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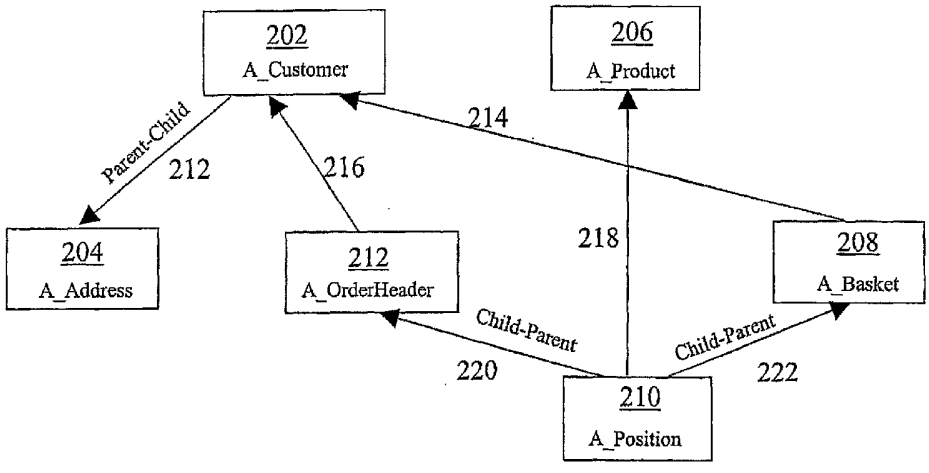

(57) Abstract: Methods and apparatus, including computer program products, that include generating a first application by providing a definition of an object representing a first set of attributes of a first collection of data elements and a first set of operations on the first collection, each data element in the first collection having the attributes and a list of the operations in common with other data elements from the first collection. The method also includes extending the definition of the object with a second definition, the second definition comprising a second set of attributes of the data elements or a list of second set of operations on the data elements, receiving from the client a request to execute an operation from the first set of operations or the second set of operations on one or more data elements from the first collection, the request having input parameters, checking the request against the definition and the second definition, executing, with a first set of parameters, the operation on the one or more data elements of the first collection, the operation resulting in output parameters, and sending a second set of parameters.

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EXTENDING SERVICE-ORIENTED BUSINESS FRAMEWORKS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of the filing date of United States Provisional Application No. 60/489,573 for ENTERPRISE SERVICES FRAMEWORK TECHNOLOGIES, filed July 22, 2003, and United States Utility Application No. 10/746,963 for EXTENDING THE FUNCTIONALITY OF ENTERPRISE SERVICES, filed December 23, 2003, the disclosure of which are incorporated by reference in their entirety.

BACKGROUND

The present invention relates to data processing by digital computer, and more particularly to extending service-oriented business frameworks. The present invention relates to data processing by digital computer, and more particularly to self describing business objects.

Large scale business software applications are sometimes categorized in terms of a "front end component" that includes a graphical user interface (GUI) to present data to users and accept data entry from users. Such front end components are customized for specific customers. Another component of such software applications is sometimes referred to as a "back end component" that stores business data and processes the business data according to business logic. The back end component retrieves, generates, and maintains the business data. The back end component is usually responsible for the consistency and correctness of the data. The back end component also can store relationships between the various data. In a typical business software application, the front end component includes application code to display and aggregate data of the back end and provides help to generate requests to the back end for update operations.

The data of the back end can be represented using relational database terminology. In relational database terminology, an *entity* is a record and an *entity type* is a set of entities with common attributes to which a unique name and a unique description are assigned. Typically, a database has multiple two dimensional tables where each table represents an entity type and each row in each table represents an entity. An *attribute* is a description of a characteristic of

an entity or entity type. Typically, an attribute is specified in a field or a column in a database table. Entity types can also have relationships that enable linking one or more entities of an entity type to other entities of another entity type. This linking can be done using foreign keys by having one or more fields in one table pointing to a primary key of a second table. This enables traversing from a set of entities in one table to related entities in another table.

SUMMARY OF THE INVENTION

In one aspect, the invention features a method that includes generating a first application by providing a definition of an object representing a first set of attributes of a first collection of data elements and a first set of operations on the first collection, each data element in the first collection having the attributes and a list of the operations in common with other data elements from the first collection. The method also includes extending the definition of the object with a second definition, the second definition comprising a second set of attributes of the data elements or a list of second set of operations on the data elements, receiving from the client a request to execute an operation from the first set of operations or the second set of operations on one or more data elements from the first collection, the request having input parameters, checking the request against the definition and the second definition, executing, with a first set of parameters, the operation on the one or more data elements of the first collection, the operation resulting in output parameters, and sending a second set of parameters.

Embodiments may include one or more of the following. The first set of parameters includes the input parameters and the second parameters comprise the output parameters. The method further includes providing a definition of a module representing a set of one or more collections of data elements, the set comprising the first collection of data elements, wherein the definition of the module comprises a query on one or more collections of data elements. In some cases, the method further includes extending the definition of the module with a second definition, the second definition comprising a second query on one or more collections of the data elements. In some of these cases, the method further includes receiving from the client a request to execute the first or second query on one or more collections of the data elements, the request having input parameters,

checking the request against the definition and the second definition of the module, executing, with a first set of parameters, the query on the one or more collections of the data elements, the operation resulting in output parameters, and sending a second set of parameters. In some of these cases, the second definition further includes a second collection of data elements and the second definition may further include a relation between the first collection and the second collection, the relation enabling a navigation from the first collection to the second collection.

Embodiments may include one or more of the following. The method further includes sending the request with the input parameters, generating the first set of parameters by modifying the input parameters, and receiving the first set of parameters. The method of can further include sending the request with the output parameters, generating the second set of parameters by modifying the output parameters, and receiving the second set of parameters.

Embodiments may include one or more of the following. The method further including extending the definition and the second definition of the object with a third definition, the third definition comprising a third set of attributes of the data elements or a third set of operations on the data elements, and checking the request against the definition, the second definition, and the third definition. The method further including extending the definition of the module with a third definition, the third definition comprising a third query on one or more collections of the data elements. The method further including generating a second application by extending the definition of the object with a third definition, the third definition comprising a third set of attributes of the data elements or a third set of operations on the data elements, receiving from the client a request to execute an operation from the first set of operations or the third set of operations on one or more data elements from the first collection, the request having input parameters, and checking the request against the definition and the third definition.

In another aspect, the invention features a system that includes a first computer configured to execute a client program, a second computer configured to execute a server program, a network linking the first and second computers such that the server program is configured to execute the following. Provide to the

client program a first application with a definition of an object representing a first set of attributes of a first collection of data elements and a list of first set of operations on the first collection, each data element in the first collection having the attributes and the operations in common with other data elements from the first collection. Extend the definition of the object with a second definition, the second definition including a second set of attributes of the data elements or a second set of operations on the data elements. Receive from the client program a request to execute an operation from the first set of operations or the second set of operations on one or more data elements from the first collection, the request having input parameters. Check the request against the definition and the second definition. Execute, with a first set of parameters, the operation on the one or more data elements of the first collection, the operation resulting in output parameters. Send to the client program a second set of parameters.

Embodiments may include one or more of the following. The first set of parameters include the input parameters and the second parameters include the output parameters. The server program is further configured to provide a definition of a module representing a set of one or more collections of data elements, the set comprising the first collection of data elements, the definition of the module comprising a query on one or more collections of data elements. In some cases, the server program is further configured to extend the definition of the module with a second definition, the second definition comprising a second query on one or more collections of the data elements. In some of these cases, the server program is further configured to execute the following. Receive from the client a request to execute the first or second query on one or more collections of the data elements, the request having input parameters. Check the request against the definition and the second definition of the module. Execute, with a first set of parameters, the query on the one or more collections of the data elements, the operation resulting in output parameters. Send a second set of parameters. In some cases, the second definition further includes a second collection of data elements. The second definition further can include a relation between the first collection and the second collection, the relation enabling a navigation from the first collection to the second collection.

The client program is configured to execute the following. Send the request with the input parameters. Generate the first set of parameters by modifying the input parameters. Receive the first set of parameters.

The client program is configured to execute the following. Send the request with the output parameters. Generate the second set of parameters by modifying the output parameters. Receive the second set of parameters.

The server program is further configured to execute the following. Extend the definition and the second definition of the object with a third definition, the third definition comprising a third set of attributes of the data elements or a third set of operations on the data elements. Check the request against the definition, the second definition, and the third definition.

The server program is further configured to extend the definition of the module with a third definition, the third definition including a third query on one or more collections of the data elements.

The server program is further configured to execute the following. Generate a second application by extending the definition of the object with a third definition, the third definition comprising a third set of attributes of the data elements or a third set of operations on the data elements. Receive from the client a request to execute an operation from the first set of operations or the third set of operations on one or more data elements from the first collection, the request having input parameters. Check the request against the definition and the third definition.

These and other embodiments may have one or more of the following advantages. A service-oriented business framework can be extended without modification based on business requirements. This extension can have multiple layers. This extension includes additional metadata as well as additional coding.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of an example logical representation of a business software application.

FIG. 2 is a view of a network configuration for a business software application.

FIG. 3 is a block diagram of the business software application of FIG. 1.

FIG. 4 is a Unified Modeling Language (UML) representation of a structure of a meta model repository.

FIG. 5 is a flow diagram of a business process.

FIG. 6 is a diagram showing relations between different aspects for a business software application.

FIG. 7 is a view of a network configuration for a business software application.

FIG. 8 is a view of an information flow from an extension of a repository object to the repository object.

FIG. 8A is a view of two chains of extensions for two different customers.

FIG. 9 is a sequence diagram of providing a service upon request from an application program using a service framework with an extension.

DETAILED DESCRIPTION

FIG. 1 illustrates an overview logical representation of a business software architecture **2**, which includes a client **3**, a separation layer **5**, a repository **7** and backend data **9** and **9'**. Client **3** provides a user interface (UI) that enables a user to interact with the backend data **9** and/or **9'**. Backend data **9** and **9'** can be associated with different backend applications and/or can be arranged and formatted differently from each other. Separation layer **5** separates the front end user interface provided by client **3** from the back end data **9** and **9'**. This separation enables client **3** to interact with backend data **9** and **9'** in a consistent and similar manner, regardless of the formatting or application-associated differences between backend data **9** and **9'**. In other words, separation layer **5** provides a canonical interface to backend data **9** and **9'** so that client **3** is configured to interact with separation layer **5** and only needs to be updated if separation layer **5** changes. Changes to backend data **9** and **9'** do not necessitate an update to client **3**. Further, separation layer **5** is scalable and configured to handle changes and growth to backend data **9** and **9'** and any other disparate backend data and backend services that are further connected to separation layer **5**.

As described in more detail below, separation layer **5** is based on a meta model that defines how backend data (e.g., **9** and **9'**) are represented in separation

layer **5**. Meta data is stored in repository 7 that describes how the backend data **9** and **9'** fit into the meta model representation. Client **3** interacts with backend data **9** and **9'** using a generic command set defined by separation layer **5**. As described in more detail below, separation layer **5** accesses service providers that perform the generic commands from client **3**, using the meta data in repository **7**, to effect the requested manipulation of backend data **9** and **9'**. The service providers are configurable so that different service providers can be used for different backend data **9** and **9'**. Separation layer **5** includes an interface (e.g., a service manager) that hides the characteristics of the corresponding backend data **9** and **9'** and also the granularity and distribution of the implementation (i.e., the service providers).

FIG. 2 illustrates an example implementation of the business software architecture **2**. As shown in FIG. 2, the business software architecture **2** includes a first computer **4** and a second computer **6**. The computers **4** and **6** each can include a processor, a random access memory (RAM), a program memory (for example, a writable read-only memory (ROM) such as a flash ROM), a hard drive controller, a video controller, and an input/output (I/O) controller coupled by a processor (CPU) bus. The computers **4** and **6** can be preprogrammed, in ROM, for example, or the computers **4, 6** can be programmed (and reprogrammed) by loading a program from another source (for example, from a floppy disk, a CD-ROM, or another computer) into a RAM for execution by the processor. The hard drive controller is coupled to a hard disk suitable for storing executable computer programs, including programs embodying the present invention, and data. The I/O controller is coupled by an I/O bus to an I/O interface. The I/O interface receives and transmits data in analog or digital form over communication links, e.g., a serial link, local area network, wireless link, or parallel link. Also coupled to the I/O bus are a display and a keyboard. Alternatively, separate connections (separate buses) can be used for the I/O interface, display, and keyboard.

A network **20** connects computers **4** and **6**. The network **20** is any form or medium of digital data communication, e.g., a communication network. Examples of communication network **20** include a local area network ("LAN") and a wide area network ("WAN"), e.g., the Internet.

Computer **4** executes instructions of a front end application program **12**. Application program **12** represents a front end component of the business software

architecture **2**. Service manager **16**, running on computer **6**, is a service layer between the front end application program **12** and a set of back end service providers **26**. Service manager **16** provides a service interface to front end application program **12** to enable indirect interaction with the set of back end service providers **26** running on computer **6**. This service interface allows for a partial separation of software development for front end application program **12** and the set of back end service providers **26**.

Computer **6** includes a data storage device **22** that stores a back end database **24** containing data that can be used by the set of back end service providers **26**. Computer **6** also includes a data storage device **8** containing an information repository **18** that defines and describes the services provided by the set of back end service providers **26**. The meta data in repository **18** is organized according to a meta model.

