("CAS Span <Span#>") and owner ("IM <Slot#>") attributes.

The External SS7 Span interface class **324** provides the attributes and methods of External SS7 Span MOs **114**, which model the behavior of configured SS7 PSTN spans coupled to any IM **20** of the system **10**. Each External SS7 Span MO **114** is logically contained within an IM object **110**. The External SS7 Span interface class **324** is responsible for all tasks related to communicating with the PSTN over an SS7 span. All operations available by this interface are inherited. In addition to the inherited types of attributes, the External SS7 Span interface class **324** provides the description ("External SS7 Span number <span#> on IM in <Shelf#> and <Slot#>"), name ("External SS7 Span <Span#>") and owner ("IM <Slot#>") attributes.

Interface B relates to the interface between the RM **100** and the call processing application (CPA) **220** running on the call processor **12**. In the exemplary system of FIG. **1**, this interface is internal to the call processor **12**, as both the RM **100** and the CPA **220** run on the call processor **12**. This is indicated in FIG. **2** by a dashed line. In accordance with the present invention, however, the RM **100** and the CP application **220** need not be running on the same hardware platform and in fact can run on widely distributed platforms.

Like interface A, interface B is a CORBA-compliant ORB interface. Unlike the call-and-return mechanism of interface A, however, interface B is event-based. The primary purpose of interface B is to provide a call processing event interface for interaction with the CPA **220**. Interface B is preferably "channel-based," wherein events are passed across interface B containing handles to a channel associated with the event. This ORB interface is not a "Managed Object" model, but rather presents an event-based API between the RM **100** and the CP application **220**. This allows the CPA **220** to send call processing events to the RM **100** and vice versa. In some cases these events are simply translated into Platform Message events, and passed on through interface C (described below) to the IOSS platform **27**. In other cases, these events correspond to state changes in the managed objects of the RM **100** and to one or many Platform Message events. Similarly, one or more message events over interface C may result in one or more events over interface B and vice versa. An exemplary transaction involving events over both interfaces will be described below in greater detail.

Interface B can be thought of as comprising two one-way CORBA-compliant (IDL) interfaces. Each one-way interface provides a collection of events that encompass all of the functionality necessary to perform call processing over both the air and land lines to which the switching system **10** may be coupled. These interfaces are said to be "channel-based" because each event takes at least one argument, namely an identifier of a "channel" associated with that event. This provides a convenient mechanism for keeping the hardware details of the IOSS **27** out of the CPA **220**, and making call processing substantially independent of the actual platform implementation.

The first one-way IDL interface, referred to as the CPA-RM interface comprises a CPA-RM proxy **151** in the RM **100** and a CPA-RM object **221** in the CP application **221**, as depicted in FIG. **2**. The CPA-RM proxy **151** acts as a server, and the CPA-RM object **221** acts as a client to that server.

Exemplary methods that can be called by the CPA **220** from the RM **100** on the CPA-RM proxy **151** include:

LAPD Methods

These include methods called by the CPA **220** for causing the IOSS **27** to add or delete LAPD channels, or links within LAPD channels, between the switching system **10** and a base transceiver station (BTS) coupled to the switching system **10** via an E1 span. Another LAPD method includes sending data across a specified LAPD link.

Traffic Channel Methods

These include methods for causing the IOSS **27** to add or delete traffic channels to or from a specified E1 span between the switching system **10** and a BTS. If the CPA **220** does not properly specify an E1 span (e.g., the identifier does not correspond to a configured E1 span coupled between the switching system and a BTS), the RM **100** sends an error event to the CP application **220** and reports an alarm to an OA&M application **230** (described below).

Trunk Methods

These include methods for causing the IOSS **27** to add or delete trunks to or from a specified E1 span between the switching system **10** and a PSTN. Other trunk methods include methods to seize a specified trunk for an originating call; to release a specified trunk (thereby tearing down a call); to configure a specified trunk (by specifying such parameters as line signaling type, register signaling type and direction); to collect an incoming sequence of digits on a incoming call; to send out a sequence of digits for an originating call; to indicate whether or not a incoming call has been successfully setup and routed and, if not, why; and to indicate that a dialed phone has answered a incoming call on a specified trunk. For each such method, if the CP application **220** does not properly specify an E1 span or trunk (e.g., the identifier does not correspond to a configured E1 span or trunk between the switching system and the

PSTN), the RM **100** sends an error event to the CPA **220** and reports an alarm to the OA&M application **230**.

Echo Canceler Control Methods

These include methods for causing the IOSS platform **27** to enable or disable echo cancellation on a specified traffic channel. A method is also included to indicate the occurrence of an intra-switch hand-over to the echo canceler DSPs handling the source and destination traffic channels. As with the other methods, any errors or alarms are reported to the CP application **220** and/or the OA&M application **230**.

Switch Matrix Control Methods

These include methods for directing the IOSS platform **27** to setup or terminate one-way (simplex) or two-way (duplex) connections between specified pairs of channels. Methods are included to create or release three-way conferenced circuits and to add or drop channels from existing conferenced circuits.

Tone Playback Control Methods

These include methods for causing the IOSS **27** to generate a specified tone (e.g., ringback, dialtone, busy, DTMF) on a specified channel for a specified duration and to perform a specified action (e.g., apply silence or ringback or return to previous connection) with the specified channel after the tone has been removed. Other methods provide for initiating and terminating continuous tone playback and for generating a specified series of DTMF tones on a specified channel.

Announcement Control Methods

These include methods for causing the IOSS platform **27** to initiate or terminate the playback of a specified voice announcement for a specified number of repetitions on a specified channel and to perform a specified action (e.g., apply silence or ringback or return to previous connection) with the specified channel before the announcement is generated and after the announcement has terminated. Methods are also provided for initiating and terminating the recording of voice announcements from a specified channel.

