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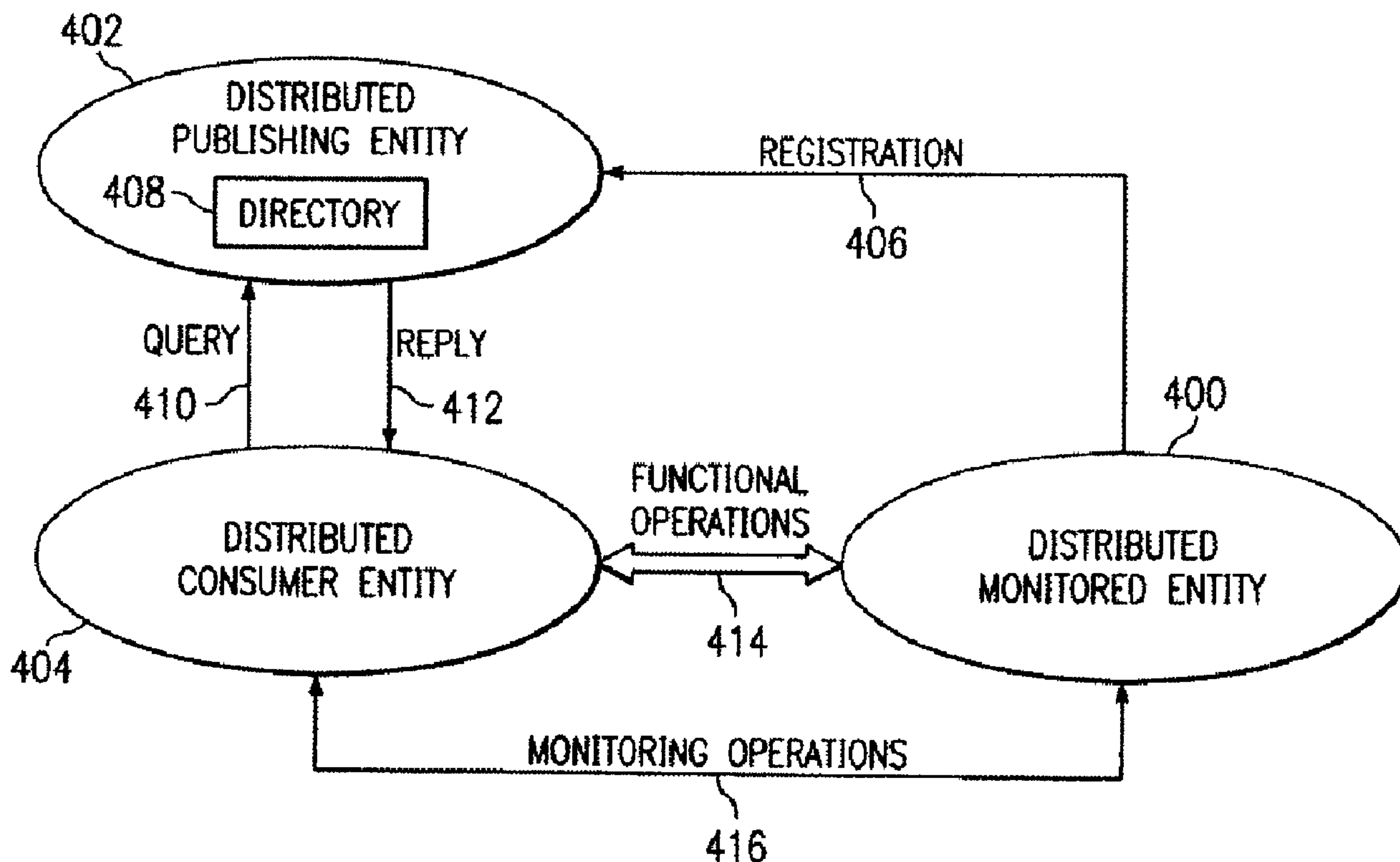
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(54) Titre : PROCEDE ET APPAREIL DESTINES A PUBLIER ET A CONTROLER DES ENTITES OFFRANTS DES SERVICES DANS UN SYSTEME A TRAITEMENT REPARTI DE DONNEES

(54) Title: METHOD AND APPARATUS FOR PUBLISHING AND MONITORING ENTITIES PROVIDING SERVICES IN A DISTRIBUTED DATA PROCESSING SYSTEM



(57) Abrégé/Abstract:

A method, apparatus, and computer instructions for providing identification and monitoring of entities. A distributed data processing system (100) includes one or more distributed publishing entities (400, 402, 404), which publish computer readable announcements (800) in a standard language. These announcements (800) may contain a description of a monitoring method

(57) **Abrégé(suite)/Abstract(continued):**

(802) that may be used to monitor the behavior of one or more distributed monitored entities (400, 402, 404). These announcements also may include information used to identify a monitoring method (802) that may be used by the distributed monitored entity (400) to monitor its own behavior or by a distributed consumer entity to monitor the behavior of the distributed monitored entity (400). The monitoring also may be performed by a third-party distributed monitoring entity (400).

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ABSTRACT OF THE DISCLOSURE**METHOD AND APPARATUS FOR PUBLISHING AND MONITORING ENTITIES
PROVIDING SERVICES IN A DISTRIBUTED DATA PROCESSING SYSTEM**

A method, apparatus, and computer instructions for providing identification and monitoring of entities. A distributed data processing system (100) includes one or more distributed publishing entities (400, 402, 404), which publish computer readable announcements (800) in a standard language. These announcements (800) may contain a description of a monitoring method (802) that may be used to monitor the behavior of one or more distributed monitored entities (400, 402, 404). These announcements also may include information used to identify a monitoring method (802) that may be used by the distributed monitored entity (400) to monitor its own behavior or by a distributed consumer entity to monitor the behavior of the distributed monitored entity (400). The monitoring also may be performed by a third-party distributed monitoring entity (400).

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**METHOD AND APPARATUS FOR PUBLISHING AND MONITORING ENTITIES
PROVIDING SERVICES IN A DISTRIBUTED DATA PROCESSING SYSTEM**

CROSS REFERENCE TO RELATED APPLICATIONS

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The present invention is related to the following applications entitled: "Method and Apparatus for Automatic Updating and Testing of Software", U.S. Patent Application Publication No. US 2004-0060044 A1; "Composition Service for Autonomic Computing", U.S. Patent Application Publication No. US 2004-0060054 A1; "Self-Managing Computing System", U.S. Patent Application Publication No. US 2004-0059704 A1; and "Adaptive Problem Determination and Recovery in a Computer System", U.S. Patent Application Publication No. US 2004-0059966 A1; all filed even date hereof and assigned to the same assignee.

BACKGROUND OF THE INVENTION

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1. Technical Field:

The present invention relates generally to an improved distributed data processing system, and in particular, to a method and apparatus for monitoring entities in a distributed data processing system. Still more particularly, the present invention provides a method and apparatus for identifying and monitoring entities providing services in a network data processing system.

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2. Description of Related Art:

Modern computing technology has resulted in immensely complicated and ever-changing environments. One such environment is the Internet, which is also referred to as an "internetwork". The Internet is a set of computer networks, possibly dissimilar, joined together by means of gateways that handle data transfer and the conversion of messages from a protocol of the sending network to a protocol used by the receiving network. When capitalized, the term "Internet" refers to the collection of networks and gateways that use the TCP/IP suite of protocols. Currently, the most commonly employed method of transferring data over the Internet is to employ the World Wide Web environment, also called simply "the Web". Other Internet resources exist for transferring information, such as File Transfer Protocol (FTP) and Gopher, but have not achieved

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the popularity of the Web. In the Web environment, servers and clients effect data transaction using the Hypertext Transfer Protocol (HTTP), a known protocol for handling the transfer of various data files (e.g., text, still graphic images, audio, motion video, etc.). The information in various data files is formatted for presentation to a user by a standard page description language.

- 5 The Internet also is widely used to transfer applications to users using browsers. Often times, users of software packages may search for and obtain updates to those software packages through the Internet.

Other types of complex network data processing systems include those created for facilitating work in large corporations. In many cases, these networks may span across regions in various worldwide locations. These complex networks also may use the Internet as part of a virtual private network for conducting business. These networks are further complicated by the need to manage and update software used within the network. Often times, interaction between different network data processing systems occurs to facilitate different transactions. These transactions may include, for example, purchasing and delivery of supplies, parts, and services. The transactions may occur within a single business or between different businesses.

Such environments are made up of many loosely-connected software components. These software components are also referred to as “entities”. In a modern complex network data processing system, innumerable situations exist in which a need arises to test or monitor the operation of another entity, such as, a particular running process or a particular service.

- 20 Currently, a human operator must test and monitor the proper functioning of entities, such as important system services, to detect and correct faults and failures in these entities. In many cases, a service may depend on other services for its correct functioning. In this case, it is important to determine whether those other services are functioning correctly, in order to take steps or produce alerts when the services are not functioning correctly. For example, a purchasing entity used for ordering supplies may infrequently require a selected component from a particular provider. Although this component is needed infrequently, it is essential to be able to obtain the component quickly when the need arises. If the provider changes its inventory and no longer offers the component or if the order entity used at the provider to generate the order is unavailable, it is crucial for the purchasing entity to be able to locate another service.
- 30 Currently, a human operator is required to identify a process to test the order entity to determine whether the order entity is functioning correctly. In this example, the order entity is functioning correctly if the order entity offers the selected component as being available in inventory. After identifying this process, the human operator must monitor the order entity.