In general, a meta model is a collection of "concepts" that are the vocabulary with which a certain domain can be described. Meta models typically are built according to a strict rule set, which in most cases is derived from entity-relationship-attribute or object-oriented modeling. The front end application program **12** can access (and interpret according to the strict rule set) the contents of repository **18** via the service manager **16**. These services support the functionality of application program **12** and include retrieving and reading data in addition to modifying stored data. The service providers **26** can access or modify stored data in backend database **24** to provide services to front end application program **12**. To provide the services, the set of back end service providers **26**, upon request from the front end application program **12**, either access or modify stored data in backend database **24** or calculate new data.

The repository **18** defines a syntax for requesting services provided by the set of back end service providers **26** and semantically describes the services. As front end application program **12** executes, front end application program **12** can use this syntax and semantic description from the repository **18** (accessed through the service manager **16**) to determine what services front end application program **12** can use to meet its requirements. This syntax and semantic description for stored or computed backend data can be referred to as "meta data". This stored or computed backend data is conceptually organized using object-oriented

terminology in terms of *business objects*, where each business object is an instance of a class or data entity type. In one example, a class of business objects refers to a relational database table where each row of data in the table represents the data for a particular business object. In this example, each field in the table represents an attribute of the business object class. In another example, there is a class of business objects that partially refers to a relational database table such that some of the fields in the table represent attributes of the business object class and other fields are computed upon request.

In the business software architecture **2**, services provided to front end application program **12** are focused on data (i.e., data-centric) so the description of these services in repository **18** is also data-centric. Thus, the meta data in repository **18** is structured around representations of classes of these business objects. This meta data includes *aspects,* or descriptions of these representations of business object classes, and descriptions of available operations on aspects such as select, insert, update, delete, select by relation, and update fields that are provided by service providers **26**. Each description of these aspects includes data attributes as well as actions that can be requested to be executed by the set of backend service providers **26** on instances of these aspects.

Classifications of data, relations between data classes, prebuilt queries for accessing data, and other descriptions of data provided by the set of backend service providers **26** are represented by repository **18**. This representation, or meta data, of data (e.g., stored in backend database **24**) provided by the set of backend service providers **26** describes different abstract types or classes of data in backend database **24** and how different data classes relate to each other. Objects are instances of these different abstract types. Meta data is information about data rather than content of the data. The meta data also defines a set of pre-built queries that can be executed on the data in database **24**.

The semantic description in repository **18** can enable front end application program **12** to determine which services to request from service manager **16**. These services often take the form of requesting data to display. Front end application program **12** reads the meta data in repository **18** and can flexibly request data organized in different ways that are specified by the meta data. For example, two service managers **16** with two different repositories **18** handle

services that determine prices of books for companies A and B. For A and B, book prices are represented by different aspects with different data fields. Front end application program **12** reads A's repository **18** to obtain descriptions of data (including a price) concerning a particular book from A's service providers **26**. Front end application program **12** reads B's repository **18** to obtain descriptions of data (including a price) concerning a particular book from B's service providers **26**. Front end application program **12** is able to request and display the information from A's service provider **26** and the information organized differently from B's service provider **26** to present the book price information to a user.

For requesting the services described by the semantic description in repository **18**, service manager **16** provides a canonical interface for services on the business objects in the backend. This canonical interface includes a set of standard operations on the business objects. Such standard operations on the business objects include select, insert, update, delete, select by relation, and update fields. These standard operations are intended to be easy to understand and use. The usage of these standard operations is understood through the strict rule set of the meta model of the repository **18.** Furthermore, the repository **18** also includes documented modeling of the side effects of the usage of the operations. The side effects for an operation model which stored business objects are affected by executing the method. For example, "delete" usually has a side effect on other stored business objects related to the deleted object. Other standard operations perform more specialized tasks and support functionality for transactions between front end application program **12** and service manager **16** (e.g., a lock operation).

The canonical interface provided by the service manager **16** also includes specialized actions that are defined for specific classes of business objects and queries that can be defined for clusters of classes of business objects. The clusters are modeled as service modules (described in more detail below) in the meta data. These actions and queries are also defined in the meta data of the repository **18**.

During execution, front end application program **12** issues service requests to service manager **16**, service manager **16** checks the requests for consistency with the meta data in repository **18**, and then the service manager **16** passes the requests to back end service providers **26** according to the meta data in the

repository database **18**. The manner of implementing the set of back end service providers **26** and data in database **24** is independent of application **12**, with back end service providers **26** and data in database **24** conforming to the definitions and descriptions of the meta data in the repository **18**. Database **24** can be a relational database. However, database **24** can be modified to use a different mode of data organization other than a relational database and front end application program **12** does not need to be modified if back end service providers **26** and data in database **24** still conform to the meta data in the repository **18**. One such different mode of data organization for database **24** can be an object-oriented database.

Front end application program **12** provides user interfaces displayed on monitor **10**. Front end application program **12** provides application code to display and aggregate the data received from the set of backend service providers **26**. Front end application program **12** generates requests, via service manager **16**, to the set of backend service providers **26** for standard operations such as select, insert, update, delete, and execute, in addition to more specialized operations. Front end application program **12** is interaction-centric, focused on aggregating data of the back end service providers **26** and combining interactive steps into a flow of screens and syndicated screen elements.

Front end application program **12** contains screen-flow logic of User Interface (UI) oriented applications and front end application program **12** binds a UI to the meta data in repository **18**. Front end application program **12** can be indirectly bound to a specific set of backend services by back end service providers **26** via descriptions of the services in the metadata of the repository **18**. Front end application program **12** can also be formed from various generic interaction-centric front-end layers that are only bound by configuration to a highly standardized service layer by service manager **16** serving as an intermediary to back end service providers **26**.

In some implementations, a service manager proxy **14** gives the front end application program **12** a buffered access to a service interface provided by service manager **16**. Service manager proxy **14** is a server on computer **4** that acts as an intermediary between the front end application program **12** and the service manager **16** so that the business software architecture **2** can ensure security, administrative control, and caching service. The service manager **16** offers a

queuing functionality, which is used by the front end application program **12** to bundle several service requests or commands (resulting in service methods) into a single service method queue in order to save round trips. Service manager proxy **14** allows front end application program **12** and service manager **16** to be separated onto different computers **4, 6**. Furthermore, use of service manager proxy 14 can allow service manager **16** and the set of backend service providers **26** to be distributed over multiple computers.

In one example, the service manager proxy **14** communicates with service manager **16** using SOAP (Simple Object Access Protocol) messages via network **20**. SOAP is a way for a program running in one kind of operating system (such as a Windows® XP Operating system available from Microsoft Corporation of Redmond, WA) to communicate with a program in the same or another kind of an operating system (such as Linux) by using the World Wide Web's Hypertext Transfer Protocol (HTTP) and Extensible Markup Language (XML) as mechanisms for information exchange. Since Web protocols are installed and available for use by all major operating system platforms, HTTP and XML provide a solution to a problem of how programs running under different operating systems in a network can communicate with each other. SOAP specifies exactly how to encode an HTTP header and an XML file so that a program in one computer can call and pass information to a program in another computer. SOAP also specifies how the called program can return a response.

As shown in FIG. 3, the service manager **16** provides an interface (defined by the meta data in repository **18**) to front end application program **12** that hides the characteristics of the corresponding back end service providers from the set of backend service providers **26** and data in database **24**. Front end application **12** uses this interface to retrieve data from backend database 24 to display in graphical user interface (GUI) **28** for interaction with a user.

The service manager **16** provides the interface to front end application program **12** by receiving and executing requests from front end application program **12** to backend service providers **26**. After each receipt of a request by the service manager **16**, the service manager **16** delegates the request to one or more service providers **30, 32, 34, 40, 42, 44,** and **46**. Service provider **30** is an instance of a software class repository service provider. Service providers **32, 34,**

40, **42**, **44**, and **46** represent instances of software classes such as query service provider class (**32**), aspect service provider class (**34**), transaction service provider class (**40**), locking service provider class (**42**), action service provider class (**44**), and query relation service provider class (**46**). The software classes for service providers **32**, **34**, **40**, **42**, **44**, and **46** can be implemented as ABAP global classes maintained by the ABAP class library using the ABAP development environment available from SAP of Walldorf, Germany. They also can be implemented by any other programming language on any other platform, e.g., Java on Linux or C# on Windows.

Repository service provider **30** handles requests to get or modify meta data from repository **18**. Query service provider **32** handles queries on data in backend database **24** from front end application program **12**. Aspect service provider **34** handles accessing and modifying data, navigation through relations, and calling actions. The aspect service provider **34** has a standard set of methods that correspond to the standard operations on aspects that can be requested from the service manager **16**. These standard operations include select, insert, update, delete, select by relation, and update fields. Transaction service provider **40** allows business logic to act on different states of a transaction between front end application program **12** and service providers 26. Locking service provider **42** enables separation of concurrent accesses on data types in backend database **24**. Action service provider **44** enables execution of actions on aspects. Query relation service provider **46** is the interface for the target aspect of a relation. In some examples, service manager **16** can have different multiple instances of service providers **32**, **34**, **40**, **42**, **44**, and **46** for different elements in repository **18** representing services. Upon receiving a request for a service represented by an element in repository **18**, the service manager **16** can look up a name of a service provider (e.g., **32**, **34**, **40**, **42**, **44**, and **46**) in the meta data for the element in repository **18**. For example, the meta data describing an aspect in repository **18** defines which aspect service provider **34** is designed to handle services for the aspect. The service manager **16** uses this information in the meta data to direct requests from the front end application program **12** to the appropriate aspect service provider **34**. Similarly, the meta data describing a query in repository **18** defines which query service provider **32** is designed to handle services for the

query.

The interface provided by the service manager **16** provides requests or commands to front end application program **12**. As mentioned previously, standard commands select, insert, update, delete, select by relation, and update fields are standard operations on aspects in the repository **18**. These standard operations are provided by aspect service provider **34** and correspond to some of the requests or commands available to front end application program **12**. A "Select" command provides a capability such that if the identifiers (or keys) of instances of a data type (e.g., stored in database **24**) provided by aspect service provider **34** are known, front end application program **12** can select and read the attributes of these instances. An "Insert" command allows front end application program **12** to add new instances of a data type (e.g., stored in database **24**) provided by aspect service provider **34**. A "Select By Relation" command provides a capability that if a data type is known, front end application program **12** can find other data types that have relations to this data type as defined in repository **18**. An "Update" command provides a capability to modify instances of data types (e.g., stored in backend database **24**) provided by aspect service provider **34**. A "Delete" command provides the capability to delete one or more selected instances of one or more data types (e.g., stored in backend database **24**) provided by aspect service provider **34**.

An "Execute" action command provides a capability to execute a semantically defined action on one or more instances of one or more data types (e.g., stored in database **24**) provided by aspect service provider **34**. Either the aspect service provider **34** or the action service provider **44** executes the Execute action command. A "Query" command provides a capability to search and find particular data of interest. The Query command is a method with a fixed set of search parameters and a result set with a defined structure. Queries are defined for particular service modules, or clusters of aspects in the meta data of the repository **18**. The query service provider **32** executes a Query command.

The meta data in repository **18** is classified into data types or classes. The names of meta model classes representing the data type classifications in repository **18** have the suffix "descriptor" to express their belonging to the meta model and to differentiate them from runtime classes used by service manager **16**.

Descriptors of classes of the meta data of the repository **18** and their class relations are illustrated using an Unified Modeling Language (UML) class diagram **50** in FIG. 4.

Comparing the meta data to data described by relational database terminology, an aspect in the repository **18** can represent a class or an entity type fully or partially stored in backend database **24** and an aspect descriptor **56** includes attributes for the entity type in addition to other information about the entity type. The meta data in the repository **18** also can include relations descriptors **84** defining relations between aspects that can be implemented in database **24** as relationships using foreign keys in relational databases. The meta data also can include service modules descriptors **54** representing service modules that are aggregations of aspects and have predefined queries for accessing data in database **24**.

The service modules defined in repository **18** are the building blocks for a set of applications (e.g., front end application program **12**) in business software architecture **2** for a particular application area or industry. The service modules encapsulate the implementation and business logic and provide access to data and functionality in a unified canonical way. Examples for service modules in repository **18** are "business partner", "employee", "sales order", or "business activity". Service module descriptor **54** describes services modules in the data model of the meta data of the repository **18** and how the service modules can be accessed by queries from application program **12**.

In repository **18**, each defined query is an entry point to search instances of a data type (represented by an aspect) provided by service providers **26** via service manager **16**. A "key" is an identifier of an instance of a data type provided by service providers **26**. An "action" is a specialized method on one or more instances of an aspect. A "structure" is the aggregation of attributes representing the data of an aspect. A "relation" is the relation between objects of a source and a target aspect. A service module group is associated with a service module and is an aggregation of aspects, relations, and queries. An aspect group is associated with an aspect and is an aggregation of relations, aspect actions, and field descriptors **86**. The meta data in the repository **18** also includes a text description of each aspect, query, key, action, structure, relation, service module group, and

aspect group that is included in the available back end (e.g., backend database **24**). So, the organization of the meta data in the repository **18** can be described in terms of those data types (e.g., aspect, query, key, action, structure, relation, service module group, and aspect group).

The data model for attributes of aspects, queries, keys, and actions is based on structure descriptors **74**. In one example, every aspect has one structure descriptor **74** that defines the data attributes of the aspect. Structure descriptors **74** refer to a data dictionary in repository **18**. A data dictionary is a collection of descriptions of the data objects or items in a data model for the benefit of programmers and others who need to refer to them. The structure descriptors **74** can be defined in an XML Schema or in one or more database tables in repository **18**.