For each of the above-described method calls, the RM **100** will check the method call for errors or inconsistencies (e.g., the CPA **220** specified an invalid LAPD channel in a data request method call). If an error is detected, the RM **100** will inform the CPA **220** accordingly by sending an event (e.g., "invalid LAPD") to the CPA **220** and will report an alarm to the OA&M application **230** (described more fully below).

The second one-way IDL interface, from the RM **100** to the CP application **220**, referred to as the RM-CPA interface, comprises an RM-CPA proxy **222** in the CPA **220** and an RM-CPA object **152** in the RM **100**, as depicted in FIG. **2**. The RM-CPA proxy **222** acts as a server, and the RM-CPA object **152** acts as a client to that server.

Exemplary methods that can be called by the RM **100** from the CPA **220** on the RM-CPA proxy **222** include:

Startup Control Method

This method is called by the RM **100** once during the startup sequence after the IOSS **27** has indicated that its configuration has been completed. This method indicates the host server name of the RM **100** and is used by the CPA **220** to bind back to the CPA-RM interface.

LAPD Methods

These include methods called by the RM **100** to indicate to the CPA **220** that the IOSS platform **27** has established or released a LAPD link or to pass to the CPA **220** data received over a LAPD link by the IOSS platform **27**.

Traffic Channel Control Methods

These methods are called by the RM **100** to indicate to the CPA **220** that a particular traffic channel is enabled or disabled or to indicate to the CPA that the CPA had previously invalidly specified a traffic channel in an operation requested over the RM-CPA interface.

Trunk Methods

These include methods by which the RM **100** indicates to the CPA **220** that a particular trunk has been enabled, disabled, seized or released (along with the duration of the call for billing). Other methods are included to indicate to the CPA **220** that an incoming call setup has begun on a particular trunk; that digits have been received on a given trunk, and what those digits are; that a call on a given trunk has been answered by the far end; that a glare condition has been detected during an attempted seizure of a trunk; and that an outgoing or incoming call has or has not been successfully set-up and routed.

Switch Matrix Control Report Methods

These include methods called by the RM **100** to inform the CPA **220** of failures in duplex or simplex connections; to report the creation or failure of a requested conference connection; and to report the success or failure of a requested addition of a port to a conferenced connection.

Tone Playback Control Report Methods

These include methods for informing the CPA **220** of a failure or completion of a continuous playback of a tone.

Announcement Control Report Methods

Included are methods called by the RM **100** for informing the CPA **220** of a failure or completion of an announcement playback; and for reporting to the CPA **220** whether or not the recording mechanism is available for recording a requested announcement or that the recording of an announcement has been completed.

Interface C provides the communication link between the RM **100** and the various hardware resources in the IOSS resource platform **27** that the RM is modeling. Interface C is carried over the LAN **28** coupling the call processor **12** and the IOSS resource platform **27** (more specifically, the redundant SMs **16**) and is implemented as a TCP/IP connection-oriented socket. Interface C follows a messaging protocol for passing information through the TCP/IP socket.

An exemplary message format for both commands and events exchanged between the RM **100** and the IOSS platform **27** is set forth in Table 1 (where "UNITn" refers to an unsigned integer of n bytes).

TABLE 1

RM-IOSS Platform Message Format

Field Name	Type	Description
length	UINT2	The overall length of the message including header and payload data. Minimum legal length is for a message with a header only (e.g., 16 bytes). A length limit (e.g., 4096 bytes) is preferably placed on

TABLE 1-continued

RM-IOSS Platform Message Format

Field Name	Type	Description
		all messages, and if the message is to be relayed via control bus 24, the length limit is preferably shorter (e.g., 336 bytes for messages to an IM 20 or TSM 18 and 536 bytes for messages to an SPM 22).
msg_type	UINT2	Indicates the type of message. Messages are preferably grouped in ranges depending on the destination task in the operational software of the SM 16.
lci	UINT4	The Logical Component Identifier of the entity to which the message refers. This is either the component acted upon by the command or the component referred to by the alarm/event/response message.
tag	UINT4	Used to identify each individual instance of a command. The value in this field should be included in the tag field of any response to the RM 100 which relates to this particular command. A message in response to a request must contain the same tag ethat was initially delivered in the request.
source	UINT2	Used by the IOSS 27 for internal routing of the message.
data_offset	UINT2	This field points to the data payload, interpreted as an offset from the beginning of the header. If the message has no payload, then this will be equal to the size of a message header (e.g., 0 × 10).

Logical component identifiers (LCIs) and their use in a telecommunications switching system are described in U.S. patent application Ser. No. 09/026,229 (Docket No. 2419400.186), filed on Feb. 19, 1998, entitled SYSTEM AND METHOD FOR DYNAMICALLY MAPPING COMPONENTS WITHIN A TELECOMMUNICATIONS SWITCHING PLATFORM and incorporated herein by reference in its entirety.

Exemplary types of command and event messages that can be exchanged between the RM **100** and the IOSS platform **27** will now be described.

A first group of messages includes configuration and state control messages. These messages are used to control and to report on the various components and resources in the IOSS **27**. These include a configuration message from the SM **16** to inform the RM **100** what state the SM is in, as well as what type of resource module (**16**, **18**, **20**, **22**) is in each slot of the connected IOSS backplane. The RM sets the state of the SM managed object **130** (see FIG. **2**) to correspond to the SM state delivered in the message payload. By default, the RM **100** initializes itself with the contents of a standard backplane with a managed object for each resource module that could possibly be inserted into the IOSS backplane. If the RM **100** detects from the configuration message that the SM **16** is not connected to a standard backplane, the RM **100** will destroy the default managed objects and create new ones to correspond to the new backplane information contained in the message. The RM **100** responds to such a configuration message with a message to the SM **16** indicating that the RM is ready.