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Currently, the testing and monitoring of computing entities is performed primarily on an *ad hoc* basis. A human operator needing to monitor a particular service will write a monitoring program for that service or manually search for such a program that someone else has written to perform monitoring. The monitoring program will be deployed and configured manually, and

5 the human operator will manually inspect its output. In some cases the human operator may wrap the monitoring program in a shell that will automatically take some action, such as restarting the service, when a problem is detected.

Existing maintenance and administration tools such as the IBM Tivoli Enterprise Console include features such as administration consoles that display the monitoring status and test

10 results from a number of different entities, including detected faults and generated alerts, and allow administrators to specify actions that should be taken automatically when certain alerts occur. IBM Tivoli Enterprise Console is available from International Business Machines Corporation. Standards, such as the Simple Network Management Protocol (SNMP), specify well-documented ways of communicating alerts and other system events between entities. Some

15 modern computing systems, both in hardware and in software, are designed with testability in mind, and in some cases either the original manufacturer or one or more third parties provide specific testing tools or algorithms for testing specific products.

Even with these types of maintenance and administration tools, a human operator is required to identify entities and methods that are to be used to monitor those entities. Such a

20 system is time consuming and often may require extensive research to identify how a service is to be monitored. Therefore, it would be advantageous to have an improved method, apparatus, and computer instructions for identifying and monitoring entities providing services.

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SUMMARY OF THE INVENTION

The present invention provides a method, apparatus, and computer instructions for providing identification and monitoring of entities. A distributed data processing system includes one or more distributed publishing entities, which publish computer readable announcements in a standard language. These announcements may contain a description of a monitoring method that may be used to monitor the behavior of one or more distributed monitored entities. These announcements also may include information used to identify a monitoring method that may be used by the distributed monitored entity to monitor its own behavior or by a distributed consumer entity to monitor the behavior of the distributed monitored entity. The monitoring also may be performed by a third-party distributed monitoring entity.

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BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and
5 advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 depicts a pictorial representation of a network of data processing systems in which the present invention may be implemented;

Figure 2 is a block diagram of a data processing system that may be implemented as a
10 server in accordance with a preferred embodiment of the present invention;

Figure 3 is a block diagram illustrating a data processing system in which the present invention may be implemented;

Figure 4 is a diagram illustrating message flows used in monitoring entities in accordance with a preferred embodiment of the present invention;

Figure 5 is a diagram illustrating message flow used to monitor entities in which a
15 third-party distributed monitoring entity is present in accordance with a preferred embodiment of the present invention;

Figure 6 is a flowchart of a process used for identifying and monitoring an entity in accordance with a preferred embodiment of the present invention;

Figure 7 is a flowchart of a process used by a third-party distributed monitoring entity to
20 monitor an entity in accordance with a preferred embodiment of the present invention; and

Figure 8 is a diagram illustrating a data structure used in publishing monitoring methods for an entity in accordance with a preferred embodiment of the present invention.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference now to the figures, **Figure 1** depicts a pictorial representation of a network of data processing systems in which the present invention may be implemented. Network data processing system **100** is a network of computers in which the present invention may be implemented. Network data processing system **100** contains a network **102**, which is the medium used to provide communications links between various devices and computers connected together within network data processing system **100**. Network **102** may include connections, such as wire, wireless communication links, or fiber optic cables.

In the depicted example, server **104** is connected to network **102** along with storage unit **106**. In addition, clients **108**, **110**, and **112** are connected to network **102**. These clients **108**, **110**, and **112** may be, for example, personal computers or network computers. In the depicted example, server **104** provides data, such as boot files, operating system images, and applications to clients **108-112**. Clients **108**, **110**, and **112** are clients to server **104**. Network data processing system **100** may include additional servers, clients, and other devices not shown. Server **104** and clients **108-112** may contain different distributed entities, which may communicate with each other through network **102**. A “distributed entity” is any entity in a network data processing system that is able to perform functions, including without restriction, autonomic elements, agents, brokers, aggregators, monitors, consumers, suppliers, resellers, and mediators.

In the depicted example, network data processing system **100** is the Internet with network **102** representing a worldwide collection of networks and gateways that use the Transmission Control Protocol/Internet Protocol (TCP/IP) suite of protocols to communicate with one another. At the heart of the Internet is a backbone of high-speed data communication lines between major nodes or host computers, consisting of thousands of commercial, government, educational and other computer systems that route data and messages. Of course, network data processing system **100** also may be implemented as a number of different types of networks, such as for example, an intranet, a local area network (LAN), or a wide area network (WAN). **Figure 1** is intended as an example, and not as an architectural limitation for the present invention. The mechanism of the present invention may be implemented in any network data processing system containing different data processing systems, which communicate with each other.

Referring to **Figure 2**, a block diagram of a data processing system that may be implemented as a server, such as server **104** in **Figure 1**, is depicted in accordance with a preferred embodiment of the present invention. Data processing system **200** may be a single or a

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symmetric multiprocessor (SMP) system including a plurality of processors **202** and **204** connected to system bus **206**. Alternatively, a single processor system may be employed. Also connected to system bus **206** is memory controller/cache **208**, which provides an interface to local memory **209**. I/O bus bridge **210** is connected to system bus **206** and provides an interface to I/O bus **212**. Memory controller/cache **208** and I/O bus bridge **210** may be integrated as depicted.

Peripheral component interconnect (PCI) bus bridge **214** connected to I/O bus **212** provides an interface to PCI local bus **216**. A number of modems may be connected to PCI local bus **216**. Typical PCI bus implementations will support four PCI expansion slots or add-in connectors. Communications links to clients **108-112** in **Figure 1** may be provided through modem **218** and network adapter **220** connected to PCI local bus **216** through add-in boards.

Additional PCI bus bridges **222** and **224** provide interfaces for additional PCI local buses **226** and **228**, from which additional modems or network adapters may be supported. In this manner, data processing system **200** allows connections to multiple network computers. A memory-mapped graphics adapter **230** and hard disk **232** may also be connected to I/O bus **212** as depicted, either directly or indirectly.

Those of ordinary skill in the art will appreciate that the hardware depicted in **Figure 2** may vary. For example, other peripheral devices, such as optical disk drives and the like, also may be used in addition to or in place of the hardware depicted. The depicted example is not meant to imply architectural limitations with respect to the present invention. The data processing system depicted in **Figure 2** may be, for example, an IBM eServer pSeries system, a product of International Business Machines Corporation in Armonk, New York, running the Advanced Interactive Executive (AIX) operating system or LINUX operating system.

With reference now to **Figure 3**, a block diagram illustrating a data processing system is depicted in which the present invention may be implemented. Data processing system **300** is an example of a client computer, such as client **108** in **Figure 1**.

Data processing system **300** employs a peripheral component interconnect (PCI) local bus architecture. Although the depicted example employs a PCI bus, other bus architectures such as Accelerated Graphics Port (AGP) and Industry Standard Architecture (ISA) may be used. Processor **302** and main memory **304** are connected to PCI local bus **306** through PCI bridge **308**. PCI bridge **308** also may include an integrated memory controller and cache memory for processor **302**. Additional connections to PCI local bus **306** may be made through direct component interconnection or through add-in boards. In the depicted example, local area network (LAN) adapter **310**, SCSI host bus adapter **312**, and expansion bus interface **314** are connected to PCI

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local bus 306 by direct component connection. In contrast, audio adapter 316, graphics adapter 318, and audio/video adapter 319 are connected to PCI local bus 306 by add-in boards inserted into expansion slots. Expansion bus interface 314 provides a connection for a keyboard and mouse adapter 320, modem 322, and additional memory 324. Small computer system interface (SCSI) host bus adapter 312 provides a connection for hard disk drive 326, tape drive 328, and CD-ROM drive 330. Typical PCI local bus implementations will support three or four PCI expansion slots or add-in connectors.

An operating system runs on processor 302 and is used to coordinate and provide control of various components within data processing system 300 in Figure 3. The operating system may be a commercially available operating system, such as Windows XP, which is available from Microsoft Corporation. Instructions for the operating system and applications or programs are located on storage devices, such as hard disk drive 326, and may be loaded into main memory 304 for execution by processor 302.

Those of ordinary skill in the art will appreciate that the hardware in Figure 3 may vary depending on the implementation. Other internal hardware or peripheral devices, such as flash read-only memory (ROM), equivalent nonvolatile memory, or optical disk drives and the like, may be used in addition to or in place of the hardware depicted in Figure 3. Also, the processes of the present invention may be applied to a multiprocessor data processing system.

The depicted example in Figure 3 and above-described examples are not meant to imply architectural limitations. For example, data processing system 300 also may be a notebook computer or hand held computer in addition to taking the form of a PDA. Data processing system 300 also may be a kiosk or a Web appliance.

The present invention provides an improved method, apparatus, and computer instructions for identifying and monitoring services provided by entities in a network data processing system. In particular, the mechanism of the present invention takes advantage of standards, such as Web Services Description Language (WSDL) and systems such as Universal Description, Discovery, and Integration (UDDI), which allow a program to locate entities that offer particular services and to automatically determine how to communicate and conduct transactions with those services. WSDL is a proposed standard being considered by the WorldWide Web Consortium, authored by representatives of companies, such as International Business Machines Corporation, Ariba, Inc., and Microsoft Corporation. UDDI version 3 is the current specification being used for Web service applications and services. Future development and changes to UDDI will be handled by the Organization for the Advancement of Structured

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Information Standards (OASIS). The mechanism of the present invention uses these standards to publish additional information not normally provided. This information includes an identification of a method or process that may be used to monitor an entity. The monitoring may include, for example, testing the entity to determine whether the service is functioning. The monitoring may be performed by the client that uses the entity providing the service or by the entity itself to test its own functionality and availability. This information also may be used by a third-party monitoring entity to monitor the entity for the client.