In one example, structure descriptors **74** defined in repository **18** include flat structures in database tables. A flat structure is a sequence of pairs of attribute names and field descriptors **86** of simple value types such as real, integer, character string, and boolean. For instance, a structure descriptor **74** defining a two dimensional point can be a list {X, real, Y, real}, where X and Y are attribute names having real values.

In another example of the repository **18**, structure descriptors **74** can include nesting and collections of other structure descriptors **74**. Nesting of other structure descriptors **74**, or sub-structures, to enable the generation of larger aspects is useful whenever the use of keys for sub-structures defining smaller aspects does not make sense.

For front end application program **12** to access data (e.g., data stored in backend database **24**) from service providers **26** through the service manager **16**, instances of business object classes are identified by unique keys within a service module, for example the number of an order or the id of a product. To differentiate between different types of keys for different aspects in a service module, key descriptors **64** define different types of keys. A key descriptor **64** is associated with a structure descriptor **74** that can include more than one data attribute. In one example, every key has a character string attribute. A service module can be associated with different key descriptors **64** for different aspects, e.g., an order key may have another key descriptor **64** as an order item key.

Service module descriptor **54** includes a collection of aspect descriptors **56**. An aspect descriptor **56** refers to one structure descriptor **74** and one key descriptor **64**. The structure descriptor **74** includes all key attributes of the corresponding key descriptor 64. Key descriptors **64** are specialized aspect descriptors **56**. The key descriptor **64** attribute of a key refers to itself as a self-reference. Examples for aspect descriptors **56** within a simple sales order service module can include: Order, Order Detail, Shipping Address, Billing Address, and Order Item as well as descriptors for key aspects like Order ID and Order Item Key. Service module descriptor **54** specifies the collection of supported aspect descriptors **56**. Multiple service module descriptors **54** can be associated with the same aspect descriptor **56**.

Aspect descriptors **56** relate to each other specified by relation descriptors **84**. A relation descriptor **84** has one source aspect descriptor **56** and one target aspect descriptor **56**. In this sense, relation descriptors **84** are directed. Relation descriptors **84** also have an optional cardinality (e.g., 1..n) and a category. Supported categories are, for example, Parent-Child or Child-Parent.

A relation descriptor **84** defining a relation between source aspect A and target aspect B means that it is possible to traverse from instances of aspect A to instances of aspect B. For example, given that aspects A and B are implemented in backend database **24** as relational database tables, this means that one or more fields in a table corresponding to aspect A point to the primary key of a table corresponding to aspect B. The relation descriptor **84** defining a Parent-Child relation from source aspect A and target aspect B means that aspect B depends on the existence of aspect A. For example, given that aspects A and B are implemented in backend database **24** as relational database tables, this means that a primary key of a table corresponding to aspect B is derived from a table corresponding to aspect A. Relation descriptors **84** are introduced to describe internal navigation from one aspect to another within the same service module, e.g., from an order to the shipping address (cardinality 1..1) or to the order items (cardinality 1..n) within a sales order service module. Relation descriptors **84** are independent of service modules and can be reused by different service modules. For an internal navigation or traversal from one data type to another in backend database **24**, the visible (usable) relation descriptors of a source aspect descriptor

56 are defined by the service module descriptor **54**, which has a list of supported relation descriptors **84**. Navigation is allowed for those supported relation descriptors **84** that have a target aspect descriptor **56** that is also supported by the service module descriptor **54**.

Operations for accessing and acting on data types in backend database **24** are described in operation descriptors **70**. The structure descriptor **74** defines input parameters of the operation descriptor **70**. This structure descriptor **70** also includes an input key descriptor **64** that enables mass and filter operations. Mass operations are operations specified by front end application program **12** on multiple instances of a data type in backend database **24**. Filter operations filter the results of an operations, e.g., a query, by the keys defined by the input key descriptor. Input parameters for operation descriptors **70** are optional.

There are three types of operation descriptors **70** i.e., query descriptors **104**, aspect action descriptors **92**, and action descriptors **96**. The aforementioned commands Query and Execute action are defined by operation descriptors **70**.

Query descriptors **104** describe query methods that allow searching for instances of aspects within a service module. The query descriptor **104** includes an input parameter, an input key descriptor **64**, and a result aspect descriptor **56**. The input parameter is a structure descriptor **74** that defines the search parameter structure of the query. The input key descriptor **64** defines which keys may be used for filtering. For example, executing a query defined by a query descriptor **104** with filtering keys results in a list of keys meeting the criteria of the first input. This list of keys is filtered by the set of filtering keys of the input key descriptor **64** so that a subset of the list of keys can be returned. The result aspect descriptor **56** for the query descriptor **104** specifies the type of result of the query, which could be any aspect descriptor **56** that is associated with the service module.

Each service module descriptor **54** has a set of supported query descriptors **104**. Service module descriptors **54** cannot use query descriptors **104** defined in other service module descriptors **54** since the query descriptor **104** belongs to one service module descriptor **54**.

Aspects provide additional operations (beyond the standard operations select, insert, update, delete, select by relation, and update fields) in the form of

actions, which are described by aspect action descriptors **92.** Aspect action descriptors **92** are specialized operation descriptors **70** on aspects. The aspect descriptor **56** can have a set of supported aspect action descriptors **92.** The input parameter for an aspect descriptor **96** defines the parameter structure of the action. The input key descriptor **64** specifies which keys may be used for mass operations, e.g., an email action may have as input a list of keys representing multiple emails.

Action descriptors **96** can define actions for multiple actions like Print, Email, Fax, Approve, Clear, Cut, Copy, Paste and Cancel. But there also may be more aspect specific actions that can be only used for one or a few aspects. Action descriptors **96** are introduced to enforce reuse. Each aspect action descriptor **92** is associated with an action descriptor **96**, where the name and the meaning (textual description) are defined.

Action descriptors **96** specify a name and the meaning (textual description) of the action. They do not specify parameters and are not used to describe polymorphic behavior of operations. They can be used for taxonomies.

A service module group descriptor **58** can be associated with aspect descriptors **56**, relation descriptors **84**, and query descriptors **104**. An aspect group descriptor **78** can be associated with relation descriptors **84**, aspect action descriptors **92**, and field descriptors **86**.

The diagram **50** includes a zero or more to zero or more relationship **52** between service module descriptor **54** and aspect descriptor **56,** since multiple instances of aspects can be associated with multiple instances of service modules. Service module group descriptor **58** has a zero or more to zero or more directed relation **60** towards aspect descriptor **56** since aspects can be grouped together in a service module group. Service module group descriptor **58** also has a zero or more to one composite aggregation relationship **62** with service module descriptor **54** because service module groups can be aggregated together in a service module. Key descriptor **64**, as a specialization of aspect descriptor **56**, has an inheritance relationship **66** with aspect descriptor **56**. Key descriptor **64** also has a one to zero or more relationship **68** with aspect descriptor **56,** since each aspect has a key associated with that aspect to uniquely identify instances of the aspect. Operation descriptor **70** has a directed zero or more to zero or more relationship **72** with key

descriptor **64,** since operations can include input keys. Aspect descriptor **56** has a zero or more to one relationship **76** with structure descriptor **74** since each aspect descriptor **56** can have a structure descriptor **74** defining its attributes. Aspect group descriptor **78** has a zero or more to one composite aggregation relationship **80** with aspect descriptor **56** since an aspect can be an aggregation of aspect groups. Aspect group descriptor **78** also has a directed zero or more to zero or more relationship **82** with relation descriptor **84** since aspect groups also include relations. Structure descriptor **74** has a one to zero or more ownership relationship **90** with field descriptor **86** since a structure can use many data fields to define itself. Aspect group descriptor **78** also has a zero or more to zero or more relationship **88** with field descriptor **86.**

Aspect action descriptor **92** has a zero or more to one aggregation relationship **100** with aspect descriptor **56** since aspects can provide actions that can be executed on the aspect. Aspect action descriptor **92** has an inheritance relationship **102** with its superior class operation descriptor **70.** Query descriptor **104** also has an inheritance relationship **106** with its superior class operation descriptor **70.** Service module descriptor **54** has a one to zero or more relationship **108** with query descriptor **104** since a service module can include zero or more queries. Service module group descriptor **58** has a zero or more to zero or more directed relationship **110** with query descriptor **104** since queries can also be grouped together in a service module group.

Operation descriptor **70** has a zero or more to zero or one relationship **112** with structure descriptor **74** since each operation includes input parameters in the form of structures. Query descriptor **104** has a zero or more to zero or one relationship **114** with aspect descriptor **56** since queries include a resulting aspect. Relation descriptor **84** has zero or more to one relationships **116** and **118** with aspect descriptor **56** since relations have source and target aspects.

To illustrate these descriptors defining an organization of the meta data in repository **18,** the examples below use a fixed set of relational database tables. Other persistence mechanisms (e.g., XML) can also be used. The relational database tables are defined in Tables 1-6, where each row of Tables 1-6 defines a field or column of the relational database tables. The main data type of repository **18** is the aspect. The database tables for describing an aspect are Table 1,

SCOL_ASPECT, and Table 2, SCOL_ASP_ACTION. Table 1 includes descriptions of properties of an aspect. The key field for Table 1, SCOL_ASPECT, is the ASPECT_NAME field because an aspect's name is unique for an aspect. The ASPECT_CATEGORY field indicates if the aspect represents a non-key aspect or a key aspect. The STRUCTURE field indicates a data structure name for data attributes of the aspect. A key is associated with an aspect by putting the key's name in the KEY_ASPECT field. The SERVICE_PROVIDER field defines the aspect service provider **34** for an aspect. The TRANSAC_PROVIDER field defines the transaction service provider **40** for an aspect. The LOCKING_PROVIDER field defines the locking service provider **42** for an aspect. The repository **18** can also have a corresponding table for the description of an aspect.

Table 1. SCOL_ASPECT definition

Field Name	Key	Description
ASPECT_NAME	X	Name of the aspect
ASPECT_CATEGORY		Aspect type: aspect or key aspect
STRUCTURE		The corresponding data structure of the aspect
KEY_ASPECT		The corresponding key aspect
SERVICE_PROVIDER		The name of the corresponding aspect service provider class
TRANSAC_PROVIDER		The name of the corresponding transaction provider class
LOCKING_PROVIDER		The name of the corresponding locking provider class

Aspects can provide actions that can be executed on the aspect. Descriptions of the actions are stored in Table 2, SCOL_ASP_ACTION. The actions are uniquely denoted by the aspect name and the name of the action so ASPECT_NAME and ACTION_NAME fields are key fields for SCOL_ASP_ACTION table. The field PARAM_STRUCTURE refers to a data structure that holds input data parameters for the action. The field INPUT_KEY_ASPECT refers to the name of a key aspect that defines the type of keys used to designate which instances of data types in repository **18** are acted upon by the action. The field PROVIDER_CLASS refers to the name of the action service provider class providing the action from the service provider implementing the aspect named in ASPECT_NAME field.

Table 2. SCOL_ASP_ACTION definition

Field Name	Key	Description
ASPECT_NAME	X	Name of the aspect
ACTION_NAME	X	Name of the Action
PARAM_STRUCTURE		The corresponding data structure of the input parameters
INPUT_KEY_ASPECT		The name of the key aspect of the input aspects
PROVIDER_CLASS		The name of the action service provider class

Aspects can be related with each other. Descriptions of the relations between aspects are stored in Table 3, SCOL_RELATION. A relation is uniquely defined by its name so the key of a relation table is the relation name specified in field RELATION_NAME. For each relation, the field SOURCE_ASPECT defines the aspect that is the source of the directed relation, the field TARGET_ASPECT defines the aspect that is the target of the directed relation, the field TARGET_PROVIDER defines the query relation service provider for the target aspect, the field REL_PARAM_TYPE defines the type of the relation (Parent-Child or Child-Parent), and the field REL_PARAMETER defines the cardinality of the relation. The repository **18** can also have a corresponding table for the description of a relation.

Table 3. SCOL_RELATION definition

Field Name	Key	Description
RELATION_NAME	X	Name of the relation
SOURCE_ASPECT		Name of the source aspect of the relation
TARGET_ASPECT		Name of the target aspect of the relation
TARGET_PROVIDER		Name of the query relation service provider class
REL_PARAM_TYPE		Type of the relation
REL_PARAMETER		Parameter of the relation

The properties of a service module are stored in the Table 4, SCOL_SVC_MODULE. Each Service module is uniquely described by its name so SVC_MODULE_NAME field is the key field for a SCOL_SVC_MODULE table. For each service module, the field TRANSAC_PROVIDER specifies the name of the transaction provider **40** for the service module. The repository **18** also has a corresponding table for the description of a service module.

Table 4. SCOL_SVC_MODULE definition

Field Name	Key	Description
SVC_MODULE_NAME	X	Name of the service module
TRANSAC_PROVIDER		The name of the corresponding transaction service provider class

Every service module is associated with aspects that can be used within the service module. Names of the aspects that can be used within each service module are stored in the Table 5, SCOL_ASPECT_USE. Since each aspect-service module usage is uniquely described by a name of a service module and the name of an aspect, the fields SVC_MODULE_NAME and ASPECT_NAME are the keys for SCOL_ASPECT_USE table.