In addition to informing the RM **100** of the configuration of the IOSS platform **27**, the SM **16** will also send messages to the RM **100** with configuration data for each module coupled to the IOSS backplane that checks-in or "registers" with the SM. The configuration data sent may include the LCI of the registering module, the module type (SM, IM, TSM, SPM), the state of the module (RESET, ONLINE, OFFLINE, ERROR), the hardware revision number of the module, the version numbers of the boot and field-programmable software codes of the module. One such message is sent for each module at startup or upon insertion of a module into the IOSS platform **27**. The secondary SM **16** will send a configuration message with configuration data just for itself. The RM **100** looks at the configuration data for each module and sets the managed object associated with that module to appropriately reflect the state of the module, the reported hardware version and the various code versions. Depending on the module type and state, the RM may also send configuration messages to the module.

Messages are also included to indicate to the RM **100** that a particular IOSS resource has gone online or offline. For all RM Resource interface class **302** managed objects for which the RM **100** receives such a message, the RM will accordingly set their operational state to ENABLED or DISABLED, their availability status to AVAILABLE or OFF LINE, and their unknown states to KNOWN. The RM **100** also uses these messages to determine which ones of the various redundant resource modules (i.e., SM, TSM, or SPM) are the active modules. If a message is received by the TM **100** informing the RM that a particular IM **20**, SPM **22** or span has gone offline, the RM **100**, in turn, informs the CPA **220** that any channels associated with the now offline resource are now also disabled. The SM **16** will also inform the RM **100** if a module has stopped communicating with it (i.e., as when the module is removed). In that case, the RM **100** will reset the configuration for that board and put it in an UNKNOWN state.

The RM **100** can send a message to the IOSS **27** requesting that a specified resource be brought back online. If the request cannot be met, the IOSS **27** will respond with an alarm identifier related to the reason of failure. The RM **100** can also request that a specified resource be taken offline, usually in response to a command from the OA&M application **230**. If the resource is, for example, an SPM **22** or IM **20** that is currently providing channel resrouces to the CPA **220**, the RM **100** notifies the CPA **220** of the loss of these resources.

The RM **100** can command the SM **16** or any other module to perform a reset of its software, usually in response to a reset command from the OA&M application **230**. The RM **100** can also request a module to load itself with certain software or other dynamic data (e.g., tone data, voice messages). Such a request can be initiated by a module itself.

Another subset of configuration messages allows the RM **100** to request the IOSS platform **27** to add or delete a LAPD channel on a specified timeslot of a specified span. When requesting the addition of a LAPD channel, the RM **100** will specify a SAPI and a TEI of an initial LAPD link which the IOSS platform will establish over the newly added LAPD channel.

Similarly, the RM **100** can command the IOSS platform **27** to add or delete a traffic channel on a specified timeslot of a specified span. These messages are usually sent when the CPA **220** requests the addition of the first traffic channel to a traffic channel circuit or when it requests the deletion of the last traffic channel on a traffic channel circuit. (It should be noted that each 64 kbps traffic channel circuit can carry up to four 16 kbps traffic channels in the exemplary switching platform of the present invention.) Furthermore, with

respect to traffic channels, the IOSS platform **27** can send messages to the RM **100** indicating that 1) a traffic channel has moved (such as when a resource such as an SPM or DSP to which the traffic channel is allocated becomes unavailable and as a result, the traffic channel is reallocated), or that 2) a traffic channel has been lost (such as when a resource such as an SPM or DSP to which the traffic channel is allocated becomes unavailable and no other resources are available for reallocation). In the second case, the RM **100** responds by disabling the traffic channel and marking it as unconfigured.

Another configuration message allows the RM **100** to notify the appropriate IM **20** that the RM **100** is deleting a span (i.e., deleting the MO modeling the span) and that the IM **20** is to reset the physical span connection to its initialized state, thereby deconfiguring the span. Similarly, a further configuration message allows the RM **100** to notify the appropriate IM **20** that the RM is deleting a trunk (object) from a particular span (object) and that the IM **20** is to reset the trunk (i.e., the timeslot assigned to the trunk) to its initialized state.

Another subset of configuration messages deals with the system clock, whereby the RM **100** can request that a specified clock source, such as a clock extracted from a span, be used as the system clock or that a specified span extract its clock to the bus. These messages are sent by the RM **100** to the IOSS platform **27** at startup or on command from the OA&M application **230**.

The RM **100** can also send a message to the IOSS platform **27** to configure a specified IM **20** and any number of the four spans coupled to that IM. This message is sent every time an IM **20** checks-in and there is configuration information available for the IM. The configuration parameters sent for each span can include the type of signaling used (e.g., CAS or OOB signaling), whether error correction (e.g., CRC4) is enabled and the type of span (e.g., GSM Abis, PSTN, GSM A, CDMA, AMPS, E1).

A second group of messages exchanged between the RM **100** and the IOSS platform **27** includes test control messages. These include messages whereby the RM **100** requests that a specified span perform a test, such as a fault isolation test (FIT) or a loopback test. Such requests are usually sent by the RM **100** on command from the OA&M application **230**. The IOSS **27** responds to a FIT request with the results of the test. If there was a failure, the IOSS **27** indicates the LCI of the resource that failed. The RM **100** passes these results to the OA&M application **230**. When requesting a loopback test, the RM **100** can specify one of several test modes (e.g., remote, local, framer). The IOSS platform **27** responds to such a request upon successful completion of the requested test.

A third group of messages, which are applied on a call-by-call basis, are used for turning on or off certain functions on the SPMs **22**. With these messages, the RM **100** can direct the IOSS platform **27** to enable or disable echo cancellation on a specified traffic channel. In the case of an intra-system handover in which echo cancellation is required, the RM **100** can send another message to the IOSS platform **27** informing the platform of the source and destination traffic channels. The purpose of this message is to allow the IOSS platform **27** to move DSP data from the echo cancellation DSP assigned to the source traffic channel to the echo cancellation DSP assigned to the destination traffic channel. These messages are sent by the RM **100** to the IOSS platform **27** upon receipt by the RM **100** of corresponding events from the CPA **220**, described above.