Turning now to **Figure 4**, a diagram illustrating message flows used in monitoring entities is depicted in accordance with a preferred embodiment of the present invention. The message flow in **Figure 4** flows between distributed monitored entity **400**, distributed publishing entity **402**, and distributed consumer entity **404**. A distributed monitored entity is a distributed entity for which there exists at least one method or algorithm that can be used to establish, with some probability, that at least some portion of the entity is working correctly or is able to carry out at least one function. A distributed publishing entity is a distributed entity that publishes or otherwise makes available certain information in such a way that it can be accessed by at least one distributed entity. A distributed consumer entity is a distributed entity, which depends upon at least one other distributed entity in order to properly, or optimally, perform its functions. In these examples, the entities are software components or processes executing on a data processing system, such as data processing system **200** in **Figure 2** or data processing system **300** in **Figure 3**. Depending on the particular implementation, these entities may all be located on different data processing systems or some or all of the entities may be located on the same data processing system.

In this example, distributed monitored entity **400** sends registration message **406** to distributed publishing entity **402**, which functions as a directory service. Information about registered entities may be stored in directory **408**. Directory **408** allows distributed publishing entity **402** to provide information about distributed monitored entity **400** as well as other entities registered with distributed publishing entity **402**. In particular, directory **408** provides a mechanism to allow searching for registered entities matching selected criteria. In these examples, the selected criteria are a selected service. Other criteria may include, for example, a geographic location of the computer on which a distributed monitored entity is located or a particular protocol used to communicate with a distributed monitored entity. Registration message **406** includes both information about the services provided by distributed monitored entity **400** and information about how distributed monitored entity **400** may be automatically

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monitored for proper operation. This registration information may include a description of a monitoring method used to monitor distributed monitored entity **400**. For example, distributed monitored entity **400** may include a monitoring interface specifically designed to enable monitoring of the entity. For example, the monitoring method may describe the particular

5 commands and parameters to initiate a test to monitor distributed monitored entity **400**. The interface may simply accept a request and provide a response indicating that it is able to respond to requests. The interface may be more complex and generate a data stream continuously or on some periodic basis based on some request sent to its monitoring interface. Distributed monitored entity **400** may be verified as functioning correctly if the data stream is received or if

10 specific data is returned in the data stream. The response may be data generated from the particular service or set of services requested by the client, distributed consumer entity **404**. Alternatively, the request sent may be an invalid request in which an expected error message is to be received. In another type of monitoring method, a particular universal resource endpoint on distributed monitored entity **400** may be provided to which a Simple Object Access Protocol

15 (SOAP) request may be sent. In response to this request, a particular reply may be specified as one that is to be expected if distributed monitored entity **400** is functioning correctly. Another monitoring method may involve sending a particular pattern of data to a specified port in distributed monitored entity **400**. A response to this data pattern should have some selected corresponding pattern if distributed monitored entity **400** is functioning correctly. In another

20 monitoring method, a particular request or class of requests may be sent to distributed monitored entity **400** with a reply being received within a selected period of time if distributed monitored entity **400** is functioning correctly. This specific period of time may be specified in the request that is sent. In other cases, the monitoring method may be a particular program or program fragment that is to be used to test distributed monitored entity **400**. This type of program may

25 take various forms, such as, for example, a Practical Extraction Report Language (PERL) script, a Remote Method Invocation (RMI) client, a RMI stub class, and a binary executable. Of course, other types of monitoring methods may be implemented depending on the particular implementation.

Further, information about how distributed monitored entity **400** may be automatically

30 monitored for proper operation may be sent to distributed publishing entity **402** for entry into directory **408** by an entity other than distributed monitored entity **400**. For example, this registration information may be sent through a testing expert agent or even a human operator inputting data. In some cases, the information about how distributed monitored entity **400** may

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be monitored is retained at distributed monitored entity **400** and not entered into directory **408**.

In this case, the client, such as distributed consumer entity **404**, would obtain the method for monitoring distributed monitored entity **400** directly from distributed monitored entity **400**.

Directory **408** includes identifications of entities, and services provided by entities, as well as monitoring methods for monitoring an entity. This directory also may include other information, such as, for example, distributed monitored entities currently being monitored, previously monitored, or expected to be monitored in the future.

Later, when distributed consumer entity **404** needs to locate an entity to provide a particular service, this entity sends query message **410** to distributed publishing entity **402**.

Alternatively, this query may be a broadcast message that is received by a number of distributed publishing entities with one or more of these entities providing a reply. Distributed publishing entity **402** locates the appropriate service in directory **408** and returns information about entities providing the particular service in reply message **412** to distributed consumer entity **404**. This reply may contain information about a number of different entities, which provide the particular service. If more than one entity is included in reply message **412**, distributed consumer entity **404** may select one or more of these entities with which to operate or communicate. In this example, distributed consumer entity **404** selects distributed monitored entity **400**. The information in reply message **412** includes information on how to contact distributed monitored entity **400** as well as how this entity may be monitored for proper operation. This information may include at least one description of a monitoring method that may be applied to distributed monitored entity **400**. The monitoring method may be a process that is initiated on the distributed monitored entity on distributed monitored entity **400**. The process in the monitoring method may be located within distributed monitored entity **400** or at another location, such as at distributed consumer entity **404**. Depending on the particular implementation, the monitoring information may be excluded from reply message **412** with this monitoring information being obtained directly from distributed monitored entity **400** by distributed consumer entity **404**.

The entities identified and the monitoring methods provided may be based on particular service level agreements or other agreements between the different entities. For example, the monitoring method used to monitor distributed monitored entity **400** may be provided by distributed publishing entity **402** to distributed consumer entity **404** based on some service level agreement or other agreement established between distributed monitored entity **400** and distributed publishing entity **402**.

Distributed consumer entity **404** contacts distributed monitored entity **400** after receiving

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reply message **412** to initiate functional operations **414** using methods and protocols. These are methods and protocols known in the art, such as, for example, WSDL and UDDI. This contact is initiated to allow distributed consumer entity **404** to use a service or services offered by distributed monitored entity **400**. Distributed consumer entity **404** also performs monitoring operations **416** with distributed monitored entity **400** to verify that distributed monitored entity **400** continues to operate properly. These monitoring operations are described in reply message **412** in these examples. The monitoring operations may be initiated through different events, such as a periodic event or a non-periodic event. The periodic event may be an expiration of a timer that triggers the monitoring operation. The non-periodic event may be, for example, initiation of a selected operation, such as a purchase order by distributed consumer entity **404**. In these examples, monitoring operations **416** is a method, such as one or more tests that may be performed on distributed monitored entity **400**. If one or more tests fail during monitoring, distributed consumer entity **404** may take corrective actions. These corrective actions may include, for example, performing further diagnostic tests to determine a cause of the failure, notifying a human administrator of the test failure, notifying another distributed entity that a problem exists, contacting distributed publishing entity **402** to identify a replacement for distributed monitored entity **400**, attempting to restart distributed monitored entity **400**, or executing a selected sequence of actions specified within the testing method identified in reply message **412**.

In another embodiment of the present invention, distributed consumer entity **404** carries out the testing operations described in reply message **412** to verify the proper operation of distributed monitored entity **400** before distributed consumer entity **404** begins functional operations **414** with distributed monitored entity **400**. In another embodiment of this invention, distributed consumer entity **404** carries out the testing operations described in reply message **412** only after a service level agreement or other agreement is in place between distributed monitored entity **400** and distributed consumer entity **404**, and the testing operations are responsive to that agreement. In one possible embodiment, the testing operations are used to verify that the service provided by distributed monitored entity **400** is within the response-time range specified in the relevant agreement.

In the preferred embodiment of the present invention, distributed monitored entity **400** implements at least one monitoring interface specifically designed to enable monitoring operations **416**, initiated by distributed consumer entity **404** to monitor distributed monitored entity **400**. In other embodiments of the present invention, monitoring operations **416** initiated

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by distributed consumer entity **404** to monitor distributed monitored entity **400** includes sending an invalid request to distributed monitored entity **400** and verifying that the expected error indication is received. In still other embodiments, monitoring operations **416** may include requesting that distributed monitored entity **400** generate a continuous or periodic stream of messages directed to distributed publishing entity **402** and verifying that the stream of messages continues to arrive as expected.

In another embodiment of the present invention, distributed monitored entity **400** queries directory **408** in distributed publishing entity **402** to obtain information about how distributed monitored entity **400** may be monitored for proper operation. This information is used by distributed monitored entity **400** to monitor its own operation, for self-diagnostic purposes. In yet another embodiment of this invention, distributed consumer entity **404** receives the information about how distributed monitored entity **400** may be monitored for proper operation from distributed monitored entity **400** itself, rather than from distributed publishing entity **402**.

With reference now to **Figure 5**, a diagram illustrating message flow used to monitor entities in which a third-party distributed monitoring entity is present is depicted in accordance with a preferred embodiment of the present invention. In this example, the monitoring of an entity involves distributed monitored entity **500**, which is the distributed monitored entity, third-party distributed monitoring entity **502**, distributed publishing entity **504**, and distributed consumer entity **506**. In some cases, distributed consumer entity **506** may rely on services provided by another entity, such as distributed monitored entity **500** for correct or optimal functioning. In some instances, distributed consumer entity **506** may be unable to perform monitoring functions. Third-party monitoring also may be used for efficiency reasons. As a result, another entity, such as third-party distributed monitoring entity **502**, may be employed to provide the monitoring function.