Table 5. SCOL_ASPECT_USE definition

Field Name	Key	Description
SVC_MODULE_NAME	X	Name of the service module
ASPECT_NAME	X	Name of the aspect

Service Modules can provide queries to retrieve data. Descriptions of the queries of a service module are stored in the table SCOL_QUERY illustrated in Table 6 below. The structure of the database table is defined in Table 6. Since each query is uniquely defined by a service module and a query name, the fields SVC_MODULE_NAME and QUERY_NAME are key fields for SCOL_QUERY table. Other fields include RESULT_ASPECT that specifies the name of an aspect defining the data type returned by the query and PARAM_STRUCTURE that specifies a data structure containing the input parameters for the query. For example, a query done on a particular aspect (e.g., specified in field RESULT_ASPECT) associated with the service module can include input parameters that are matched with attributes of instances of the particular aspect and the matching instances are returned as a dataset of keys referring to those instances. The field INPUT_KEY_ASPECT is used to define the key aspect describing keys that could be used as filters for the query. The PROVIDER_CLASS specifies the name of the query service provider **32**

associated with each query. The repository **18** also has a corresponding table for the description of a query.

Table 6. SCOL_QUERY definition

Field Name	Key	Description
SVC_MODULE_NAME	X	Name of the service module
QUERY_NAME	X	Name of the query
RESULT_ASPECT		Name of the result aspect of the query
PARAM_STRUCTURE		The corresponding data structure of the input parameters
INPUT_KEY_ASPECT		The name of the key aspect of the input aspects
PROVIDER_CLASS		The name of the corresponding query provider class

As stated previously, architecture **38** includes six service provider classes (i.e., transaction **40**, query **32**, aspect **34**, action **44**, query relation **46**, and locking **42**) for handling requests from front end application program **12,** other than requesting meta data from repository **18,** which is handled by repository service provider class **30**. To provide services upon request by front end application program **12**, service manager **16** directly calls instances of service provider classes. These instances of service provider classes can be located on the same computer (e.g., **6**) as service manager **16** or on a different computer.

The locking service provider **42** can be used to implement a generic lock manager for a single aspect or a set of aspects. Each locking service provider **42** needs to be registered with an aspect. The name of the locking service provider **42** is set in SCOL_ASPECT table in LOCKING_PROVIDER field for each aspect. Locking service provider class has two methods that can be called by service manager **16**. These are LOCK and UNLOCK. LOCK takes as input a collection of keys representing business objects to be locked, a name of an aspect representing a class of the business objects, and a lock mode. There are various locking modes depending on the locking capability of the target system. Locking mode can specify "E", "S", or "SP". "E" means an exclusive lock or that only one client can obtain the lock. "S" means a shared lock indicating that any clients can lock and no lock exclusive to one client is possible. "SP" means the same as "S" but a subsequent upgrade to an exclusive lock is possible.

LOCK method outputs a Boolean value indicating if the request is rejected or not and also outputs a return code. UNLOCK takes as input a collection of keys representing business objects to be unlocked and a name of an aspect representing a class of the business objects to be unlocked. UNLOCK method also outputs a Boolean value indicating if the request is rejected or not and a return code. A call to UNLOCK is rejected if a transactional buffer is already in a "dirty" state, i.e. if any update, insert, delete operation or an action that is not marked as COL_AFFECTS_NOTHING has been issued since the last CLEANUP call. All locks are removed if the CLEANUP method (described below) of the transaction service provider class is called with reason 'END'.

A transaction is a sequence of information exchange and related work (such as database updating) that is treated as a unit for the purposes of satisfying a request from front end application program **12** to service manager **16** and for ensuring integrity of backend database **24**. For a transaction to be completed and changes to database **24** to be made permanent, a transaction has to be completed in its entirety. All of the steps of a transaction are completed before the transaction is successful and the database is actually modified to reflect all of the requested changes. If something happens before the transaction is successfully completed, any changes to the backend database **24** must be kept track of so that the changes can be undone.

To handle transactions, the transaction service provider **40** receives notifications on the various states of a transaction between service manager **16**, another non-transaction service provider (e.g., **32**, **34**, **44**, **46**), and front end application program **12** (or service manager proxy **14** in some cases). These notifications are the transaction service provider **40**'s methods BEFORE_SAVE, CLEANUP, and SAVE that are called by the service manager **16** during transactions.

The service manager **16** calls the transaction service provider **40**'s method BEFORE_SAVE to check if the transactional buffer can be saved. This allows checking if the internal state of the non-transaction service provider is ready for being saved. The method BEFORE_SAVE returns false if it is not possible to save the transactional buffer, the n the transaction end is aborted. Thus, the

BEFORE_SAVE method has a BOOLEAN return parameter. BEFORE_SAVE takes a Boolean as an input parameter REJECTED. The transactional service provider **16** can prevent the following save and commit operations by setting the REJECTED parameter to a non-initial value, i.e. to "true". The method BEFORE_SAVE is called within the service manager **16**'s sequence of operations triggered by the front-end application **12**'s SAVE method.

The SAVE method finally triggers the application to save the transactional buffer to the database **24**. By calling SAVE, all internal states of a non-transaction service provider are made persistent – either by direct updates or by creating appropriate calls to the update task. If all service providers in architecture **38** have received a SAVE request, service manager **16** commits the transaction.

The CLEANUP method tells all non-transaction service providers to release all their transactional buffers and enqueue-based locks. Calling CLEANUP method communicates that all service providers in architecture **38** need to clean up their internal state. CLEANUP takes a REASON string as an input parameter. The REASON field indicates the reason for the clean up operation. This can be either a 'COMMIT' due to a SAVE-operation or the 'END' of the transaction due to the system closing the transaction automatically. There is no guarantee that cleanup is called under failure conditions.

The action service provider **44** is called by service manager **16** to execute an action for an aspect. The name of action service provider **44** is set in the PROVIDER_CLASS field of SCOL_ASP_ACTION table for a row corresponding to an action. Action service provider **44** has one method EXECUTE. EXECUTE method takes as input parameters an aspect name (ASPECT), a set of keys (INKEYS) specifying which instances of the aspect are acted upon by the action, a generic input parameter (INPARAM), the name of the action (ACTION) to be executed, a set of keys (RELATION_INKEY) for an action acting on an relation, and a name of the relation (RELATION). EXECUTE method returns as output parameters the changed or newly created objects (OUTRECORDS), which have been modified by the action. The objects returned by the OUTRECORDS parameter are transported back to the calling aspect object on the client framework.

The aspect service provider **34** is called by service manager **16** to provide functionality to read and modify the content of one or more aspects. As described previously, an aspect is described by its name (the name is globally unique within a repository), an associated data structure, an associated key (i.e. identifier) structure, a set of implemented actions, a set of outgoing relations, and a set of incoming relations. Aspect service provider **34** has methods EXECUTE, SELECT, INSERT, UPDATE, DELETE, SELECT_BY_RELATION, and UPDATE_FIELDS.

The method EXECUTE is derived from the action service provider **44** and allows executing an action. EXECUTE has as input parameters a name (ASPECT) of the aspect, where the action is to be executed on, keys (INKEYS) of the objects, where the action is executed on, parameters (INPARAM) for the actions, name (ACTION) of the action. Returned parameters include modified or created aspect rows (OUTRECORDS), a Boolean flag (REJECTED) indicating if the request for the method was rejected or not, and return codes (RETURN_CODES).

The method SELECT reads the aspect data associated with the input keys for a given aspect. SELECT has as input parameters a list of keys (INKEYS) encoded within the associated key structure to describe the aspect rows to read and the name (ASPECT) of the aspect. SELECT has as output parameters the result (OUTRECORDS) encoded in the aspect data structure, a Boolean flag (REJECTED) indicating if the request for the method was rejected or not, and return codes (RETURN_CODES).

The method INSERT inserts new data into an aspect. INSERT includes as input parameters a table containing the records to be inserted, if aspect is designed for row wise write operations (INRECORDS). The method may allow the inserted record to also define key fields, depending on the aspect description (e.g., a parameter ExternalKeys = true or false). Input parameters also include the name (ASPECT) of the aspect, a set of keys (RELATION_INKEY) for an action acting on a relation, and a name of the relation (RELATION). Method INSERT returns a set of records (OUTRECORDS) representing the inserted records together with their keys and possible other modifications that aspect service provider **34** wants to do on the inserted records. For example one modification

can be filling out calculated fields for the set of records. The order of the OUTRECORDS rows has to correspond to the order of the INRECORDS rows. Other output parameters include a Boolean flag (REJECTED) indicating if the request for the SELECT method was rejected or not and return codes (RETURN_CODES).

The UPDATE method updates existing instances of an aspect either record wise or field wise. The input parameters for UPDATE method include a table (INRECORDS) containing the instance keys to be updated, if the aspect is designed for row wise write operations. Input parameters also include the name (ASPECT) of the aspect. Parameters returned by the UPDATE method include the updated records (OUTRECORDS) together with their keys and possible other modifications the service provider wants to do. The order of the OUTRECORDS rows can correspond to the order of the INRECORDS rows. Other output parameters include a Boolean flag (REJECTED) indicating if the request for the SELECT method was rejected or not and return codes (RETURN_CODES).

The DELETE method deletes rows or instances of an aspect in the backend (e.g., backend database **24**). Input parameters for DELETE method are a list of keys (INKEYS) encoded within the associated key structure to describe the aspect rows to be deleted and the name (ASPECT) of the aspect. Parameters returned by the DELETE method include a Boolean flag (REJECTED) indicating if the request for the DELETE method was rejected or not and return codes (RETURN_CODES).

The SELECT_BY_RELATION method returns, depending on the relation parameter description, either attributes to follow a relation or another aspect, where the source aspect has a relation pointing to that other aspect. Input parameters for SELECT_BY_RELATION are name (RELATION) of the relation to follow, records (INRECORDS) of the source aspect, name of the source aspect (ASPECT), and a structure (OPTIONS) describing various options of the queries for paging, etc. Output parameters returned by SELECT_BY_RELATION include the result encoded in the target aspect data structure (OUTRECORDS), an index table showing which row of the OUTRECORDS parameters belongs to which INRECORDS row (INDEX), a description of the result (DESCRIPTION), a Boolean flag (REJECTED) indicating if the request for the

SELECT_BY_RELATION method was rejected or not and return codes (RETURN_CODES).

The UPDATE_FIELDS method updates fields of instances of an aspect. Input parameters include a list of keys (INRECORDS) encoded within the associated key structure to describe the instances of the aspect to be updated. Input parameters also include a table (INFIELDS) containing pairs of names of fields and corresponding values to be updated within a set of records, if the aspect is designed for field wise write operations. If more than one instance of an aspect is to be updated, the additional field index INKEY points to the associated key record. Input parameters also include the name (ASPECT) of the aspect. Parameters returned by UPDATE_FIELDS include the created or changed instances of the aspect (OUTRECORDS) together with their keys and possible other modifications performed by the aspect service provider **34**. The index of the various OUTRECORDS rows have to be associated to the row indexes in the INFIELDS table. Other parameters returned include a Boolean flag (REJECTED) indicating if the request for the UPDATE_FIELDS method was rejected or not and return codes (RETURN_CODES).

Query service provider **32** performs queries. A query in the repository **18** is described in table SCOL_QUERY by the query name in field QUERY_NAME, the associated parameter structure in field PARAM_STRUCTURE, the associated result aspect in field RESULT_ASPECT, and optionally, the associated aspect key, with its unique data structure in field INPUT_KEY_ASPECT. Query service provider **32** has one EXECUTE method that performs a query on one or more aspects. Input parameters include the name of the query (QUERY), a data structure (INPARAM) containing the parameters for the query, and an optional table-type parameter (INKEYS), containing the keys of the aspect rows to which the query shall be restricted. INKEYS can but does not have to consist of the keys of OUTRECORDS returned by EXECUTE method. INKEYS can be of any key aspect structure. Which key structure is associated to the query is specified in the repository **18** in table SCOL_QUERY in field INPUT_KEY_ASPECT. Optionally, other input parameters can be specified including a structure describing various options (OPTIONS) of the queries (e.g., for paging) and SELECTIONS.

Parameters returned by EXECUTE method include a description (DESCRIPTION) of the query, the query result (OUTRECORDS), and a Boolean flag (REJECTED) indicating if the request for the EXECUTE method was rejected or not

The EXECUTE method returns the results specified by the query parameters. If the INKEYS table parameter is not empty, the result is restricted to the objects that fulfill the query parameters. INKEYS and INPARAM both restrict the query, but are used in different ways. For example, a query can be defined that returns a list of orders not yet delivered. In such an example, the structure INPARAM can specify that only orders from customers with last names from A-D are to be returned. The INKEYS is a table of all orders that have not yet been delivered. OUTRECORDS contains all orders from the relevant customers, in this case with last names A-D, that have not been delivered yet. In one example, the OUTRECORDS result of a query is a disconnected aspect, that is, the aspect is always read-only. No further backend operations can be performed on this aspect. In this example, the received keys can be used as parameters to select other aspect rows using the aspect service provider **34** and, for example, its SELECT method.

The query relation service provider **46** implements a routine in a service provider (e.g., aspect service provider **34**) for an aspect that is the target of a relation. Methods of query relation service provider **46** are indirectly called from the aspect service provider **34** of the source aspect, if the relation is marked as SOURCE_KEYS or ATTRIBUTES.

Query relation service provider **46** has a SELECT_TARGET method. The method SELECT_TARGET has input parameters as follows. Input parameters include the name (SOURCE_ASPECT) of the source aspect. Optionally, the method also includes an input parameter defining a proxy interface (TARGET) to the target aspect's SELECT method. Specifying the TARGET parameter allows calling the SELECT method of the aspect service provider **34** for the target aspect without directly knowing the aspect service provider **34** for the target aspect. This

enables a query relation service provider **46** to be added to a service module without knowledge of the aspect service provider **34** for the target aspect.