A fourth group of messages are used to control the switching matrix in the active SM **16**. With these messages, the RM **100** can request that the SM establish or terminate simplex or duplex connections between specified channels. Also included are messages whereby the RM **100** can direct the SM to create or kill a conferenced connection among three ports or modify a conferenced connection by adding or removing a leg therefrom. Switch SM control messages are usually sent by the RM **100** to the IOSS platform **27** in response to corresponding events from the CPA **220**.

A fifth group of messages are involved in the playing of tones on a specified connection. Included are messages by which the RM **100** can request that a TSM **18** in the IOSS platform **27** continuously play or stop a specified tone, play a specified tone for a specified duration, play a specified periodic tone for a specified number of cycles, or play a specified sequence of DTMF tones on a specified channel. These messages are usually sent by the RM **100** to the IOSS platform **27** in response to corresponding events from the CPA **220**.

A sixth group of messages are used to control the voice messaging system on the TSM **18**. These include commands by which the RM **100** can request the IOSS platform **27** to play a specified voice message on a specified channel for a specified duration and a specified number of repetitions. The RM **100** can also specify the action to be performed on the channel before and after the message playback is completed. Also included are commands for initiating and terminating the recording of voice messages. Access to the record mechanism is preferably password protected. As such, a valid password must be provided by the RM **100** to enable the recording mechanism. These messages are usually sent by the RM **100** to the IOSS platform **27** in response to corresponding events from the CPA **220**.

A seventh group of messages control the LAPD connections between the CPA **220** (in particular, the BSC component) and a BTS coupled to the switching system **10** via a span. (These messages may not mirror the complete functionality of the LAPD protocol as some LAPD functions can be performed on the SM **16**.) For the most part, the LAPD-related messages "pass through" the RM **100** on their way to or from the CPA **220** or the IOSS platform **27**. The RM **100** is preferably not involved in the state of LAPD signaling. This responsibility is owned by the appropriate parts of the CPA **220** and IOSS platform **27**

These include messages for causing the IOSS platform **27** to add or delete LAPD channels, or links within LAPD channels, between the switching system **10** and a BTS. Another such message is sent by the RM **100** to direct the IOSS platform **27** to send a packet of data across a specified LAPD link to the BTS. These messages are usually sent by the RM **100** to the IOSS platform **27** in response to corresponding events from the CPA **220**.

Also included are messages from the IOSS **27** to the RM **100** to indicate that a LAPD link has been established or released or to pass to the RM **100** a packet of data received over a LAPD link by the IOSS **27**. In response to such messages from the IOSS **27**, the RM **100** will send corresponding events to the CPA **220**.

An eighth group of messages are used for call control signaling on PSTN trunks (e.g., R1 or R2 signaling trunks). These messages are generally "passed through" by the RM **100** between the CPA **220** and the IOSS **27**. The RM **100** preferably is not involved in the state of the trunk signaling. This responsibility is preferably owned by the appropriate parts of the CPA **220** and the IOSS platform **27**. The LCI in the message header of each of these messages corresponds to the trunk associated with the message.

This group of messages includes messages sent by the RM **100** for causing the IOSS **27** to seize a specified trunk

for an outgoing call, thereby starting the outgoing call setup process; to release a specified trunk (thereby tearing down a call); to configure a specified trunk (by specifying such parameters as line signaling type, register signaling type, whether ANI should be collected, and direction); to block a specified trunk so that it cannot receive calls; to collect an incoming sequence of digits on a specified trunk; and to send out a sequence of digits for an originating call. Messages are also included whereby the RM **100** can indicate to the IOSS **27** whether or not an incoming call has been successfully setup and routed or to indicate that a dialed phone has answered an incoming call on a specified trunk. These messages are sent by the RM **100** to the IOSS platform **27** in response to corresponding events from the CPA **220**.

Also included are messages by which the IOSS platform **27** informs the RM **100** that a particular trunk has been seized or released (along with the duration of the call for billing). Other messages are included to indicate to the RM **100** that a trunk has received a ring indication (thereby indicating that an incoming call setup has begun); that digits have been received or collected on a given trunk, and what those digits are; that a call on a given trunk has been answered by the far end; that a glare condition has been detected during an attempted seizure of a trunk; and that an outgoing or incoming call has or has not been successfully set-up and routed. In response to such messages from the IOSS platform **27**, the RM **100** will send corresponding events to the CPA **220**.

A ninth group of messages are sent by the IOSS **27** to the RM **100** to indicate alarms and other events originating in the IOSS. For example, in one such message, the IOSS **27** can indicate the occurrence of a software error, a resource with which that error is associated and an indication of the severity of the error. The RM **100** preferably sends any alarm or error indications from the IOSS platform **27** to an Event Filtering and Reporting (EFR) server in the OA&M layer **230**, as discussed below.

Interface D is a one-way, event-based interface from the RM **100** to an EFR object **231** in the OA&M application **230**. In the exemplary embodiment, interface D is provided by the OA&M application **230** and used by the RM **100**. Like interface A, interface D is carried over the LAN **28** between the call processor **12** and the NMS server **14**. Interface D is a CORBA-compliant ORB interface, wrapped in a C++ class API. The RM **100** and its contained MOs will generate various "event notifications" whenever they are created, deleted, change state, or encounter an alarm, software error or operation violation. Interface D is used by the RM **100** to forward such notifications to an EFR object **231** in the OA&M application **230**. The OA&M application **230** contains an EFR server (not shown) which will provide the event notifications to any clients that are interested.