A distributed monitoring entity is a distributed entity, which makes use of at least one technique or algorithm to establish, with some probability, that at least some portion of a distributed monitored entity is working correctly, or is able to carry out at least one function. A third-party distributed monitoring entity is a distributed monitoring entity, which potentially monitors at least one distributed monitored entity upon which the entity does not itself depend for proper, or optimal, performance of its own functions. Additionally, third-party distributed monitoring entity **502** also may accept requests from other entities other than distributed consumer entity **506** to monitor distributed monitored entity **500** or other entities. In other words, third-party distributed monitoring entity **502** may provide monitoring for multiple clients

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and multiple distributed monitored entities. Additionally, a fee may be charged for monitoring services provided by third-party distributed monitoring entity **502**. Additionally, the type of monitoring, monitoring method, or parameters used in monitoring, may be changed or modified based on input received from another entity, such as, for example, distributed publishing entity **504**. A modification may include, for example, changing entities that are to be notified as to the results of monitoring of distributed monitored entity **500**. In this example, third-party distributed monitoring entity **502** sends registration message **508** to distributed publishing entity **504**, which functions as a directory service. Information about distributed monitored entity **500** as well as information about third-party distributed monitoring entity **502** may be stored in directory **510** within distributed publishing entity **504**. In this example, registration message **508** contains information about the monitoring method or methods that may be performed on distributed monitored entity **500**. In this example, third-party distributed monitoring entity **502** sends registration message **512** to register itself with distributed publishing entity **504** as an entity capable of performing monitoring operations on entities, such as distributed monitored entity **500**. Registration message **512** identifies the type of monitoring that may be performed by third-party distributed monitoring entity **502**. This information also may identify entities with which monitoring may be performed.

Depending on the particular implementation, third-party distributed monitoring entity **502** also may include information in registration message **512** to register monitoring information about distributed monitored entity **500** with distributed publishing entity **504**. Additionally, directory **510** also may contain information about third-party distributed monitoring entities currently providing monitoring services, third-party distributed monitoring entities, which have previously provided monitoring services, and third-party distributed monitoring entities expected to provide monitoring services.

In some embodiments of this invention, distributed publishing entity **504** or another distributed publishing entity may provide information including information about which third-party distributed monitoring entities have in the past monitored distributed monitored entity **500** and other distributed monitored entities, and/or about which third-party monitoring entities are likely in the future to so monitor, because distributed consumer entities like distributed consumer entity **506** may wish to use this information in determining which of several possible third-party distributed monitoring entities to make use of (on, for instance, the theory that a third-party distributed monitoring entity that has been used for this purpose in the past may be expected to be able to do it at present, or that an entity that has indicated that it is likely to do so

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in the future may be more prepared to do so now). Later, when distributed consumer entity **506** desires to locate an entity to provide a particular service, this entity sends query message **514** to distributed publishing entity **504**. In response to receiving query message **514**, distributed publishing entity **504** identifies entities that can provide services specified in query message **514**.

5 Information about these entities is returned to distributed consumer entity **506** in reply message **516**. This reply contains information about entities, such as distributed monitored entity **500**. Further, the information returned in reply message **516** to distributed consumer entity **506** also includes, in this example, information about automatically monitoring distributed monitored entity **500** for proper operation. In response to receiving reply message, distributed consumer
10 entity **506** may select one or more entities with which to operate and communicate. In this example, the entity is distributed monitored entity **500**.

In addition, distributed consumer entity **506** sends query message **518** to distributed publishing entity **504** in which query message **518** requests information about third-party distributed monitoring entities capable of performing monitoring operations described in reply
15 message **516**. In response to receiving query message **518**, distributed publishing entity **504**, identifies one or more third-party distributed monitoring entities that can perform monitoring operations on distributed monitored entity **500**. As described above, these monitoring operations may take various forms, such as tests or methods that may be executed on an entity to determine whether the entity is properly operating. This information is returned to distributed consumer
20 entity **506** in reply message **520**. Based on this information, distributed consumer entity **506** selects one or more third-party distributed monitoring entities for use in monitoring distributed monitored entity **500**.

Thereafter, distributed consumer entity **506** contacts distributed monitored entity **500** and initiates functional operations **522** to avail itself of services offered by distributed monitored
25 entity **500**. Distributed consumer entity **506** also contacts third-party distributed monitoring entity **502** using request **524** to request monitoring of distributed monitored entity **500**. The monitoring requested is for operations as described in reply message **516** received from distributed publishing entity **504**. For example, the operations may specify a monitoring method that is to be applied to distributed monitored entity **500**. Alternatively, if the monitoring method
30 is not specified in request **524**, the information in this request may include information as to how a monitoring method may be identified. In this instance, third-party distributed monitoring entity **502** may identify a monitoring method for use in monitoring distributed monitored entity **500** by

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examining published information, such as that provided in directory **510** within distributed publishing entity **504**. This request also may include any certificates, verification information, or delegation instruments required for third-party distributed monitoring entity **502** to carry out monitoring operations on distributed monitored entity **500** on behalf of distributed consumer entity **506**. As a result, third-party distributed monitoring entity **502** carries out monitoring operations **526** on distributed monitored entity **500**. Depending on the results, third-party distributed monitoring entity **502** takes actions, which may include sending notification **528** to distributed consumer entity **506** if one or more tests performed in the monitoring operations suggest the existence of a problem or failure in distributed monitored entity **500**. The failure of particular interest is a failure of the service desired by distributed consumer entity **506**. Other services provided by distributed monitored entity **500** may not be tested or failures in those services do not trigger notification **528**. Depending on the particular implementation, services provided by third-party distributed monitoring entity **502** may be provided with a fee being charged to distributed consumer entity **506** for the monitoring service.

In another embodiment of the present invention, third-party distributed monitoring entity **502** contacts distributed publishing entity **504** to obtain information about testing operations to be performed on distributed monitored entity **500**. In still other embodiments, third-party distributed monitoring entity **502** contacts distributed monitored entity **500** itself for that information. In still other embodiments, third-party distributed monitoring entity **502** may infer an appropriate method for monitoring distributed monitored entity **500** by examining other information about that entity, derived from distributed publishing entity **504** or from other sources.

In yet other embodiments of the present invention, third-party distributed monitoring entity **502** publishes or otherwise makes available information concerning which distributed monitored entities that third-party distributed monitoring entity **502** is already monitoring. With publication of this type of information distributed consumer entities, such as distributed consumer entity **506** may elect to request monitoring services of a third-party distributed monitoring entity that is already engaged in monitoring of a given distributed monitored entity, such as distributed monitored entity **500** to receive a discount on the price charged or for the sake of efficiency.

Turning now to **Figure 6**, a flowchart of a process used for identifying and monitoring an entity is depicted in accordance with a preferred embodiment of the present invention. The

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process illustrated in **Figure 6** may be implemented in a client, such as distributed consumer entity **404** in **Figure 4**.

The process begins by identifying a need for a service (block **600**). A list of providers and monitoring methods is requested from a distributed publishing entity, such as distributed publishing entity **404** in **Figure 4** (block **602**). A list of providers and monitoring methods is received from the distributed publishing entity (block **604**). One distributed monitoring entity provider is picked from the list and the monitoring method is stored (block **606**). Depending on the particular implementation, more than one entity may be selected. An agreement is formed with the selected distributed monitored entity to provide services to the selected distributed consumer entity (block **608**). This agreement may be formed using various automated negotiation protocols or methods currently employed. A determination is made as to whether the agreement terminates (block **610**). This agreement may terminate under various conditions specified in the agreement. For example, the agreement may terminate after a set amount of time, after a set amount of time without the agreement being renewed, after some number of transactions, at the initiation of either party, or based on some market condition being present, such as the price of a good or service being above or below some selected value. Another trigger for termination of the agreement may be the failure of a test announced using the present invention. With this type of failure, the process would return to the beginning of **Figure 6** at block **600**. If the agreement does not terminate, the client operates with the distributed monitored entity (block **612**). These operations may vary depending on the services being provided by the distributed monitored entity to the distributed consumer entity. The operations may include, for example, language translation, stock market quotes, news updates, mathematical calculations, storage and retrieval of binary data, database searches, provision of content such as streaming audio or video, and weather prediction.

Next, a determination is made as to whether the monitoring method requires a test of the distributed monitored entity (block **614**). If the monitoring method does require a test, the test request is sent to the distributed monitored entity (block **616**), and a reply is received from the distributed monitored entity (block **618**). A determination is made as to whether to reply as specified in the monitoring method (block **620**). Basically, block **620** is used to determine whether the distributed monitored entity is performing as expected or an error or failure has occurred. If the reply is not as specified in the monitoring method, corrective action is taken (block **622**) and the process returns to block **610** as described above. In some cases, depending on the failure and the success of the corrective action, the process may be unable to return to

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block **610**. Such a case may occur if the distributed monitored entity has suffered a serious failure and corrective action has failed to fix the failure. In this case, the distributed monitored entity may be unable to operate normally.