Another input parameter for the SELECT_TARGET method is the relation (RELATION). Another input parameter is a table of fields (INPARAMS) to describe the relation. To allow mass selection, INPARAMS is a table where every row describes a single selection. An INDEX parameter is used to relate the various rows of the INPARAMS structure to the OUTRECORDS rows. Another optional input parameter is a structure (OPTIONS) describing various options of the queries (e.g., for paging).

The SELECT_TARGET method returns parameters that include the result encoded with the structure of the target aspect (OUTRECORDS), a description of the query result (DESCRIPTION), and a proxy interface to the target aspects SELECT method. Other output parameters include an index (INDEX) to describe the relation between the INPARAMS records and the OUTRECORDS parameter, a Boolean flag (REJECTED) indicating if the request for the SELECT_TARGET method was rejected or not and return codes (RETURN_CODES).

The service providers **32**, **34**, **40**, **42**, **44**, and **46**, as described above, enable the following transactional model for the architecture **38**. Executing method SELECT of aspect service provider **34** reads from the backend database **24** or reads from a transactional buffer stored in the back-end. Aspect service provider **34** merges data from both sources – the database and its transactional buffer - in a consistent way so that the merge data reflects the updates made so far in this transaction. Next, executing UPDATE, INSERT, MODIFY, or DELETE methods of aspect service provider **34** builds up a transactional buffer. Before actually changing data in the transactional buffer, the service manager **16** has to acquire a transactional lock on the data and read the data under the protection of a lock. There are exclusive, shared, and shared promotable lock modes available using locking service provider **42** as described previously. Locking has to be accompanied by selecting the locked data again under the protection of the lock. Applications can support optimistic locking by providing time-stamped or otherwise versioned data, and merging actual and modified data on the front-end

in case of conflicts.

The BEFORE_SAVE method of the transaction service provider **40** enables all participating service providers to declare if they are ready for saving the transactional buffer. The SAVE method of the transaction service provider **40** finally triggers service manager **16** to save the transactional buffer to the backend database **24**.

The CLEANUP method of the transaction service provider **40** notifies all service providers (e.g., aspect service provider **34**) to release all their transactional buffers and enqueue-based locks. If CLEANUP is called with reason 'END', all locks have to be released. If reason is set to 'COMMIT', each service provider can chose to keep its locks.

Aspect service provider **34** must not call COMMIT WORK or ROLLBACK WORK internally on its own. The service manager **16** enforces this by automatically aborting the transaction if aspect service provider **34** is trying to commit a transaction.

The supported locking models and lock policies are as follows. Using policy S, many participants can obtain a shared lock. If a shared lock is obtained on an object, no exclusive lock or SP lock can be obtained. Shared locks can only be used to achieve a consistent view on a larger set of data during read operations. Using policy E, only a single participant can obtain a lock. Using policy SP (shared promotable), many participants can obtain the lock. If a SP lock exists, exclusive locks can only be obtained by participants already having a SP lock on the object. Only one of the participants can upgrade the lock to an exclusive lock. No other participant, who did obtain a lock prior to the upgrade, can upgrade to exclusive even if the first participant did release its lock.

Example

The architecture **38** (of FIG. 3) implements a simple task of creating a new customer, receiving the customer's order of one or more products via GUI **28** and submitting the order to a business process. To support this example, backend database **24** can be implemented using a relational database designed according to the definitions in Tables 1-6 above to define lists of customers, addresses, product types, baskets, positions of products in a basket for each order, and orders. In

Tables 7-12, key field headings are denoted with an asterisk. Customers Table 7 defines customers and each customer is uniquely identified by a CustomerId field. Customers Table 7 also includes a NAME field and a foreign key field AddressId that links addresses in an Addresses table to customers.

Table 7. Customers

CustomerId*	NAME	AddressId
1	John Smith	1
2	David Klein	2

Addresses Table 8 defines addresses having a town and a street. The Address id itself is a valid unique key for an address and the connection between address and customer is done through the Customers Table 7 (AddressID field).

Table 8. Addresses

AddressId*	Town	Street
1	Athens	Main Street
2	Louisville	Willow Avenue

Table 9 defines products having names with key ProductId.

Table 9. Products

ProductId*	Name
1	Saw
2	Hammer
3	Wrench
4	Screwdriver

Table 10 defines shopping baskets having customers with key BasketId.

Table 10. Baskets

BasketId*	CustomerId
1	2
2	1

Table 11 defines positions of orders in baskets and having products. Positions are dependent on the existence of baskets and orders so the primary key

for positions is a combination of PositionId, BasketId, and OrderId.

Table 11. Positions

PositionId*	BasketId*	OrderId*	ProductId
1	1	3	2
2	1	2	3
3	2	1	4

Table 12 defines orders having customers and indicating whether or not each order is submitted with primary key OrderId.

Table 12. Orders

OrderId*	CustomerId	Submitted
1	1	False
2	2	False
3	2	False

As shown in FIG. 5, process **150** defines the database operations on backend database **22** that are needed for this simple task using these tables 7-12. Process **150** includes front end application program **12** receiving (**152**) a name of a customer. Process **150** includes the business software application querying (**154**) a database with Customers table (Table 7) for the name in the NAME field. Process **150** includes checking if the customer's name matches (**156**) a row in the Customers table (Table 7). If no match is made, process **150** includes the business software application obtaining (**158**) the address of the customer, inserting (**160**) a new row in the Addresses table (Table 8) with a new AddressID and address, and inserting (**162**) a new row in the Customers table (Table 7) with a new CustomerId and the AddressID. If a match is made, process **150** includes the business software obtaining (**164**) a name of a product to order for the customer. Process **150** includes the business software querying (**166**) the Products table (Table 9) for the product name.

Process **150** includes checking if the product name matches (**168**) a row in the Products table (Table 9). If a match is made, then process **150** includes the business software inserting (**170**) a new order in the Orders table (Table 12) with the customer's CustomerId and setting the Submitted field to "False". Otherwise, process **150** returns to obtaining (**164**) the name of the product to order. Process

150 includes the business software inserting (**172**) a new basket in the Basket table (Table 10) with the customer's CustomerId.

Process **150** includes the business software inserting (**174**) a new position in the Positions table (Table 11) with the CustomerId, BasketId, and ProductId. Process **150** includes the business software receiving (**176**) a request to submit the order. Process **150** includes the business software querying (**178**) the Orders table (Table 12) by the customer's CustomerId and this query returns orders matching the customer's CustomerId. Process **150** includes the business software selecting (**180**) orders in the Orders table (Table 12) matching the orders for the customer's CustomerId. Process **150** includes the business software setting (**182**) the Submitted field in the selected rows in the Orders table (Table 12) to "True". Process **150** includes the business software getting (**184**) the address of the customer from the Addresses Table 8 for order delivery by querying Customers Table 7 for an AddressId and then querying Addresses Table 8 for a matching AddressId.

Tables 13-19 show tables in one implementation of repository **18** representing meta data for the example database illustrated by Tables 7-12. Tables 13-19 follow the definitions of Tables 1-6 described above such that definitions in rows of Tables 1-6 correspond to columns or fields in Tables 13-19. As with Tables 7-12, key fields in Tables 13-19 are labeled by an asterisk.

Table 13 follows the definition of a SCOL_ASPECT table (defined in Table 1) to define aspects A_Customer, A_Address, A_Product, A_Basket, A_Position, and A_OrderHeader. Each aspect has a corresponding key aspect that defines a unique key for each instance. For example, aspect A_Customer has a key aspect Customer_Key. This key aspect in the meta data repository **18** can correspond to a key for a relational database table in backend database **24**. For example, the key for Customers table (Table 7) is CustomerId field. The rows in STRUCTURE field correspond to a data dictionary in Table 19 below. For example, Table 19 can define Customer_Structure to have a NAME field of type CHAR indicating a character string. The rows in SERVICE_PROVIDER field correspond to particular aspect service providers handling services for aspects. In Table 13, all of the aspects are assigned to S_provider aspect service provider (e.g., **34** referring to FIG. 3). The rows in TRANSAC_PROVIDER field

correspond to particular transaction service providers **40** handling transactions for aspects. In Table 13, all of the aspects are assigned to T_provider transaction service provider (e.g., **40** referring to FIG. 3). The rows in LOCKING_PROVIDER field correspond to particular locking service providers handling locking for aspects. In Table 13, all of the aspects are assigned to L_provider locking service provider (e.g., **42** referring to FIG. 3).

Table 13. Example SCOL_ASPECT table

ASPECT_ NAME*	ASPECT_ CATEGORY	STRUCTURE	KEY_ ASPECT	SERVICE_ PROVIDER	TRANSAC_ PROVIDER	LOCKING_ PROVIDER
A_Customer	aspect	Customer_ Structure	Customer_ Key	S_provider	T_provider	L_provider
Customer_Key	key aspect	Customer_ Key_Table	Customer_ Key	S_provider	T_provider	L_provider
A_Address	aspect	Address_ Structure	Address_ Key	S_provider	T_provider	L_provider
Address_Key	key aspect	Address_ Key_Table	Address_ Key	S_provider	T_provider	L_provider
A_Product	aspect	Product_ Structure	Product_ Key	S_provider	T_provider	L_provider
Product_Key	key aspect	Product_ Key_Table	Product_ Key	S_provider	T_provider	L_provider
A_Basket	aspect	Basket_ Structure	Basket_ Key	S_provider	T_provider	L_provider
Basket_Key	key aspect	Basket_ Key_Table	Basket_ Key	S_provider	T_provider	L_provider
A_Position	aspect	Position_ Structure	Position_ Key	S_provider	T_provider	L_provider
Position_Key	key aspect	Position_ Key_Table	Position_ Key	S_provider	T_provider	L_provider
A_OrderHeader	aspect	OrderHeader_ Structure	OrderHeade r_Key	S_provider	T_provider	L_provider
OrderHeader_ Key	key aspect	OrderHeader_ Key_Table	OrderHeade r_Key	S_provider	T_provider	L_provider

Table 14 follows the definition of a SCOL_ASP_ASPECT table (defined in Table 2) to define an action Submit for aspect A_OrderHeader. Field INPUT_KEY_ASPECT specifies the key aspect that is sent by application **14** with the action to specify which instances of aspect A_OrderHeader should be acted upon by the action. Action Submit changes the Submitted field of those instances in backend database **24** to True. No extra parameters are required for this action Submit so PARAM_STRUCTURE field is blank in Table 14. Field PROVIDER_CLASS specifies the aspect service provider **34** (referring to FIG. 3) assigned to each action. In Table 14, action Submit is assigned to aspect service

provider S_provider (e.g., **34** referring to FIG. 3).

Table 14. Example SCOL_ASP_ACTION Table

ASPECT_NAME*	ACTION_NAME*	PARAM_STRUCTURE	INPUT_KEY_ ASPECT	PROVIDER_ CLASS
A_OrderHeader	Submit		OrderHeader_ Key	S_provider

Table 15 follows the definition of a SCOL_RELATION table (defined in Table 3) to define relations between aspects defined in Table 13. These relations reflect relations between data tables in backend database **24** illustrated by example tables 7-12. These relations between aspects are also illustrated in FIG. 6 for aspect A_Customer **202**, aspect A_Address **204**, aspect A_Product **206**, aspect A_Basket **208**, aspect A_Position **210**, and aspect A_OrderHeader **112**. These relations include R_Customer_To_Address **212**, R_Basket_To_Customer **214**, R_OrderHeader_To_Customer **216**, R_Position_To_Product **218**, R_Position_To_OrderHeader **220**, and R_Position_To_Basket **222**.

Table 15. Example SCOL_RELATION Table

RELATION_ NAME*	SOURCE_ ASPECT	TARGET_ ASPECT	TARGET_ PROVIDER	REL_PARAM_ TYPE	REL_ PARAMETER
R_Customer_ To_Address	A_Customer	A_Address	S_provider	Parent-Child	
R_Basket_To_ Customer	A_Basket	A_Customer	S_provider		
R_OrderHeader To_Customer	A_OrderHeader	A_Customer	S_provider		
R_Position_To_ Product	A_Position	A_Product	S_provider		
R_Position_To_ OrderHeader	A_Position	A_OrderHeader	S_provider	Child-Parent	
R_Position_To_ Basket	A_Position	A_Basket	S_provider	Child-Parent	

Table 16 follows the definition of a SCOL_SVC_MODULE table (defined in Table 4) to define example service modules for the example definitions of backend database **24** given in tables 7-12. Table 16 defines service modules S_Customer, S_Product, S_Basket, and S_Order. Field TRANSAC_PROVIDER specifies a transaction service provider **40** (referring to FIG. 3) to each service module. In Table 16, transaction service provider T_provider (e.g., **40**, referring

to FIG. 3) is assigned to the service modules.

Table 16. Example SCOL_SVC_MODULE Table

SVC_MODULE_NAME*	TRANSAC_ PROVIDER
S_Customer	T_provider
S_Product	T_provider
S_Basket	T_provider
S_Order	T_provider

Table 17 follows the definition of a SCOL_ASPECT_USE table (defined in Table 5) to associate service modules (provided by Table 16) with aspects (provided by Table 13).

Table 17. Example SCOL_ASPECT_USE Table

SVC_MODULE_NAME*	ASPECT_NAME*
S_Customer	A_Customer
S_Customer	A_Address
S_Product	A_Product
S_Basket	A_Basket
S_Basket	A_Position
S_Order	A_OrderHeader
S_Order	A_Position

Table 18 follows the definition of a SCOL_QUERY table (defined in Table 6) to define queries designed to facilitate business process **150** of FIG. 5. For example, QueryByName query associated with S_Customer service module takes a Customer_Stucture as input for the query and a set of customer keys (Customer_Key) that defines which keys may be used for filtering. Field PROVIDER_CLASS specifies which query service provider **32** (referring to FIG. 3) is associated with each service module. In Table 18, query service provider Q_provider (e.g., **32**) is associated with each service module.