An event notification may contain the following information fields:

Notification Type; a CCITT X.721 recommended enumeration of notification types (e.g., COMMUNICATION_ALARM, ENVIRONMENTAL_ALARM, EQUIPMENT_ALARM, OBJECT_CREATION, OBJECT_DELETION, SOFTWARE_ERROR, TEST_RESULT, STATE_CHANGE, ATTRIBUTE_VALUE_CHANGE, OPERATION_VIOLATION, PROCESSING_ERROR_ALARM);

Object ID; a stringified object reference of the MO originating the event;

Additional Text: a string of additional text related to the event;

Attribute ID: if the Notification Type is STATE_CHANGE or ATTRIBUTE_VALUE_CHANGE, this element identifies the associated attribute;

Old Value: if the Notification Type is STATE_CHANGE or ATTRIBUTE_VALUE_CHANGE, this element indicates the old value of the attribute ID;

New Value: if the Notification Type is STATE_CHANGE or ATTRIBUTE_VALUE_CHANGE, this element indicates the old value of the attribute ID;

Probable Cause; an enumeration of possible probable causes;

Source Indicator: set to RESOURCE for events originated from the RM **100**;

Specific Problems: a string of text that identifies the problems associated with an event;

Perceived Severity: an enumeration of severity levels.

The event notifications generated by the RM **100** and its MOs can be categorized into three groups: Event reports, State Change reports, and Alarm reports.

All event reports generated by the RM **100** and its MOs are common to the RM Base interface class **301** (see FIG. **3**). This means that any of the following events can be generated from an RM Base object, but in general each RM Base object will only generate a subset of the events described below. Such events include:

object creation

Whenever an RM Base Managed Object is created via user configuration (e.g., create_BTSSpan or create_PSTNSpan) or via restoration from configuration data (i.e., at startup). The creation of an RM Base Managed Object does not necessarily correspond with the physical existence of the resource that the object represents. Such a determination can be made from the state attributes of the object.

object deletion

This event is reported whenever an RM Base MO is deleted via user configuration (e.g., delete_BTSSpan or delete_PSTNSpan) or when the RM **100** is shutting down. This does not necessarily mean that the actual resource modeled by the object has been physically removed or destroyed, but could mean that the process managing these objects has been shutdown.

software error

This event is reported whenever the RM **100** encounters a software error or whenever it receives a SOFTWARE_EVENT message from the Platform. Software errors are distinguished from alarms in that the operator cannot take any corrective action to solve the indicated error.

software alarm

operation violation

This event is reported whenever the RM **100** encounters an illegal invocation on interface A (with the OA&M application **230**). The RM can determine the invocation to be illegal if a bad parameter is passed or the invocation is made during an incompatible operating state of the invoked object of the RM.

In the exemplary system of the present invention, some state change reports are common to all RM Base interface class **301** managed objects (or "RM Base MOs") and some are common to all RM Resource interface class **302** managed objects (or "RM Resource MOs"). State change events include:

Unknown Status State Change

This event is reported whenever the RM **100** loses or establishes the status of any RM Base MO. Until the unknown status of an MO has moved to KNOWN, the integrity of all attributes on that object cannot be trusted.

Administrative State State Change

This event is reported whenever the administrative state of an RM Resource MO undergoes a state change. This event is usually initiated by the operator's performing a "lock" or "unlock" operation on an RM Resource MO. Normally, on a lock request, the RM Resource MO will move to a $SHUTTING_{13}$ DOWN state until the MO's usage state moves to IDLE, at which time the availability status will completely move to LOCKED. Each state change in this sequence will include an appropriate state change event.

Usage State State Change

This event is reported whenever the usage state of an RM Resource MO undergoes a state change. There are times when the usage state of an RM Resource MO may be IDLE, meaning it is completely free of use; ACTIVE, meaning it is in use, but can accommodate further usage requests; and BUSY, meaning it is completely in use, and can accommodate no more usage requests. This state can change as a side effect of a "lock" request from an operator, or it may occur naturally during operation. As an example, the usage state of a span will move from IDLE to ACTIVE as calls are placed on that span. Once all the circuits on the span are involved in calls, the usage state will move from ACTIVE to BUSY, implying that no more calls can be placed on the span at that time. Subsequently, an operator may request that a span be "locked". This causes the span usage to be controlled and eventually driven to IDLE. As each circuit becomes free from use, further usage is blocked. Once all channels are free from use, the span will be moved to the IDLE usage state, and the administrative state can be moved to LOCKED.

Operational State State Change

All RM Resource MOs change operational state once the corresponding physical resource reports that it has gone ONLINE (ENABLED) or OFFLINE (DISABLED). This can occur as a result of an operator request that an RM Resource MO be "locked" or as a natural change during operation of the system (e.g., during system startup, RM Resource MOs move from DISABLED to ENABLED as each RM Resource MO notifies the RM **100** of its initial startup state).

Availability Status State Change

All RM Resource MOs send availability status state change reports to provide detail about why a resource is or is not currently available for use. In the exemplary embodiment of the RM **100** described, only RM Board Mos will report a new availability status of LOADING. However, all other values can be assumed by all RM Resource MOs.

The types of events for which Alarm Reports are generated by the RM and/or its MOs include: EQUIPMENT_ALARM Events (e.g., module cannot run in this slot, Wrong software loaded on this module, TSM failover, DSP hardware has failed, System is no longer redundant, SM Failure, download failed, etc.); ENVIRONMENTAL_ALARM Events (e.g., excessively high or low temperature level, IM detected span slip, etc.); COMMUNICATION_ALARM Events (e.g., received invalid message from SM, BIT determined that a QSM span failed, SM receiving bad frames from BTS, unknown BTS requesting access, etc.); and PROCESSING_ERROR_ALARM Events (generated by the firmware of the IOSS **27** and indicate that a software problem has occurred, such as no free resources available, problem sending data over TCP/IP socket, problem receiving data over socket, problem creating socket, etc.)

Interface E is an interface between the RM **100** and a specialized resource manager, the SS7 RM **210**, which is used to manage the SS7 trunk signaling resources of the switching system **10**. Like interface B, this interface is internal to the call processor **12**, as both the RM **100** and the SS7 RM **210** run on the call processor **12**, in the exemplary embodiment.