The corrective action performed in block **622** may take various forms, including, for example, restarting the distributed monitored entity, sending a notification to a human operator, selecting another distributed monitored entity, terminating execution of the distributed monitored entity, or generating an entry in a log file. A restive or corrective action taken may be a particular message being sent based on the results of testing matching selected criteria. For example, if no response is received from application of the monitoring method, the message may indicate that the entity is unavailable. If an error is returned in response to the testing, the message may indicate that the entity is functioning improperly. These messages may be sent to various entities, including, for example, the distributed consumer entity requesting the monitoring and the distributed publishing entity at which the distributed monitored entity is registered. Further, the corrective action also may include executing a program or process in response to testing matching selected criteria. For example, the corrective action might consist of starting a standard problem-determination program or process, giving it parameters containing sufficient information to identify the entity that failed the test, and the nature of the test that was failed. One way the distributed consumer entity would know what corrective measures to try would be by consulting its own internal policies about what to do in such a case. Another way the distributed consumer entity would know what corrective measures to try would be by finding that information bundled along with the test-method information that it received from the distributed publishing entity. Another corrective action may include taking an action with respect to the distributed monitored entity that is likely to break an internal deadlock within that entity when the results of testing match selected criteria. With respect to breaking an internal deadlock, a request may be sent to the platform on which the distributed monitored entity is running. This request may be one asking the platform to terminate any thread of the distributed monitored entity that has been waiting for a lock for some selected period of time. Criteria initiating this corrective action may be based on any policy desired for the particular implementation.

With reference again to block **620**, if the reply is as specified in the monitoring method, the process returns to block **610** as described above. Turning again to block **614**, if the monitoring method does not require a test, the process returns to block **610** as described above. With reference again to block **610**, if the agreement terminates, the process terminates.

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With reference now to **Figure 7**, a flowchart of a process used by a third-party distributed monitoring entity to monitor an entity is depicted in accordance with a preferred embodiment of the present invention. The process illustrated in **Figure 7** may be implemented in a third-party distributed monitoring entity, such as third-party distributed monitoring entity **502** in **Figure 5**.

5 The process begins by registering with a distributed publishing entity (block **700**). In block **700**, the third-party distributed monitoring entity sends information about monitoring operations that this entity may perform. The information also may identify particular entities that may be monitored. Thereafter, the process waits for requests (block **702**). In block **702**, the requests waited for are those from an entity, such as those from a distributed consumer entity
10 desiring monitoring of an entity providing a service. A request is received from the distributed consumer entity to monitor the distributed monitored entity by a particular monitoring method (block **704**). An agreement is formed with the distributed consumer entity (block **706**). This agreement may be reached through any presently known or used negotiation protocol. For instance, the distributed consumer entity may propose one of a set of standard monitoring
15 agreements to the third-party distributed monitoring entity, and the latter may accept the proposal. Alternatively, the monitoring agreement may be formed by any of various automated negotiation protocols or other methods known to the art. In any case, as part of the agreement, the distributed consumer entity will provide the third-party distributed monitoring entity with information sufficient to allow it to perform the requested monitoring of the distributed
20 monitored entity.

Thereafter, a determination is made as to whether the agreement terminates (block **708**). Various factors, as discussed above, may cause the agreement to terminate. The most common factor is typically time. If the agreement does not terminate, a determination is made as to whether the monitoring method identified for the distributed monitored entity requires a test
25 (block **710**). If the monitoring method does require a test, the test request is sent to the distributed monitored entity and a reply is received (block **712**).

Next, a determination is made as to whether the results in the reply are as specified in the monitoring method (block **716**). If the results in the reply are not as specified in the monitoring method, a notification is sent to the distributed consumer entity (block **718**) and the process
30 returns to block **708** as described above. With reference again to block **716**, if the results in the reply are as specified in the test method, the process returns to block **708** as described above. Turning again to block **710**, if the monitoring method does not require a test yet, the process returns to block **708** as described above. With reference again to block **708**, if the agreement

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terminates, the process terminates.

With reference now to **Figure 8**, a diagram illustrating a data structure used in publishing monitoring methods for an entity is depicted in accordance with a preferred embodiment of the present invention. Data structure **800** is an example of a data structure that may be used to
5 provide information to an entity, such as, for example, a distributed consumer entity or a third-party distributed monitoring entity. Section **802** contains lines of description describing an operation that may be performed on a language-translation service to determine whether or not it is correctly performing its basic functions, and the reply that will be received from that operation if the element is correctly performing its basic function. Section **804** contains lines of
10 description describing the fact that a Web service port of a particular service port type may be tested using the operation and expected reply described in section **802**.

Prior art methods send data structures such as data structure **800** without sections **802** and **804** as part of normal WSDL fragments. The present invention adds information such as illustrative sections **802** and **804** to provide for the monitoring mechanisms described above.
15 Section **804** includes an assertion that the port type may be tested using a particular operation and expecting a particular message to be returned in response to the operation. Section **802** defines the operation and the response. The lines in sections **802** and **804** are provided as extensions to WSDL with the other portions being standard WSDL coding. The example illustrated in **Figure 8** uses extensible markup language (XML). This example is provided as an illustration, but is
20 not intended to limit the invention to using this particular format. Any other format may be used depending on the particular implementation.

Thus, the present invention provides an improved method, apparatus, and computer instructions for publishing and providing information to identify and monitor entities in an autonomic computing system. The mechanism uses standardized languages, such as WSDL or
25 UDDI, to provide or publish information about monitoring methods that may be used for particular entities that have been registered with the mechanism of the present invention. In this manner, a client, such as a distributed consumer entity, may request and receive an identification of entities that are able to provide a desired service. In addition to an identification of the service, the mechanism of the present invention provides information indicating how the entity
30 providing the service may be monitored to verify that the entity is able to provide the service as required by the client. With this information, the client is able to monitor the service and take corrective action if monitoring indicates that the entity is unable to function in the manner required.

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It is important to note that while the present invention has been described in the context of a fully functioning data processing system, those of ordinary skill in the art will appreciate that the processes of the present invention are capable of being distributed in the form of a computer readable medium of instructions and a variety of forms and that the present invention applies
5 equally regardless of the particular type of signal bearing media actually used to carry out the distribution. Examples of computer readable media include record able-type media, such as a floppy disk, a hard disk drive, a RAM, CD-ROM's, DVD-ROMs, and transmission-type media, such as digital and analog communications links, wired or wireless communications links using transmission forms, such as, for example, radio frequency and light wave transmissions. The
10 computer readable media may take the form of coded formats that are decoded for actual use in a particular data processing system.

The description of the present invention has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art.
15 The embodiment was chosen and described in order to best explain the principles of the invention, the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

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CLAIMS

What is claimed is:

- 5 1. A method for providing testing in a distributed data processing system, the method comprising:
- responsive to a request from a client for information for a selected service, identifying a registered entity providing the selected service; and
- 10 sending a reply to the client, wherein the reply includes information identifying the registered entity providing the selected service and a monitoring method for the entity, wherein the information is in a computer readable format, and wherein the information allows the client to monitor the registered entity providing the selected service.
- 15 2. The method of claim 1, wherein the identifying and sending steps are performed in at least one of the registered entity and a distributed publishing entity.
3. The method of claim 1 further comprising:
- 20 receiving a request to register the selected service from the registered entity, wherein the request includes information about the selected service and how the registered entity can be monitored for proper operation of the selected service; and
- responsive to receiving the request, registering the selected service, wherein the registered entity providing the selected service may be identified in response to the request from the client.
- 25 4. The method of claim 1, wherein the client is the registered entity providing the selected service.
- 30 5. The method of claim 1, wherein identifications of registered entities are stored in a directory.

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6. The method of claim 1 further comprising:
storing monitoring information on registered entities.

5 7. The method of claim 1, wherein the monitoring information includes at least one
of registered entities currently being monitored, registered entities previously monitored,
and registered entities expected to be monitored.

8. The method of claim 1 further comprising:
sending the monitoring information to the client in response to a request from the
10 client for the monitoring information.

9. The method of claim 1, wherein the monitoring method includes at least one of an
identification of a monitoring interface in the registered entity, sending a request to the
monitoring interface in which a response indicates that the registered entity is functioning
15 correctly, sending a request to the monitoring interface in which a response indicates that
at least one service in the registered entity is functioning correctly, sending an invalid
request to the registered entity in which a selected error is expected, sending a pattern of
data to a port in the registered entity in which a particular pattern is expected in response
to the pattern of data, sending a request to the registered entity in which a response is
20 expected within a selected period of time to indicate that the registered entity is
functioning correctly, a program, a PERL script, a RMI client, a RMI stub, and a binary
executable.

10. A data processing system for providing testing in a distributed data processing
25 system, the data processing system comprising:

identifying means, responsive to a request from a client for information for a
selected service, for identifying a registered entity providing the selected service; and

sending means for sending a reply to the client, wherein the reply includes
information identifying the registered entity providing the selected service and a
30 monitoring method for the entity, wherein the information is in a computer readable

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format, and wherein the information allows the client to monitor the registered entity providing the selected service.

11. The data processing system of claim 10, wherein the identifying and sending means are performed in at least one of the registered entity and a distributed publishing entity.

12. The data processing system of claim 10 further comprising:

receiving means for receiving a request to register the selected service from the registered entity, wherein the request includes information about the selected service and how the registered entity can be monitored for proper operation of the selected service; and

registering means, responsive to receiving the request, for registering the selected service, wherein the registered entity providing the selected service may be identified in response to the request from the client.

13. The data processing system of claim 10, wherein the client is the registered entity providing the selected service.

14. The data processing system of claim 10, wherein identifications of registered entities are stored in a directory.

15. The data processing system of claim 10 further comprising:

storing means for storing monitoring information on registered entities.

16. The data processing system of claim 10, wherein the monitoring information includes at least one of registered entities currently being monitored, registered entities previously monitored, and registered entities expected to be monitored.

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17. The data processing system of claim 10, wherein the sending means is a first sending means and further comprising:

second sending means for sending the monitoring information to the client in response to a request from the client for the monitoring information.