Table 18. Example SCOL_QUERY Table

SVC_MODULE_ NAME*	QUERY_NAME*	RESULT_ ASPECT	PARAM_ STRUCTURE	INPUT_KEY_ ASPECT	PROVIDER_ CLASS
S_Customer	QueryByName	Customer_ Key	Customer_ Structure	Customer_ Key	Q_provider
S_Product	QueryByName	Product_ Key	Product_ Structure	Product_ Key	Q_provider
S_Basket	QueryByCustomer	Basket_Key	Customer_Key_ Table	Customer_Key	Q_provider
S_OrderHeader	QueryByCustomer	OrderHeader _Key	Customer_Key_ Table	Customer_Key	Q_provider

Table 19 defines a data dictionary for the implementation of repository **18** defined in Tables 13-18. Each row defines a structure having a name and multiple data entries and their types. For example, structure Customer_Structure has one data entry titled "NAME" with a CHAR type indicating a character string. The Customer_Key_Table structure defines a CustomerId key for each customer and also has a CHAR type.

Table 19. Example SCOL_STRUCT Table

STRUCT_NAME*	DATA1	TYPE1	DATA2	TYPE2
Customer_Structure	NAME	CHAR		
Customer_Key_Table	CustomerId	CHAR		
Address_Structure	Town	CHAR	Street	CHAR
Address_Key_Table	AddressId	CHAR		
Product_Structure	Name	CHAR	ProductId	CHAR
Product_Key_Table	ProductId	CHAR		
Basket_Structure				
Basket_Key_Table	BasketId	CHAR		
Position_Structure				
Position_Key_Table	PositionId	CHAR		
OrderHeader_ Structure	Submitted	CHAR		
OrderHeader_Key_ Table	OrderId	CHAR		

The database operations described above for process **150** are defined in this implementation of repository **18** as follows. Querying (**154**), included in process **150**, of the Customers database table (Table 7) is described in meta data repository **18** by the QueryByName query associated with aspect service module S_Customer in Table 18. This QueryByName query associated with aspect service module S_Customer is selected because the front end application program **12** has obtained a customer name and service module S_Customer contains

aspects with customer names. For example, front end application program **12** can submit query QueryByName associated with service module S_Customer with NAME = "John Smith" and no filtering Customer_Key specified to service manager **16**. Service manager **16** checks repository **18** to ensure that the query is defined. Service manager **16** then submits the query to Q_provider (e.g., **32**) that queries the Customer database table (Table 7) in database **24** and the output is sent back to front end application program **12** is a record set containing CustomerId = {1}.

Inserting (**160**), included in process **150**, on Addresses database table (Table 8) and inserting (**162**), included in process **150**, on Customers database table (Table 7) are described by standard Insert operations (described previously) on aspects A_Address and A_Customer, respectively, in the meta data repository **18**.

Querying (**166**), included in process **150**, on the Products database table (Table 9) for a product name is described by QueryByName query associated with service module S_Product defined in Table 18. For example, application **12** can submit the query QueryByName associated with service module S_Product with Name = "Wrench" and no filtering Product_Key specified to service manager **16**. Service manager **16** checks repository **18** to ensure that the query is defined. Service manager **16** then submits the query to Q_provider (e.g., **32**) queries database **24** and the output sent back to application **12** is a record set containing ProductId = {3}.

Inserting (**170**, **172**, and **174**), included in process **150**, are defined by insert operations on aspects A_OrderHeader, A_Basket, and A_Position, respectively.

Querying (**178**), included in process **150**, Orders database table (Table 12) by customer is described by the QueryByCustomer query associated with service module S_Order defined in Table 18. For example, front end application program **12** can submit query QueryByCustomer associated with service module S_Order with Customer_Key (CustomerId) = {2} and no filtering OrderHeader_Key. Service manager **16** checks repository **18** to ensure that the query is defined. Service manager **16** then submits the query to Q_provider (e.g., **32**) that queries database **24** and the output is sent back to application **12** is a record set containing

OrderHeader_Key (OrderId) = {2, 3}.

Selecting (**180**), included in process **150**, order operation on Orders database table (Table 12) and setting (**182**) submitted field to true on selected orders are defined by the Execute Submit action (defined in Table 14) on aspect A_OrderHeader in repository **18**. For example, front end application program **12** sends the Submit action on aspect A_OrderHeader to service manager **16** with OrderHeader_Key = {2, 3}. Service manager **16** then sends the submit operation to S_provider (e.g., **34**) that changes the Submitted field in Orders database table (Table 12) to "True" for selected rows corresponding to OrderId = {2, 3}.

Getting (**184**) customer address, included in process **150**, from Addresses database table (Table 8) is defined by the standard Select By Relation action on A_Customer aspect. For example, the front end application program **12** sends a Select By Relation action on A_Customer aspect specifying relation R_Customer_To_Address and Customer_Key = {2} to service manager **16**. Service manager **16** checks the request against repository **18** and passes the request to service provider S_provider (e.g., **34**) that looks up foreign key AddressId matching CustomerId = {2} and navigates to Addresses table 8. S_provider (e.g., **34**) returns a record set containing {Louisville, Willow Avenue} from Addresses database table (Table 8) to application **12** via service manager **16**.

As described previously, front end application program **12** sends commands and requests for data in backend database **24** indirectly to service providers **26** through service manager **16**. There are different front end application programs **12** to view data and execute commands using service providers **26**. Furthermore, there are different companies or customers from different industries using different or same front end application programs **12** with the same software for service manager **16** and service providers **26** but with different backend databases **24**. These different customers of services provided by service manager **16** and service providers **26** can have differing requirements for standard applications provided by service manager **16** and service providers **26**. Architecture **38** enables these different customers to extend the functionality of the services provided by service manager **16** and service providers **26** without modifying the standard core development software of service manager **16** and service providers **26**. This extension is done by extending the meta data in the

repository **18**.

One area for extending the repository **18** is the extension of a data dictionary structure described by the Structure Descriptor **74** (of FIG. 3). In the repository **18**, aspects, actions and queries have references to data dictionary structures (see Tables 1, 2, 6 above). For example, a data dictionary structure of an aspect designed by a vendor may not be exactly the same data dictionary structure that a customer needs for the front end application program **12**. Field extensions are used to extend a data dictionary structure for a particular customer.

As described previously, an aspect in the architecture **38** supports actions that are defined in Table 2, SCOL_ASP_ACTION. In some examples, a customer needs to implement additional actions for the aspect. The customer can also extend an implementation in the service providers **26** of an action for the aspect. To do this extension of the implementation of the action, the customer's front end application program **12** can keep control of the execution of the extension during the execution of the action by service providers **26**.

In another example, the customer adds custom aspects to a service module in the repository **18** to extend the functionality of the service module. When the customer extends the service module with aspects, the customer can also generate additional relations between the custom aspects and standard aspects in the repository **18**.

Customers can also extend service modules in repository **18** by adding queries with their own implementation.

When a customer enhances the data dictionary structure of an aspect, the customer also extends the implementation of the query in the service provider. Thus, the customer's front end application program **12** has control of the extended portion of the implementation during the execution of the query by service providers **26**.

Customers can also configure the architecture **38** by extending the implementation of service providers in service providers **26**.

To enhance the services provided by service manager **16** and service providers **26** to front end application program **12**, two steps are needed. One step is extending the repository **18** by enhancing the metadata of aspects and service modules in repository **18**. Another step is extending the coding implemented in

the various service providers **26** (e.g., query service provider **32**, aspect service provider **34**, action service provider **44**).

To enhance the core repository objects (e.g., aspects, queries, actions, and service modules) stored in the repository **18**, the customer having front end application program **12** generates extensions that are stored in customer repository **252** as shown in FIG. 7. An extension is a software entity generated in the customer's namespace that has a relation "extends" to one of the core repository objects stored in the repository **18**. This relation is stored in the metadata of the extension in the repository **18**. Each extension extends exactly one repository object. In some examples, the metadata of the extension can be stored in database tables with same names and fields (Tables 1-6 shown above) in customer repository **252** as the core repository objects in repository **18**. The core repository object does need not be changed when a customer extends the core repository object. After a software upgrade of the architecture **38**, due to this separation of the metadata (core repository **18** and customer's extension repository **252**), no effort is needed to adapt the extensions to the upgrade. The customer also provides customer extension provider **254** to support extension functionality.

During execution within architecture **38**, the separation of core and extension object is transparent to the front end application program **12**. As shown in FIG. 8, the repository service provider **30** combines the metadata of the core object **302** from repository **18** and the extension **304** (from customer repository **252**) of the core object and delivers the complete metadata information of the extended object to the service manager **16**.

To enhance the metadata of an aspect, an aspect extension is generated in repository **18**. The aspect extension is special kind of aspect that extends another aspect and has the same key aspect as the extended aspect (i.e., the aspect being extended). The data dictionary structure of the extension is also mapped to the same dictionary type than the extended aspect. Within the aspect extension the following operations can be done: create actions, create configurations, create relations, and create groups.

To enhance the metadata of a service module, a service module extension can be generated. The service module extension is a special kind of service module that extends another service module. Within the service module extension

new queries can be added with the constraint that the name of the queries are restricted to customer namespace. In a service module extension the following operations can be done: add aspects (core aspects and customer aspects) to the service module, add queries, and generate groups.

To avoid name clashes after an upgrade of the architecture **38**, the names of all new elements within an extension are restricted to the customer namespace.

It is also possible to achieve multi-layer extensibility. That means that a customer is allowed to extend a service module extension or an aspect extension (concatenated extensions). Having many extensions to one aspect or service module is also possible (parallel extensions). FIG. 8A shows an illustrative scenario **350** where in one example, the core repository **352** of architecture **38** is enhanced by extension **354** provided by a vendor and extension **354** is further extended by a first customer's extension **356**. In the other example, the core metadata **352** of architecture **38** is enhanced by extension **358** provided by a vendor and extension **358** is further extended by a second customer's extension **360**.

To allow for enhancement of the functionality implemented by the service providers **26** (e.g., query service provider **32**, aspect service provider **34**, action service provider **44**), the architecture **38** provides various extension points where additional coding from customer extension provider **254** can be plugged-in.

In one example based on object oriented technology, extension points are realized with the Business Add-In (BAdI) technique that is commercially available with R/3 from SAP of Walldorf, Germany. Business Add-Ins are an enhancement technique for enterprise business software. Business Add-Ins can be inserted into a software system to accommodate requirements too specific to be included in a standard delivery. Business Add-Ins allow for a multi-level system landscape (e.g., vendor, partner, and customer solutions, as well as country versions, industry solutions, and the like). Definitions and implementations of Business Add-Ins can be created at each level within such a system infrastructure. The vendor guarantees the upward compatibility of the Business Add-In interfaces. Release upgrades do not affect enhancement calls from within the standard software nor do they affect the validity of call interfaces.

The architecture **38** provides the extension points for the aspect extensions and for the service module extensions. Each call of the service provider (e.g., query service provider **32**, aspect service provider **34**, action service provider **44**) is surrounded with a BEFORE extension point and an AFTER extension point. FIG. 9 shows a sequence diagram of the process **400** using the extension points. In process **400**, front end application program **12** sends (**404**) a request for a service to be performed by the service manager **16**. The service manager **16** sends (**406**) a BEFORE extension point with parameters to extension **304**. The customer extension provider **254** executes (**408**) instructions and possibly modifies the parameters. Customer extension provider **254** returns (**410**) the possibly modified parameters to service manager **16**. Service manager **16** sends (**412**) a request with the possibly modified parameters to service provider **402.** The service provider **402** satisfies the request by executing (**414**) instructions using the possibly modified parameters. Service provider **402** returns (**416**) a set of output parameters to service manager **16**. Service manager **16** sends (**418**) an AFTER extension point with a set of parameters (possibly including the output parameters) to customer extension provider **254.** The customer extension provider **254** executes (**420**) instructions and possibly modifies the parameters. Customer extension provider **254** returns (**422**) the possibly modified parameters to service manager **16**.

For aspect extensions, extension points are used in scenarios where a customer has enhanced a field of the data dictionary structure of an aspect. In such scenarios, extension points provide opportunity for executing extra instructions for the enhanced fields.

For service provider extensions, the tasks executed at extension points include filtering INKEYS, modifying OUTRECORDS and INRECORDS, modifying parameter values of actions and queries, setting dynamic metadata and configurations, sending messages, and handling errors.

Extension Points for aspect extensions

Extension points for aspect extensions are provided by the BAdI COL_ASPECT_EXTENSION with the name of the aspect as a filter value. Each aspect extension is related with an implementation of that BAdI. There are

extension points for before and after the following operations: select, select by relation, insert, update, update fields, delete, action execute, lock, unlock, and save.

As described above, front end application program **12** sends a select request to the service manager **16** to select a set of aspect rows for a given aspect. As described previously, this select request results in calling the method SELECT of the aspect service provider **34**. The service manager **16** sends a BEFORE_SELECT extension point to the customer extension provider **254** before the selection of aspect rows. After receiving the BEFORE_SELECT extension point, the customer extension provider **254** can filter the INKEYS parameter from the front end application program **12**. The parameters for the BEFORE_SELECT extension point are listed in Table 20 below. These parameters include the INKEYS that specifies the set of aspect rows and can be filtered by customer extension provider **254**. The call of the SELECT method can be suppressed by setting the REJECTED parameter to TRUE.