The primary purpose of interface E is to receive commands from the SS7 RM **210** that direct the RM **100** to provide connections from an internal SS7 span **15** (a span hardwired to the SS7 cards **13** installed in the call processor **12**) to an external SS7 span (a span available externally through an E1 connection). This is done to configure, or "nail-up", individual SS7 signaling links.

Like interface B, interface E can be thought of as comprising two one-way CORBA-compliant (IDL) interfaces. Interface E, although an ORB interface, is not based on a managed object model but rather is an event-based API between the RM **100** and the SS7 RM **210**.

The IDL interface from the RM **100** to the SS7 RM **210** is referred to as the RM-SS7 interface. The SS7 RM **210** provides an RM proxy **212** which acts as a server and the RM **100** acts as a client **162** to that server. Once it is done initializing, the RM **100** calls a startup method on the RM proxy **212** informing the SS7 RM **210** that the RM **100** is ready to start receiving SS7 link events from the SS7 RM and informing the SS7 RM of the name of the server of the RM **100** (i.e., SS7 proxy **161**) that the SS7 RM **210** will use to communicate with the RM **100** in the future.

The IDL interface from the SS7 RM **210** to the RM **100** is referred to as the SS7-RM interface. The RM **100** provides an SS7 proxy **161** as a server and the SS7 RM **210** acts as a client **211** to that server. Methods on the SS7 proxy **161** called by the SS7 RM **210** include: a startup method for notifying the RM **100** that the SS7 RM **210** is done initializing (the RM **100**, in turn, informs the CPA **220**); a method for notifying the RM **100** that the SS7 RM **210** is going offline and the reason for doing so; a method for adding an SS7 signaling link, in response to which the RM **100** directs the IOSS **27** (via interface C) to create a nailed-up duplex connection between a timeslot on an internal SS7 span **15** and a timeslot on an external SS7 span, as specified by the SS7 RM **210**; and a method to remove an SS7 signaling link, thereby removing an existing duplex connection between a timeslot on an internal SS7 span **15** and a timeslot on an external SS7 span. The SS7 RM **210** also sends failure notification events to the RM **100**.

The SS7 RM **210** will be described below in further detail.

Interface F is provided between the RM **100** and the call processor system controller (CPSC) **200** and is also a CORBA- compliant ORB interface. The CPSC **200** is responsible for ensuring that all processes on the call processor **12**, such as the RM **100**, have started-up and remain running. As denoted by the dotted vertical line in FIG. **2**, interface F is internal to the call processor **12**. The primary purpose of interface F is to send and receive state change events and periodic process monitoring messages between the RM **100** and the CPSC **200**. Like interface B, interface

F is event-based, as opposed to the call and return mechanism used in interface A, and can be treated as comprising two one-way CORBA-compliant (IDL) interfaces.

The CPSC-to-RM portion of interface F is preferably a common interface type; i.e., each process running on the call processor **12** has an interface of this type.

The IDL interface from the CPSC **200** to the RM **100** is referred to as the CP process (CPP) interface, in which RM **100** provides a server **171**, and the CPSC **200** acts as a client **201** to that server. The CPP interface is used for process control and monitoring.

The following methods are called by the CPSC **200** on the server **171**: an offline request method for putting the RM **100** into an offline state, in response to which the RM closes all of its write sockets and sets its internal state to OFFLINE; a lock request method for informing the RM **100** that it should be shutdown gracefully, in response to which the RM **100** sets its internal state to SHUTTING DOWN, starts monitoring usage until all resources are idle and once idle, and sends a lock indication to the CPSC **200** to inform it that it is now safe to kill the RM **100**; and an unlock request method for informing the RM **100** that it no longer needs to be locked, to which the RM **100** responds by re-enabling any resources that had previously been blocked from usage. In addition, the CPSC **200** periodically calls a "heartbeat" method on the server **171** to which the RM **100** responds with an acknowledgment, indicating that the RM **100** is up and running.

The RM-to-CPSC portion of interface F is not necessarily a common interface type. In the IDL interface from the RM **100** to the CPSC **200**, the CPSC **200** provides a proxy **202** which acts as a server, while the RM **100** acts as a client **172** to that server. This interface is available on the CPSC **200** immediately after startup and is used to streamline the system startup process and to help the CPSC **200** to determine the state of the call processor **12**.

There are two methods on the proxy **202** that may be called by the RM **100**: 1) an online indication method to notify the CPSC **200** that the RM **100** and SS7 RM **210** have finished initialization and configuration and are ready to bring the call processor **12** online; and 2) a lock indication method to notify the CPSC **200** that the RM **100** has completely shutdown and can be killed by the CPSC **200**.

To further illustrate the operation of the RM **100**, an exemplary message flow involving the RM **100** will now be described. Such a message flow is shown schematically in FIG. **4**. The exemplary message flow of FIG. **4** pertains to the process of sending digits for a trunk-terminated call which begins with an OUTPULSE DIGITS command from the CPA **220** to the RM **100** over interface B. The RM **100**, in turn, sends a TRK_DIGIT_SEND_REQ message to the SM **16** in the IOSS **27**. The SM **16** routes this request to the appropriate resource module, in this case, the TSM **18**. The SM **16** responds to the request from the RM **100** with a TRK_DIGIT_SEND_RSP message. This response message will either indicate that the request to send digits succeeded ("OK") or it will indicate an alarm ID if the request failed ("ERROR").

If the TRK_DIGIT_SEND_RSP message from the SM **16** indicates an ERROR, the RM **100** will forward a TERMINATION FAILURE event to the CPA **220**, indicating the reason for the failure (e.g., signaling failure, TSM unavailable, switching failure, etc.)