5

18. The data processing system of claim 10, wherein the monitoring method includes at least one of an identification of a monitoring interface in the registered entity, sending a request to the monitoring interface in which a response indicates that the registered entity is functioning correctly, sending a request to the monitoring interface in which a response indicates that at least one service in the registered entity is functioning correctly, sending an invalid request to the registered entity in which a selected error is expected, sending a pattern of data to a port in the registered entity in which a particular pattern is expected in response to the pattern of data, sending a request to the registered entity in which a response is expected within a selected period of time to indicate that the registered entity is functioning correctly, a program, a PERL script, a RMI client, a RMI stub, and a binary executable.

10

15

19. A computer program product in a computer readable medium for providing testing in a distributed data processing system, the computer program product comprising:

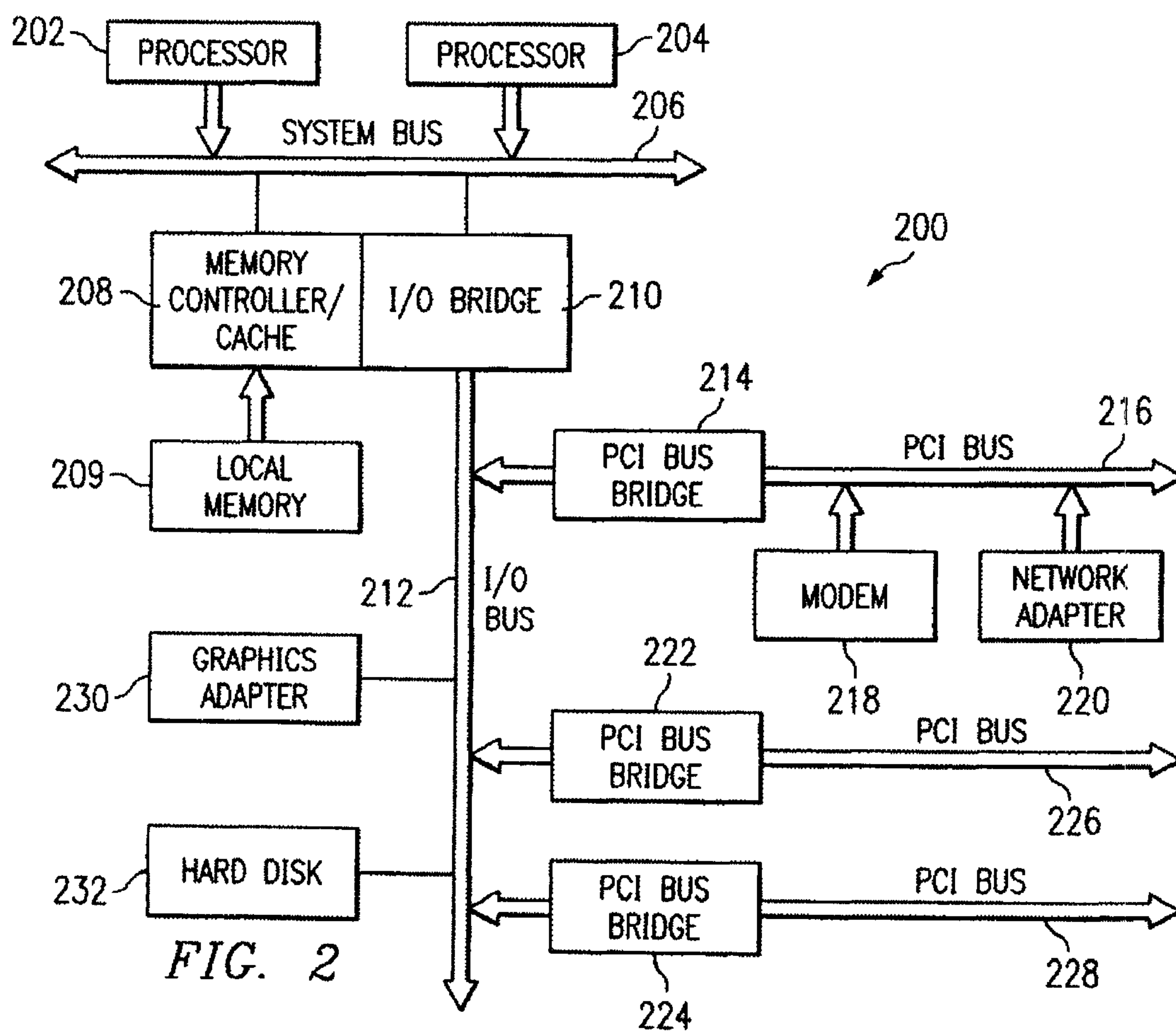
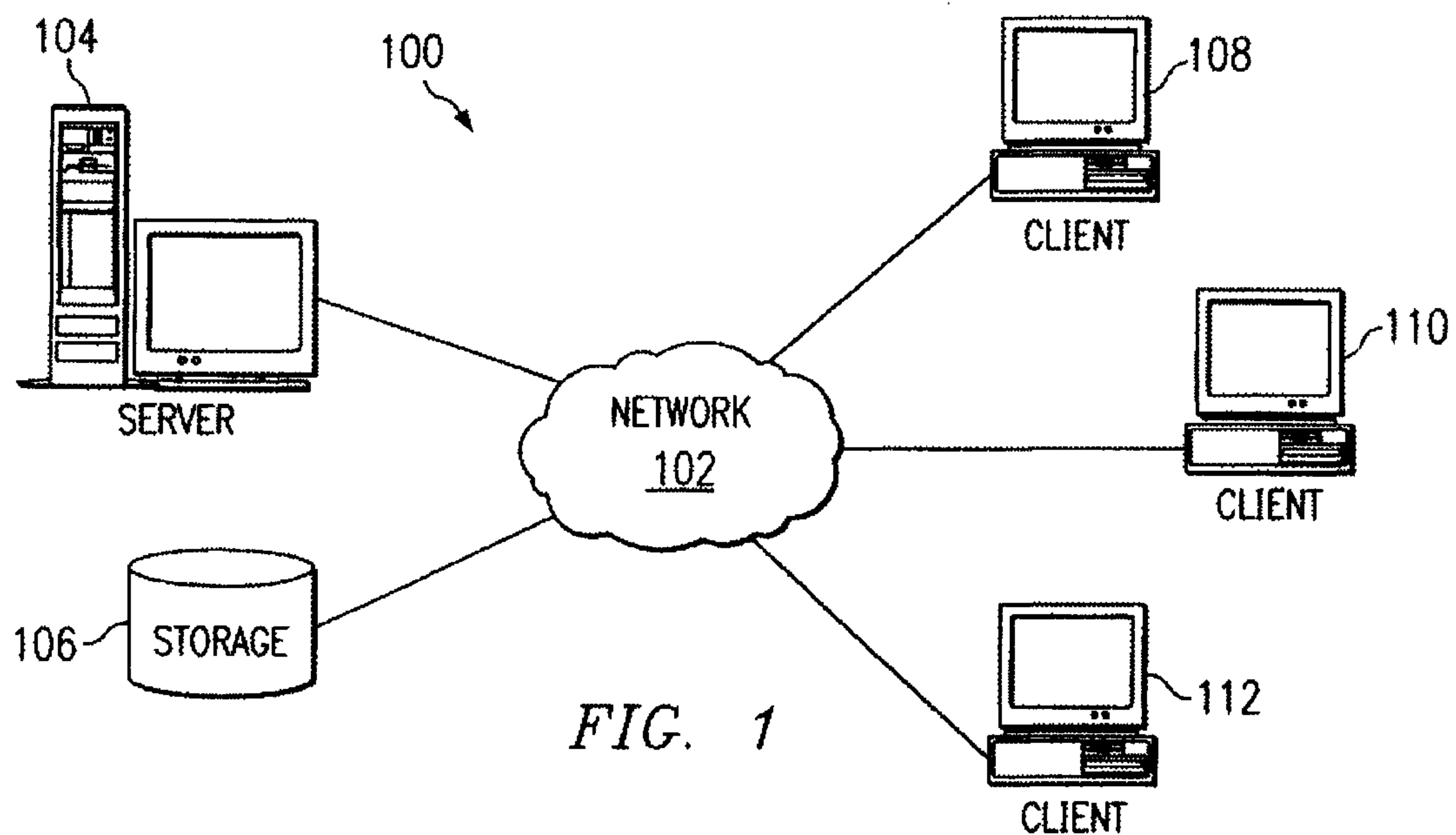
20