Table 20

Parameters	Imp./Chang.	Type	Description
INKEYS	Changing	INDEX TABLE	Keys to be selected
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend

The service manager **16** sends an AFTER_SELECT Extension Point to the customer extension provider **254** after the selection of aspect rows. In an example where a field of a data dictionary structure has been extended, after receiving the AFTER_SELECT extension point, the customer extension provider **254** can retrieve additional data and merge it into the OUTRECORDS table that is passed back to the front end application program **12**. The parameters are listed in Table 21 below.

Table 21

Parameters	Imp./Chang.	Type	Description
INKEYS	Importing	INDEX TABLE	Keys to be selected
OUTRECORDS	Changing	INDEX TABLE	Selected records
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend
RETURN_CODES	Changing	SCOL_RETURN_CODE_T	Return codes

As described previously, the SELECT_BY_RELATION request from the front end application program **12** to service manager **16** results in the service manager **16** calling the method SELECT_BY_RELATION of the aspect service provider **34**. The service manager **16** sends a BEFORE_SELECT_BY_RELATION Extension Point before calling the method SELECT_BY_RELATION of the aspect service provider **34**. After receiving the BEFORE_SELECT_BY_RELATION extension point, the customer extension provider **254** can modify the INRECORDS Parameter of the SELECT_BY_RELATION method. The parameters of the BEFORE_SELECT_BY_RELATION Extension Point are listed in Table 22 below. These parameters include RELATION that specifies the name of the relation used in the selection and INRECORDS. The call of the SELECT_BY_RELATION method can be suppressed by setting the REJECTED parameter to TRUE.

Table 22

Parameters	Imp./Chang.	Type	Description
RELATION	Importing	STRING	Name of the relation
INRECORDS	Changing	INDEX TABLE	Aspect rows
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend

The service manager **16** sends an AFTER_SELECT_BY_RELATION Extension Point to the customer extension provider **254** after the selection of aspect rows via a relation by calling the method SELECT_BY_REQUEST of the aspect service provider **34**. In an example where a field of a data dictionary structure has been extended or where a relation is added to an aspect using an

extension, after receiving the AFTER_SELECT_BY_RELATION extension point, the customer extension provider **254** can retrieve additional data and merge it into the OUTRECORDS table. The parameters are listed in Table 23 below.

Table 23

Parameters	Imp./Chang.	Type	Description
RELATION	Importing	STRING	Name of the relation
INRECORDS	Changing	INDEX TABLE	Aspect rows
OUTRECORDS	Changing	INDEX TABLE	Selected records
INDEX	Changing	SCOL_RELATION_INDEXT	Index
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend
RETURN_CODES	Changing	SCOL_RETURN_CODE_T	Return codes

The BEFORE_INSERT Extension Point is sent to the customer extension provider **254** before the insertion of aspect rows by calling the previously described method INSERT of the aspect service provider **34**. After receiving the BEFORE_INSERT extension point, the customer extension provider **254** can filter and modify the INRECORDS Parameter that is subsequently passed to the INSERT method. The parameters for the BEFORE_INSERT Extension Point are listed in Table 24 below. The call of the INSERT method can be suppressed by setting the REJECTED parameter to TRUE.

Table 24

Parameters	Imp./Chang.	Type	Description
INRECORDS	Changing	INDEX TABLE	Records to be inserted
RELATION	Importing	STRING	Name of the Relation
RELATION_INKEY	Importing	ANY	Related row
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend

The AFTER_INSERT Extension Point is sent to the customer extension provider **254** after the insertion of aspect rows by calling the previously described method INSERT of the aspect service provider **34**. In an example where a field of

a data dictionary structure has been extended, after receiving the AFTER_INSERT extension point, the customer extension provider **254** can save additional data to the database. The parameters are listed in Table 25 below.

Table 25

Parameters	Imp./Chang.	Type	Description
INRECORDS	Importing	INDEX TABLE	Records for insert
RELATION	Importing	STRING	Relation name
RELATION_INKEY	Importing	ANY	Related row
OUTRECORDS	Changing	INDEX TABLE	Inserted rows
RELATION_OUTRECORD	Changing	ANY	Changed row
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend
RETURN_CODES	Changing	SCOL_RETURN_CODE_T	Return codes

The BEFORE_UPDATE Extension Point is sent to the customer extension provider **254** before the update of aspect rows by calling UPDATE method (previously described) of the aspect service provider **34**. After receiving the BEFORE_UPDATE extension point, the customer extension provider **254** can filter and modify the INRECORDS-Parameter. The parameters are listed in Table 26 below. The call of the UPDATE method can be suppressed by setting the REJECTED parameter to TRUE.

Table 26

Parameters	Imp./Chang.	Type	Description
INRECORDS	Changing	INDEX TABLE	Records to be updated
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend

The AFTER_UPDATE Extension Point is sent to the customer extension provider **254** after the update of aspect rows. In an example where a field of a data dictionary structure has been extended, after receiving the AFTER_UPDATE extension point, the customer extension provider **254** can save additional data. The signature is defined in Table 27 below.

Table 27

Parameters	Imp./Chang.	Type	Description
INRECORDS	Importing	INDEX TABLE	Records to be updated
OUTRECORDS	Changing	INDEX TABLE	Updated Records
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend
RETURN_CODES	Changing	SCOL_RETURN_CODE_T	Return codes

The BEFORE_UPDATE_FIELDS Extension Point is sent to the customer extension provider **254** before the field update of aspect rows by calling UPDATE_FIELDS method (described previously) of the aspect service provider **34**. After receiving the BEFORE_UPDATE_FIELDS extension point, the customer extension provider **254** can filter and modify the INRECORDS Parameter. The parameters are listed in Table 28 below. The call of the UPDATE_FIELDS method can be suppressed by setting the REJECTED parameter to TRUE.

Table 28

Parameters	Imp./Chang.	Type	Description
INRECORDS	Changing	INDEX TABLE	Records to be updated
INFIELDS	Changing	SCOL_T_UPDATE_FIELDS	Fields to be updated
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend

The AFTER_UPDATE_FIELDS Extension Point is sent to the customer extension provider **254** after the field update of aspect rows. In the example where a field of a data dictionary structure has been extended, after receiving the AFTER_UPDATE_FIELDS extension point, the customer extension provider **254** can save additional data. The parameters are listed in Table 29 below.

Table 29

Parameters	Imp./Chang.	Type	Description
INRECORDS	Importing	INDEX TABLE	Records to be updated
INFIELDS	Importing	SCOL_T_UPDATE_FIELDS	Fields to be updated
OUTRECORDS	Changing	INDEX TABLE	Updated Records
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend
RETURN_CODES	Changing	SCOL_RETURN_CODE_T	Return codes

The BEFORE_DELETE Extension Point is sent to the customer extension provider **254** before the deletion of aspect rows by calling DELETE method of the aspect service provider **34**. After receiving the BEFORE_DELETE extension point, the customer extension provider **254** can filter the INKEYS-Parameter. The parameters are listed in Table 30 below. The call of the DELETE method can be suppressed by setting the REJECTED parameter to TRUE.

Table 30

Parameters	Imp./Chang.	Type	Description
INKEYS	Changing	INDEX TABLE	Keys to be deleted
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend

The AFTER_DELETE Extension Point is sent to the customer extension provider **254** after the deletion of aspect rows. In the example where a field of a data dictionary structure has been extended, after receiving the AFTER_DELETE extension point, the customer extension provider **254** can delete additional data. The parameters are listed in Table 31 below.

Table 31

Parameters	Imp./Chang.	Type	Description
INKEYS	Importing	INDEX TABLE	Keys to be deleted
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend
RETURN_CODES	Changing	SCOL_RETURN_CODE_T	Return codes

The BEFORE_ACTION_EXECUTE Extension Point is sent to the customer extension provider **254** before the execution of an aspect action. After receiving the BEFORE_ACTION_EXECUTE extension point, the customer extension provider **254** can change the value of the INPARAM parameter or change the INKEYS table. For example, a customer can restrict the action to specific keys. The parameters are listed in Table 32 below. The call of the EXECUTE method of the aspect service provider **34** can be suppressed by setting the REJECTED parameter to TRUE.

Table 32

Parameters	Imp./Chang.	Type	Description
INPARAM	Changing	ANY	Parameters of the action
INKEYS	Changing	INDEX TABLE	Objects to act again
ACTION	Importing	STRING	Name of the action
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend

The AFTER_ACTION_EXECUTE Extension Point is sent to the customer extension provider **254** after the execution of an aspect action. After receiving the AFTER_ACTION_EXECUTE extension point, the customer extension provider **254** can enhance the functionality of the action or add actions to an aspect. The parameters are listed in Table 33 below.

Table 33

Parameters	Imp./Chang.	Type	Description
INPARAM	Importing	ANY	Parameters of the action
INKEYS	Importing	INDEX TABLE	Objects to act again
ACTION	Importing	STRING	Name of the action
OUTRECORDS	Changing	INDEX TABLE	Changed aspect rows
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend
RETURN_CODES	Changing	SCOL_RETURN_CODE_T	Return codes

The BEFORE_LOCK Extension Point is sent to the customer extension provider **254** before the LOCK method (as previously described) of the locking service provider **42** is called by the service manager **16**. After receiving the BEFORE_LOCK extension point, the customer extension provider **254** can filter values from INKEYS table before calling the LOCK method. The parameters are listed in Table 34 below. The call of the LOCK method of the locking service provider **42** can be suppressed by setting the REJECTED parameter to TRUE.

Table 34

Parameters	Imp./Chang.	Type	Description
INKEYS	Changing	INDEX TABLE	Objects to be locked
LOCKMODE	Importing	STRING	Locking mode
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend

The AFTER_LOCK Extension Point is sent to the customer extension provider **254** after the LOCK method of the locking service provider **42** is called. In the example where a field of a data dictionary structure has been extended, after receiving the AFTER_LOCK extension point, the customer extension provider **254** can set additional locks. The parameters are listed in Table 35 below.

Table 35

Parameters	Imp./Chang.	Type	Description
INKEYS	Importing	INDEX TABLE	Objects to be locked
LOCKMODE	Importing	STRING	Locking mode
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend
RETURN_CODES	Changing	SCOL_RETURN_CODE_T	Return codes

The BEFORE_UNLOCK Extension Point is sent to the customer extension provider **254** before the UNLOCK method (previously described) of the locking service provider **42** is called. After receiving the BEFORE_UNLOCK extension point, the customer extension provider **254** can filter values from INKEYS table before calling the UNLOCK method. The parameters are listed in Table 36 below. The call of the UNLOCK method of the locking service provider **42** can be suppressed by setting the REJECTED parameter to TRUE.

Table 36

Parameters	Imp./Chang.	Type	Description
INKEYS	Changing	INDEX TABLE	Objects to be unlocked
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend

The AFTER_UNLOCK Extension Point is sent to the customer extension provider **254** after the UNLOCK method of the locking service provider **42** is called. In the example where a field of a data dictionary structure has been extended, after receiving the AFTER_UNLOCK extension point, the customer extension provider **254** can reset additional locks. The parameters are listed in Table 37 below.

Table 37

Parameters	Imp./Chang.	Type	Description
INKEYS	Importing	INDEX TABLE	Objects to be unlocked
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend
RETURN_CODES	Changing	SCOL_RETURN_CODE_T	Return codes

The BEFORE_SAVE Extension Point is sent to the customer extension provider **254** before the SAVE method (previously described) of the transaction service provider **40** is called. After receiving the BEFORE_SAVE extension point, the customer extension provider **254** can do some additional checks before calling the SAVE method. The parameters are listed in Table 38 below. The call of the SAVE method can be suppressed by setting the REJECTED parameter to TRUE.

Table 38

Parameters	Imp./Chang.	Type	Description
REJECTED	Changing	SCOL_BOOLEAN	Error in backend

The AFTER_SAVE Extension Point is sent to the customer extension provider **254** after the call of the SAVE method of the transaction service provider **40**. In the example where a field of a data dictionary structure has been extended, after receiving the AFTER_SAVE extension point, the customer extension provider **254** can save additional data from buffer to database. The method has no parameters.

Extension Points for service module extensions

Extension Points for service module extensions are provided by the BAdI COL_MODULE_EXTENSION with the name of the service module as a filter value. Each service module extension is related with an implementation of that BAdI.

The BEFORE_QUERY_EXECUTE Extension Point is sent to the customer extension provider **254** before calling the QUERY method (described previously) of the query service provider **32**. After receiving the BEFORE_QUERY_EXECUTE extension point, the customer extension provider

254 can change the value of the INPARAM parameter or change the INKEYS table. For example a customer can restrict the query to specific keys. The parameters are listed in Table 39 below. The call of the QUERY method can be suppressed by setting the REJECTED parameter to TRUE.

Table 39

Parameters	Imp./Chang.	Type	Description
QUERY	Importing	STRING	Name of the query
INPARAM	Changing	ANY	Parameters of the query
INKEYS	Changing	INDEX TABLE	Keys to define subset
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend

The AFTER_QUERY_EXECUTE Extension Point is sent to the customer extension provider **254** after the execution of the service module query. After receiving the AFTER_QUERY_EXECUTE extension point, the customer extension provider **254** can enhance the functionality of the query. The parameters are listed in Table 40 below.