If the RM **100** receives an OK indication from the SM **16**, it will forward a SETUP COMPLETE event to the CPA **220**. The SETUP COMPLETE event will include a setup status field with setup information (e.g., subscriber line busy or out of order, subscriber line free, congestion in network, unallocated number, etc.) that was contained in the TRK_DIGIT_SEND_RSP message sent from the SM **16** to the RM **100**. At some later time when the called party answers, the IM **20** through which the call is routed will so indicate to the SM **16** which will send a TRK_ANSWER_IND to the RM **100**. The RM **100**, in turn, sends an ANSWER event to the CPA **220** indicating that the far end has answered the call on the indicated PSTN trunk.

At some further later time when the call is terminated, the SM **16** will send a TRK_TERMINATION_IND to the RM **100** indicating that the signaling on the specified trunk has terminated and providing a metering count received from the terminating end. The metering count indicates the duration of the call. The RM **100**, in turn, sends a RELEASE event to the CPA **220** informing the CPA **220** that far end has disconnected or that it is responding to a release from the near end. The RELEASE event also includes the metering count which can be used for billing purposes.

As disclosed above, the RM **100** can interface with a specialized resource manager, namely, the SS7 RM **210** in the exemplary embodiment described above. The SS7 RM **210** will now be described in greater detail.

A typical telecommunications switching system, whether wireless or wireline-based, interfaces to the PSTN and/or PLMN over standard, digital trunk lines, such as E1 or T1 lines. In addition to carrying user data, e.g., digitized voice, such trunk lines carry signaling data in accordance with one or more established signaling protocols. One such protocol is Signaling System No. 7 (SS7), specified by the International Consultative Committee for Telegraphy and Telephony (CCITT). SS7 provides for the exchange of supervisory signals, address signals and other signals between switching systems. SS7 signaling is carried over one 64 kbps channel of the E1 or T1 trunk.

SS7 is composed of two basic components: a message transfer part (MTP) and multiple user parts (UP). The MTP has three levels of signaling which provide signaling functions over a single data link and network functions for switching signaling messages through a packet-switched network. The UPs are functional procedures for the exchange of messages through the signaling links, or network, irrespective of the modes of transmission or routing. Examples of UPs are the Integrated Services Digital Network User Part (ISUP) and the Telephone User Part (TUP).

For a wireless switching system, SS7 allows MSCs, BSCs, VLRs and HLRs to reside on different nodes or in different networks and provides a transport mechanism for MAP dialogues between them. Multiple SS7 links can be setup between such resources. It also allows for out-of-band (OOB) signaling between two SS7 switches.

In the exemplary switching system **10** of the present invention, the SS7 platform comprising the SS7 cards **13** has an E1-type interface to the PSTN and a TCP/IP interface to the call processor **12**.

FIG. **5** is a block diagram illustrating the various components of the SS7 signaling sub-system and the various entities with which it interacts. As described above, the system **10** is a redundant system with two redundant call processors **12**, with each call processor having its own dedicated SS7 platform comprising four SS7 cards **13**. The following description is of the SS7 sub-system as it pertains to a single call processor **12**. In a redundant system the configuration and characteristics of the SS7 sub-systems on both sides will be identical.

The SS7 sub-system comprises the signaling cards **13**, which interface with the call processor **12**, and several

software components running on the call processor **12**, namely, the SS7 RM **210**, a TCAP component **511**, an ISUP component **512**, a TUP component **513**, an SCCP component **514** and an MTP layer **3** component **515**. Two additional software components of the SS7 sub-system, an MTP layer **2** component **516** and an MTP layer **1** component **517** reside on the SS7 cards **13**.

All software components below the SS7 RM **210**, namely components **511–517**, as well as the cards **13** are available from Data Kinetics, Ltd. As their labels suggest, these components are respectively responsible for performing all MTP layer and SCCP layer functions as well as providing TCAP, ISUP and TUP user interfaces to the applications which utilize the SS7 signaling sub-system. The SS7 sub-system can be implemented with a PC running the QNX Operating System and having a standard ISA bus with a minimum of four ISA slots, one for each Data Kinetics SS7 controller card **13**.

The exemplary embodiment of the SS7 sub-system of FIG. **5** has four interfaces: 1) an NMS server interface, 2) an SS7 network interface, 3) a call processing application (CPA) interface and 4) interface E, described above, with the RM **100**.

The NMS server interface is an Orbix TCP/IP interface. It is used by the NMS server to transmit SS7 configuration data for MTP links, MTP link sets, MTP routes, SCCP local and remote subsystems, and SCCP Global Title Translation information. The NMS server interface is also used by the SS7 platform to report SS7 maintenance events, operational measurements, and any operational faults.

The SS7 network interface comprises four E1 ports, one per SS7 controller card **13**. Each SS7 card **13** is equipped with either two standard 75 ohm BNC connectors, one for transmit and one for receive, or one 120 ohm RJ48 module connector.

The CPA interface is also an Orbix interface and is used by the CPA **220** to send and receive SS7 messages to and from other SS7 nodes in the PSTN or PLMN. SS7 messages received by the SS7 platform from the network are delivered to the appropriate subsystem within the CPA **220**, while SS7 messages received from the CPA **220** are processed for SS7 routing information and delivered to the SS7 network.

As shown in FIG. **5**, external SS7 links on one or more E1 spans **40** coupled to the PSTN are consolidated into a single E1 span **15** using a nailed-up connection through the SM **16** in the IOSS **27**.

Like the RM **100**, the SS7 RM **210** provides a hardware-independent, object model of the resources which it manages, in this case, the SS7 signaling sub-system. FIG. **6** illustrates the relationships among the various managed objects modeled by the SS7 RM **210**. Solid lines represent containment relationships. Where a solid line meets the top of an object, a range of numbers is included representing the number of those objects that can be contained in the container object. Dotted arrows represent inter-object references and their multiplicity. The number range at the base of a dotted arrow represents the potential number of references that can be made from that object to the object type pointed to by the arrow.

The managed objects modeled in the SS7 RM **210** will now be described. Each object, except for the SS7 object, includes a name attribute. The managed objects include:

A single SS7 object representing the SS7 hardware. This object has no attributes. The SS7 object provides methods to add or delete a Point Code object (described below) to the SS7 sub-system.