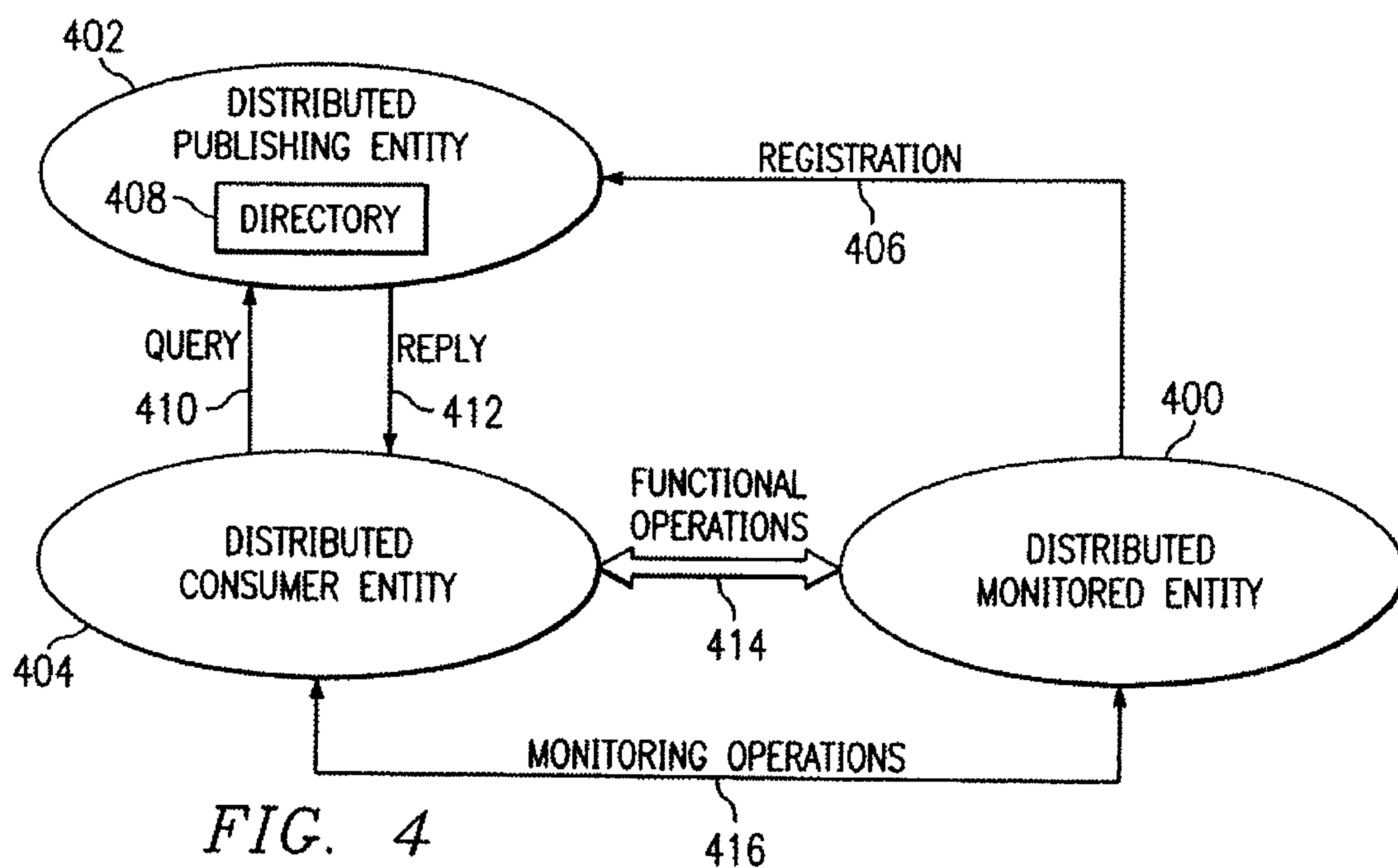
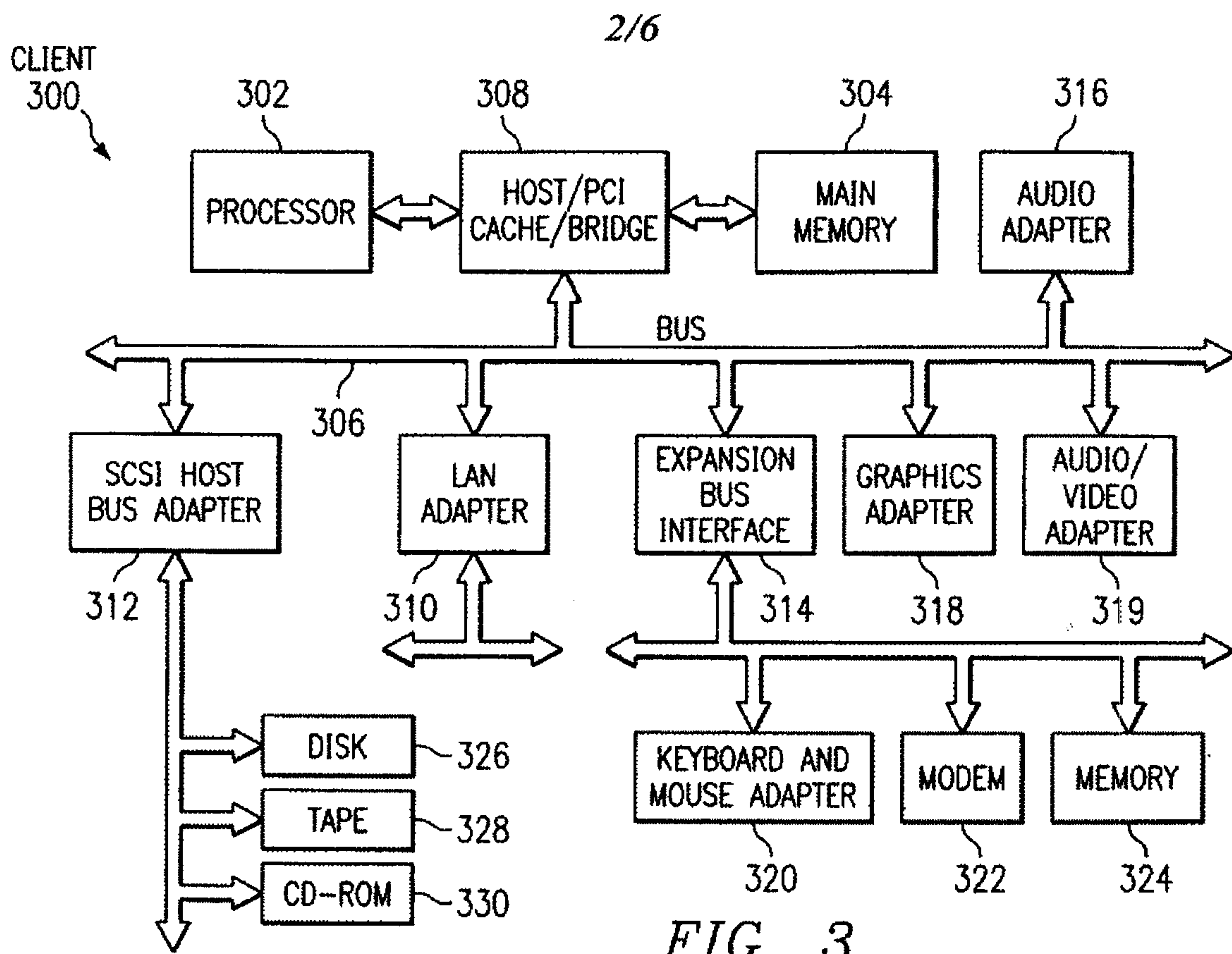
first instructions, responsive to a request from a client for information for a selected service, for identifying a registered entity providing the selected service; and

second instructions for sending a reply to the client, wherein the reply includes information identifying the registered entity providing the selected service and a monitoring method for the entity, wherein the information is in a computer readable format, and wherein the information allows the client to monitor the registered entity providing the selected service.

25

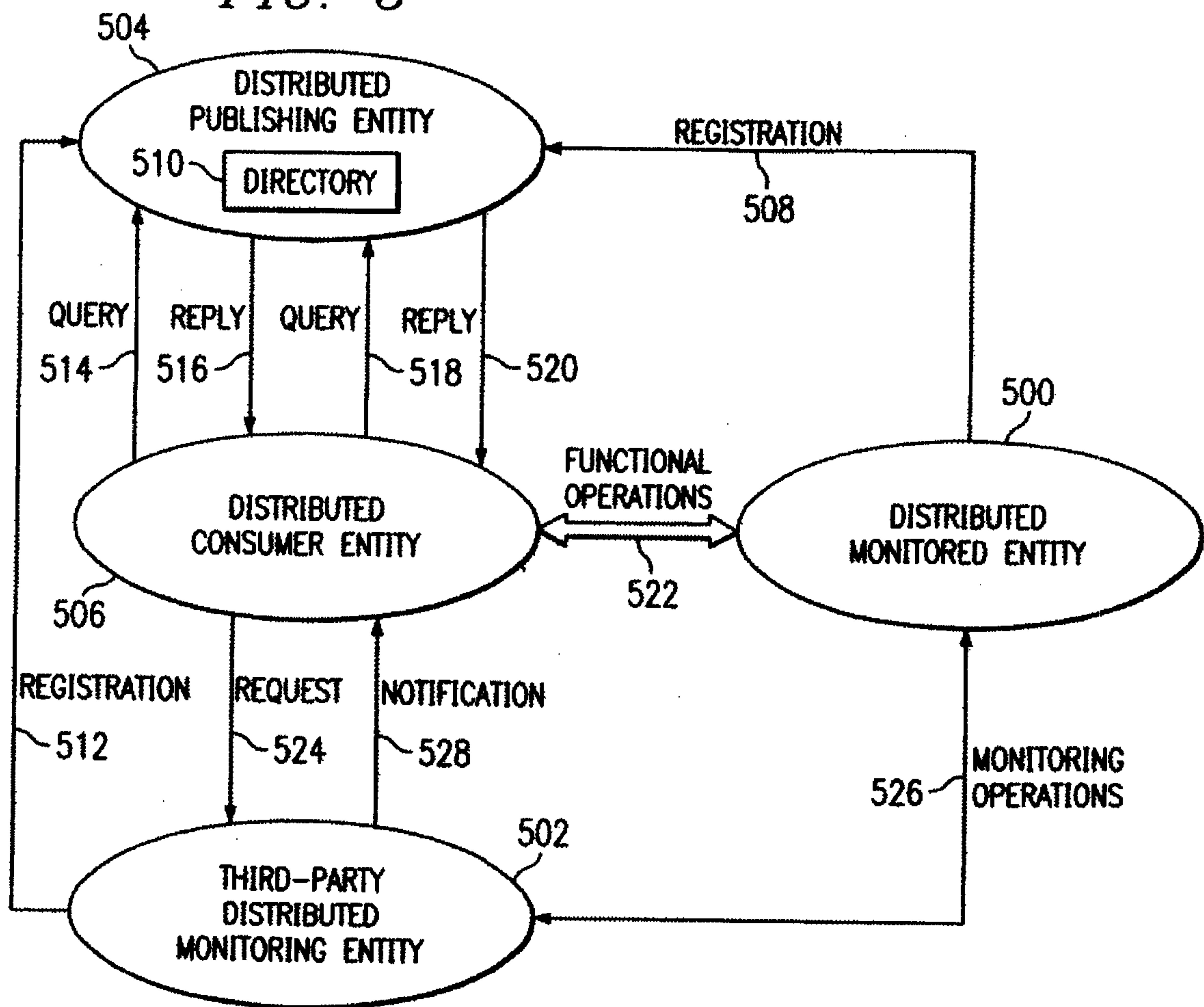
1/6





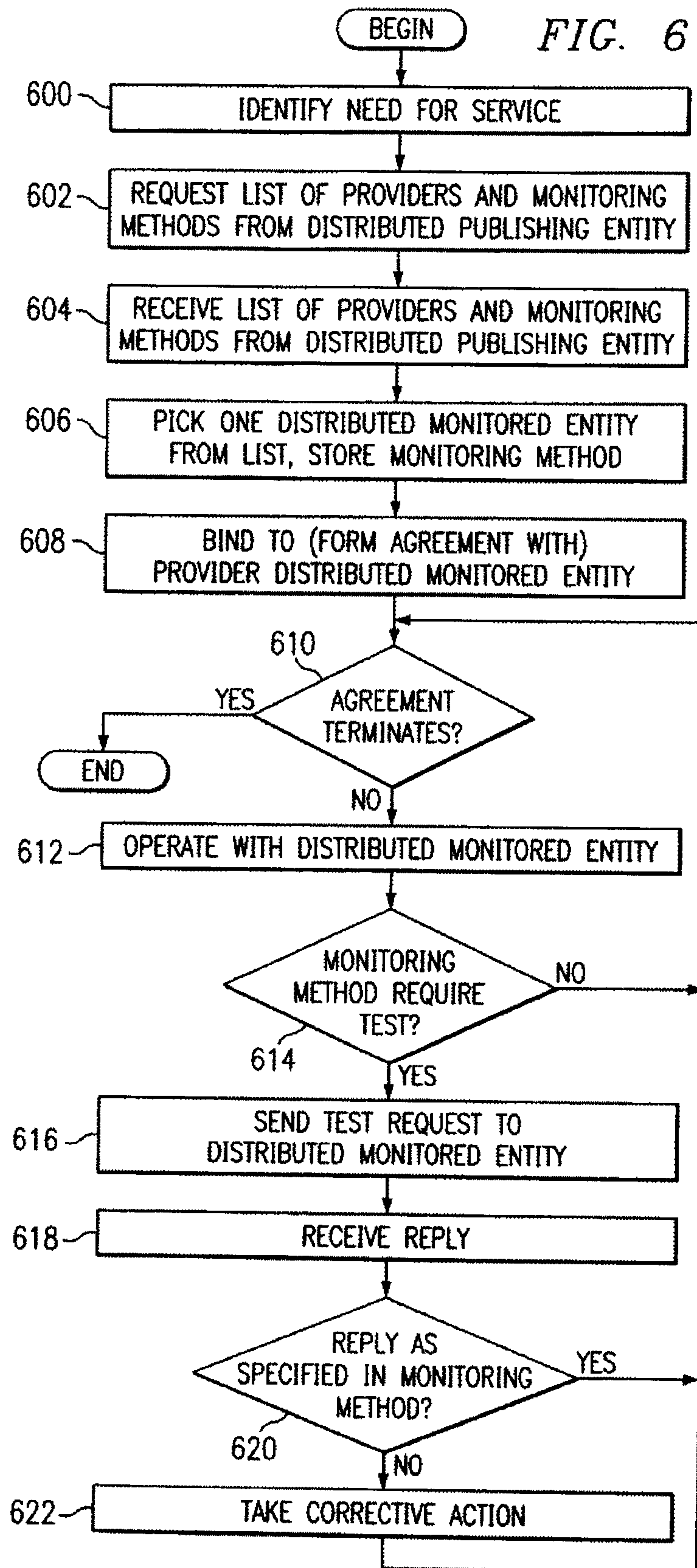
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FIG. 5



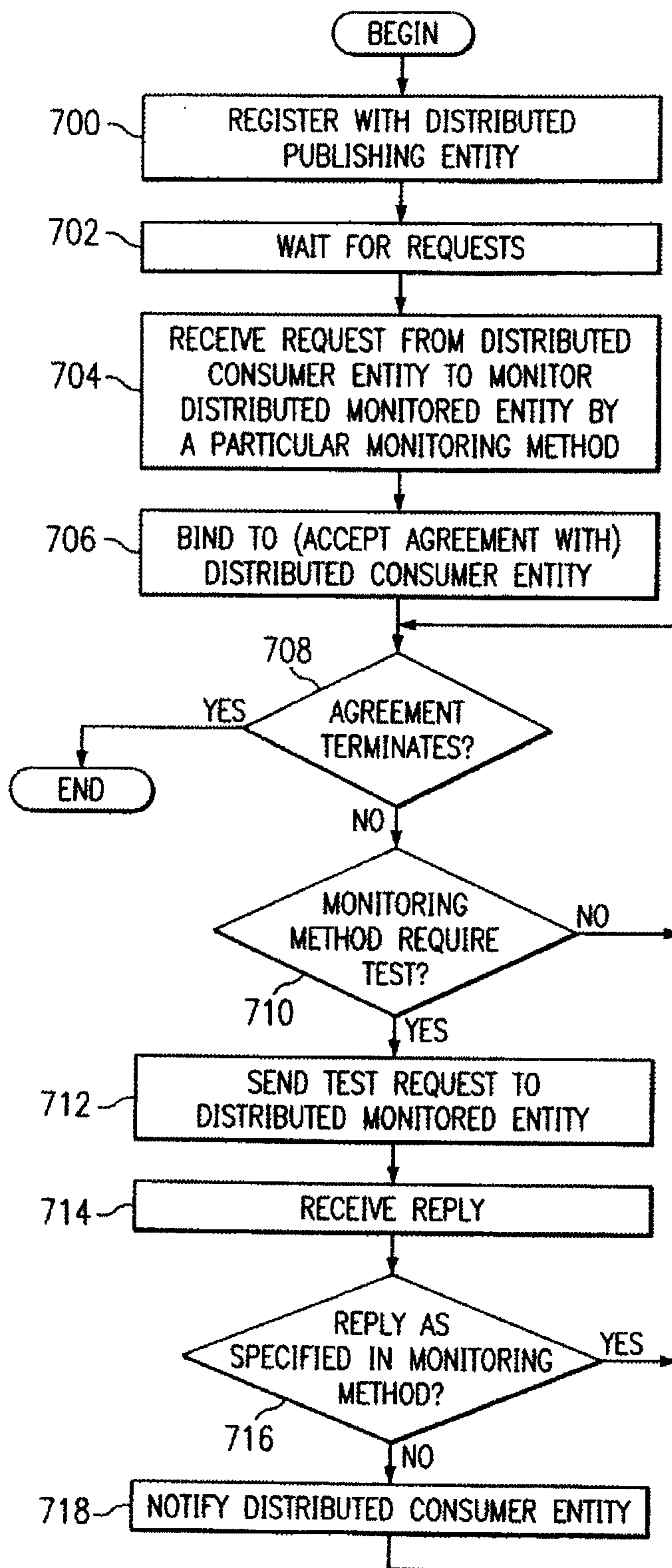
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FIG. 6



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FIG. 7



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800

```

<xsd:element name="TranslateShortStringRequest">
  <xsd:complexType>
    <xsd:all>
      <xsd:element name="ShortString" type="string"/>
      <xsd:element name="FromLanguage" type="LanguageIdentifier"/>
      <xsd:element name="ToLanguage" type="LanguageIdentifier"/>
    </xsd:all>
  </xsd:complexType>
</xsd:element>

802 { <xsd:element name="TranslateShortStringTestIn">
  <xsd:complexType>
    <xsd:all>
      <xsd:element name="ShortString" type="string" testmeth:value="cinque" />
      <xsd:element name="FromLanguage" type="LanguageIdentifier" testmeth:value="fr" />
      <xsd:element name="ToLanguage" type="LanguageIdentifier" testmeth:value="en" />
    </xsd:all>
  </xsd:complexType>
</xsd:element>

  <xsd:element name="TranslateShortStringTestOut">
    <xsd:complexType>
      <xsd:all>
        <xsd:element name="ShortString" type="string" testmeth:value="five" />
      </xsd:all>
    </xsd:complexType>
  </xsd:element>

  <wsdl:portType name="TranslationServicePortType">
    <wsdl:operation name="TranslateShortString">
      <wsdl:input message="TranslateShortStringRequest"/>
      <wsdl:output message="TranslateShortStringResponse"/>
      <wsdl:fault message="TranslateServiceFault"/>
      804 { <testmeth:testInput message="TranslateShortStringTestIn" />
        <testmeth:testOutput message="TranslateShortStringTestOut" />
      }
    </wsdl:operation>
  </wsdl:portType>

```

FIG. 8