Multiple (e.g., 33) Point Code objects, each representing an MTP point code. There is one Point Code object for each point code the SS7 sub-system communicates with plus one for the local node. Each Point Code object has an SS7-defined point code (e.g., zone, network and signal point IDs) and a national/international network indicator attribute. Each Point Code object provides get and set methods for accessing its attributes.

One MTP object representing the SS7 MTP function and having an attribute indicating the name of the Point Code object of the originating point code. The MTP object provides methods for adding or deleting Route Set and/or Link Set objects (described below) in addition to get and set methods.

One MTP Measurements object (not shown) with a resetable, read-only attribute which indicates the number of message signal units for which no outgoing routes were available.

One Link object for each SS7 signaling link. As shown in FIG. **6**, up to three Link objects can be contained in each Link Set object (described below) in the exemplary embodiment of the present invention. The attributes of each Link object include: the signaling link code (0–15) of the modeled link, which code is used by the MTP function during link selection, the name of the SS7 span hosting the modeled link, the timeslot of the link, the SS7 state of the link (e.g., UNKNOWN, IN_SERVICE, OUT_SERVICE, INIT_ALIGN, etc.), the operational state of the link (i.e.,ENABLED or DISABLED) and the administrative state of the link (e.g., LOCKED, UNLOCKED. or SHUTTING_DOWN). In addition to attribute get and set methods, each Link object provides lock and unlock methods to control the administrative state of the link.

One Link Measurements object (not shown) for each Link object provides resetable performance management measurements of a particular Link (e.g., number of changeover attempts, duration link unavailable, duration link has been locally or remotely inhibited, duration of unavailability due to failure, number of SIO and SIF octets Message Signaling Units transmitted, etc.)

Up to eight Link Set objects, one for each link set. A link set defines a set of links to an adjacent signaling port. Attributes for each Link Set object include: adjacent Point Code (the name of the Point Code object corresponding to the adjacent point code for this link set), operational state and administrative state of the link set. Besides attribute get and set methods, each Link Set object provides methods to add or delete a specified Link object and to change the administrative state (lock/unlock) of the link set.

One Link Set Measurements object (not shown) for each Link Set object; provides resetable performance management measurements of the modeled link set (e.g., duration for which link set has been unavailable, the number of times or duration for which the adjacent Signaling Point has been inaccessible).

One Route object for each Route Set object (described below). Each Route object represents the destination signaling point and is contained inside a Route Set object. Attributes include the name of the Link Set object representing the link set to be used for this route and the operational state of the route.

One Route Measurements object for each Route object; provides performance management measurements for the modeled route (e.g., number of times the route has been unavailable and the duration of unavailability).

Up to eight Route Set objects, one for each SS7 route set. Each route set defines a set of routes to a destination signaling point. Attributes of each Route Set object are used to designate the name of the Point Code object corresponding to the destination signaling point and to indicate the operational state of the route set. Besides attribute get and set methods, each Route Set object can add or delete a Route object. Each Route Set object can be referenced by managed objects in other applications such as the MSC. As shown in FIG. **6**, ISUP and TUP Trunk Group objects in the MSC can reference each Route Set object.

One Sub System object for each SCCP subsystem. There can be multiple (e.g., 32) remote SCCP subsystems defined in the SS7 system of the present invention. Each object includes an attribute to indicate whether the modeled subsystem is local or remote, an attribute with the name of the Route Set object used to route to the subsystem and an attribute with the number of the subsystem. Attribute get and set methods are provided for the aforementioned attributes.

One SCCP object representing the SCCP function. The SCCP object provides methods to add or delete a global title Translation Entry object (described below) and to add or delete a Sub System object.

One Translation Entry object for each translation entry in the global title translations table. Multiple (e.g., 40) Translation Entry objects may be contained within the SCCP object. Each entry includes a match digit pattern and a route set, which are provided as attributes of the Translation Entry object representing the entry. The match digit pattern is used to match the global title digits being routed on. If a match occurs, then the attributes, destination subsystem (the name of the Sub System object representing the destination subsystem) and called Address Format are used to select a destination and build the SCCP routing address. Instead of the destination subsystem attribute, the route set attribute can be used to route the matched address.

As with objects of the RM **100**, each object in the object model of the SS7 RM **210** may generate State Change reports, event reports and/or alarm reports. For example, the SS7 object generates an EQUIPMENT ALARM report when the SS7 Resource Manager **210** detects a hardware failure or can not communicate with one of the SS7 controller cards **13**. Each Link object can generate several kinds of COMMUNICATION ALARM reports to indicate the occurrence of such events as a changeover, a remote processor outage or signaling link congestion. The SCCP object can generate different COMMUNICATION ALARM reports to report various Q.791 events. The format and contents of the various reports generated by the SS7 RM objects are similar to those generated by the RM objects, described above.

What is claimed is:

1. A resource management system comprising:

a first interface, the first interface being adapted to exchange messages with a hardware resource; and

a second interface, the second interface including a managed object which models the hardware resource.

2. A system comprising:

a controller; and

a resource management system comprising:

a first interface, the first interface being adapted to exchange messages with a hardware resource; and

a second interface, the second interface including a managed object which models the hardware resource,

wherein the controller controls the hardware resource by interacting with the resource management system through the second interface.

3. A system comprising:

a controller;

a first resource management system, the first resource management system including:

a first interface, the first interface being adapted to exchange messages with a first hardware resource; and

a second interface, the second interface including a first managed object which models the first hardware resource; and

a second resource management system, the second resource management system including:

a third interface, the third interface adapted to exchange messages with a second hardware resource; and

a fourth interface, the fourth interface including a second managed object which models the second hardware resource;

wherein, the controller controls the first and second hardware resources by interacting with the first and second resource management systems through the second and fourth interfaces.

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