Table 40

Parameters	Imp./Chang.	Type	Description
QUERY	Importing	STRING	Name of the query
INPARAM	Importing	ANY	Parameters of the query
INKEYS	Importing	INDEX TABLE	Keys to define subset
OUTRECORDS	Changing	INDEX TABLE	Result aspect
REJECTED	Changing	SCOL_BOOLEAN	Error in Backend

The techniques described above can be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in combinations of them. The techniques also can be implemented as a computer program product, i.e., a computer program tangibly embodied in an information carrier, e.g., in a machine-readable storage device or in a propagated signal, for execution by, or to control the operation of, data processing apparatus, e.g., a programmable processor, a computer, or multiple computers. A computer program can be written in any form of programming language, including compiled or interpreted languages, and it can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A computer program can be deployed to be executed on

one computer or on multiple computers at one site or distributed across multiple sites and interconnected by a communication network.

Method steps of the techniques can be performed by one or more programmable processors executing a computer program to perform functions of the invention by operating on input data and generating output. Method steps can also be performed by, and apparatus of the invention can be implemented as, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application-specific integrated circuit). The method steps may also be performed in other orders than those described above.

Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer. Generally, a processor will receive instructions and data from a read-only memory or a random access memory or both. The essential elements of a computer are a processor for executing instructions and one or more memory devices for storing instructions and data. Generally, a computer will also include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data, e.g., magnetic, magneto-optical disks, or optical disks. Information carriers suitable for embodying computer program instructions and data include all forms of non-volatile memory, including by way of example semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks, e.g., internal hard disks or removable disks; magneto-optical disks; and CD-ROM and DVD-ROM disks. The processor and the memory can be supplemented by, or incorporated in special purpose logic circuitry.

The invention can be implemented in a computing system that includes a back-end component, e.g., as a data server, or that includes a middleware component, e.g., an application server, or that includes a front-end component, e.g., a client computer having a graphical user interface or a Web browser through which a user can interact with an implementation of the invention, or any combination of such back-end, middleware, or front-end components.

The invention has been described in terms of particular embodiments. Other embodiments are within the scope of the following claims.

What is claimed is

Claims

1. A method comprising:

generating a first application by providing a definition of an object representing a first set of attributes of a first collection of data elements and a first set of operations on the first collection, each data element in the first collection having the attributes and a list of the operations in common with other data elements from the first collection;

extending the definition of the object with a second definition, the second definition comprising a second set of attributes of the data elements or a list of second set of operations on the data elements;

receiving from the client a request to execute an operation from the first set of operations or the second set of operations on one or more data elements from the first collection, the request having input parameters;

checking the request against the definition and the second definition;

executing, with a first set of parameters, the operation on the one or more data elements of the first collection, the operation resulting in output parameters; and

sending a second set of parameters.

2. The method of claim 1 wherein the first set of parameters comprise the input parameters and the second parameters comprise the output parameters.

3. The method according to one or more of the preceding of claims further comprising providing a definition of a module representing a set of one or more collections of data elements, the set comprising the first collection of data elements, wherein the definition of the module comprises a query on one or more collections of data elements.

4. The method of claim 3 further comprising extending the definition of the module

more collections of the data elements.

5. The method of claim 4 further comprising:

receiving from the client a request to execute the first or second query on one or more collections of the data elements, the request having input parameters;

checking the request against the definition and the second definition of the module;

executing, with a first set of parameters, the query on the one or more collections of the data elements, the operation resulting in output parameters; and

sending a second set of parameters.

6. The method according to any of claims 4 or 5 wherein the second definition further comprises a second collection of data elements.

7. The method of claim 6 wherein the second definition further comprises a relation between the first collection and the second collection, the relation enabling a navigation from the first collection to the second collection.

8. The method according to one or more of the preceding claims further comprising:

sending the request with the input parameters;

generating the first set of parameters by modifying the input parameters; and

receiving the first set of parameters.

9. The method according to one or more of the preceding claims further comprising:

sending the request with the output parameters;

generating the second set of parameters by modifying the output parameters; and

receiving the second set of parameters.

10. The method according to one or more of the preceding claims further comprising:

extending the definition and the second definition of the object with a third definition, the third definition comprising a third set of attributes of the data elements or a third set of operations on the data elements; and

checking the request against the definition, the second definition, and the third

11. The method according to one or more of claims 4 to 10 further comprising extending the definition of the module with a third definition, the third definition comprising a third query on one or more collections of the data elements.

12. The method according to one or more of the preceding claims further comprising:

generating a second application by extending the definition of the object with a third definition, the third definition comprising a third set of attributes of the data elements or a third set of operations on the data elements;

receiving from the client a request to execute an operation from the first set of operations or the third set of operations on one or more data elements from the first collection, the request having input parameters; and

checking the request against the definition and the third definition.

13. A system comprising:

a first computer configured to execute a client program;

a second computer configured to execute a server program;

a network linking the first and second computers such that the server program is configured to execute the following:

provide to the client program a first application with a definition of an object representing a first set of attributes of a first collection of data elements and a list of first set of operations on the first collection, each data element in the first collection having the attributes and the operations in common with other data elements from the first collection;

extend the definition of the object with a second definition, the second definition comprising a second set of attributes of the data elements or a second set of operations on the data elements;

receive from the client program a request to execute an operation from the first set of operations or the second set of operations on one or more data elements from the first collection, the request having input parameters;

check the request against the definition and the second definition;

execute, with a first set of parameters, the operation on the one or more data elements of the first collection, the operation resulting in output parameters; and

14. The system of claim 13 wherein the first set of parameters comprise the input parameters and the second parameters comprise the output parameters.

15. The system according to any of claims 13 or 14 wherein the server program is further configured to provide a definition of a module representing a set of one or more collections of data elements, the set comprising the first collection of data elements, the definition of the module comprising a query on one or more collections of data elements.

16. The system of claim 15 wherein the server program is further configured to extend the definition of the module with a second definition, the second definition comprising a second query on one or more collections of the data elements.

17. The system of claim 16 wherein the server program is further configured to execute the following:

receive from the client a request to execute the first or second query on one or more collections of the data elements, the request having input parameters;

check the request against the definition and the second definition of the module;

execute, with a first set of parameters, the query on the one or more collections of the data elements, the operation resulting in output parameters; and

send a second set of parameters.

18. The system according to any of claims 16 or 17 wherein the second definition further comprises a second collection of data elements.

19. The system of claim 18 wherein the second definition further comprises a relation between the first collection and the second collection, the relation enabling a navigation from the first collection to the second collection.

20. The system according to one or more of claims 13 to 19 wherein the client program is configured to execute the following:

send the request with the input parameters;

receive the first set of parameters.

21. The system according to one or more of claims 13 to 20 wherein the client program is configured to execute the following:

send the request with the output parameters;

generate the second set of parameters by modifying the output parameters; and

receive the second set of parameters.

22. The system according to one or more of claims 13 to 21 wherein the server program is further configured to execute the following:

extend the definition and the second definition of the object with a third definition, the third definition comprising a third set of attributes of the data elements or a third set of operations on the data elements; and

check the request against the definition, the second definition, and the third definition.

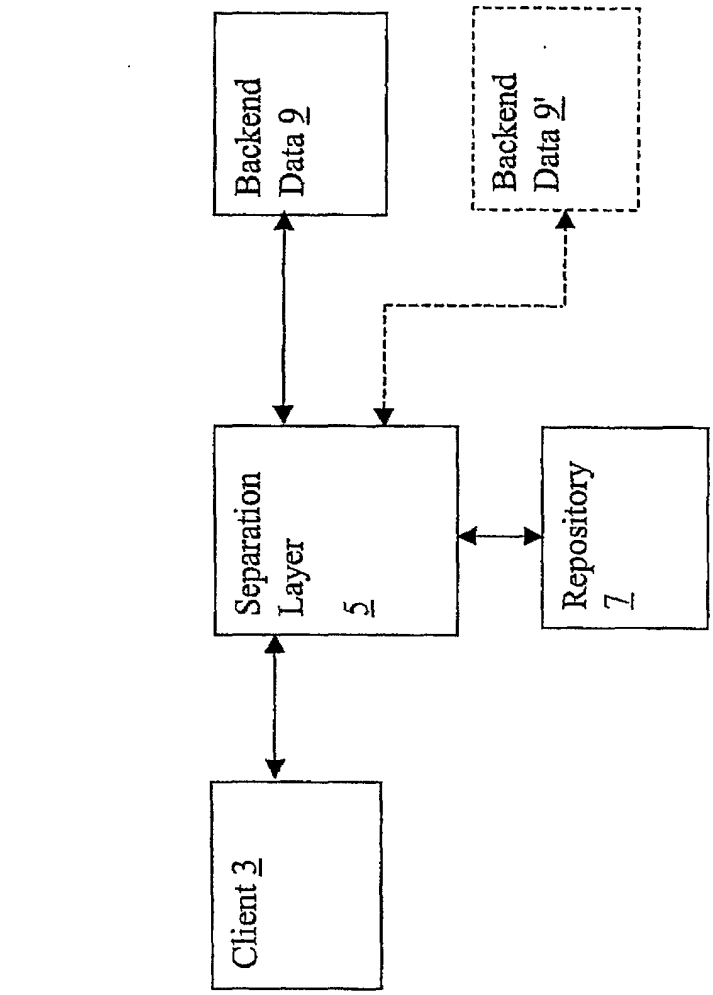
23. The system according to one or more of claims 16 to 22 wherein the server program is further configured to extend the definition of the module with a third definition, the third definition comprising a third query on one or more collections of the data elements.

24. The system according to one or more of claims 13 to 23 wherein the server program is further configured to execute the following:

generate a second application by extending the definition of the object with a third definition, the third definition comprising a third set of attributes of the data elements or a third set of operations on the data elements;

receive from the client a request to execute an operation from the first set of operations or the third set of operations on one or more data elements from the first collection, the request having input parameters; and

check the request against the definition and the third definition.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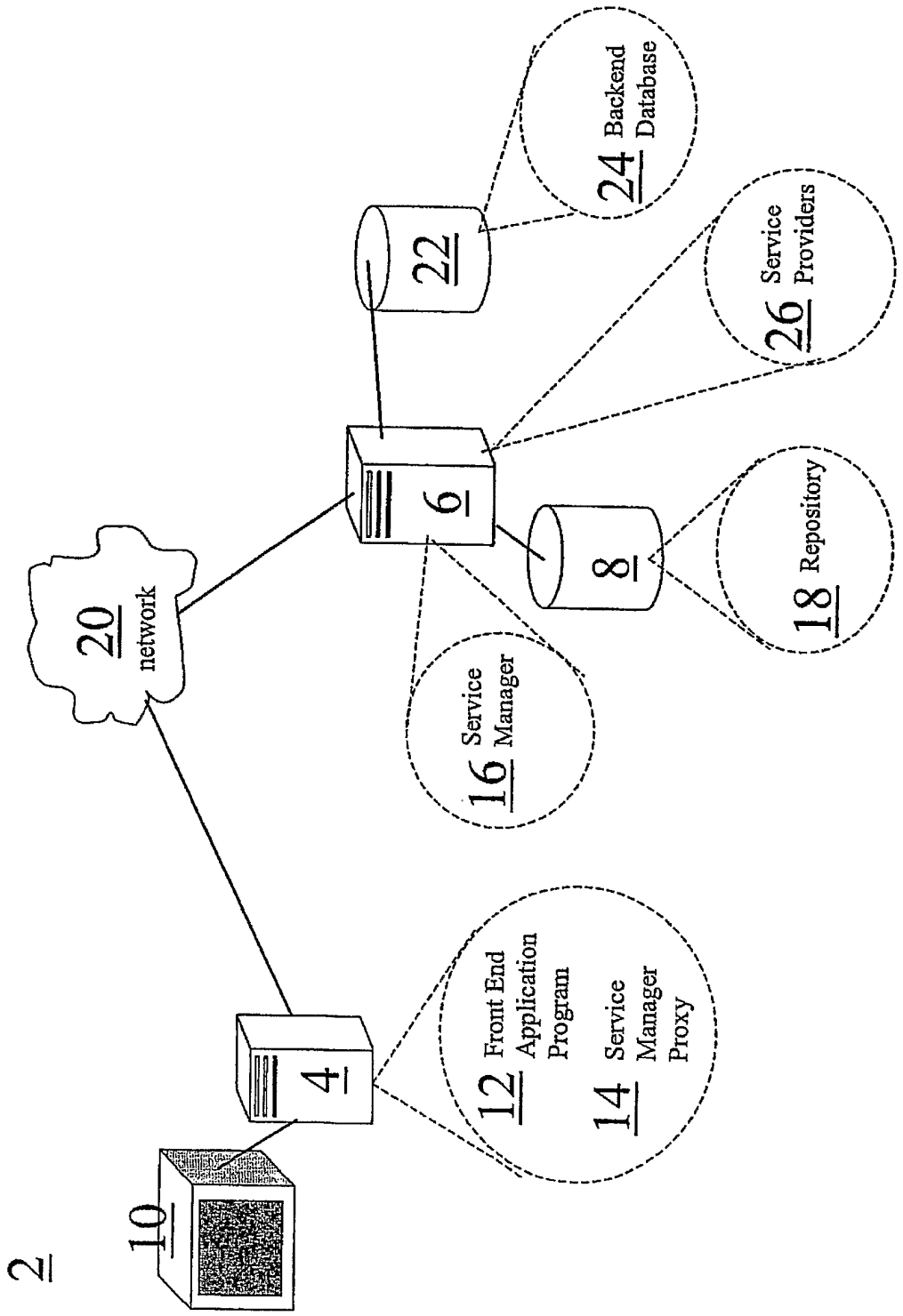
Backend Data 9'
Separation Layer 5
Repository 7
Client 3
2

FIG. 1


2
10
4
12 Front End Application Program
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20 network
6
16 Service Manager
8
18 Repository
22
24 Backend Database
26 Service Providers

FIG. 2

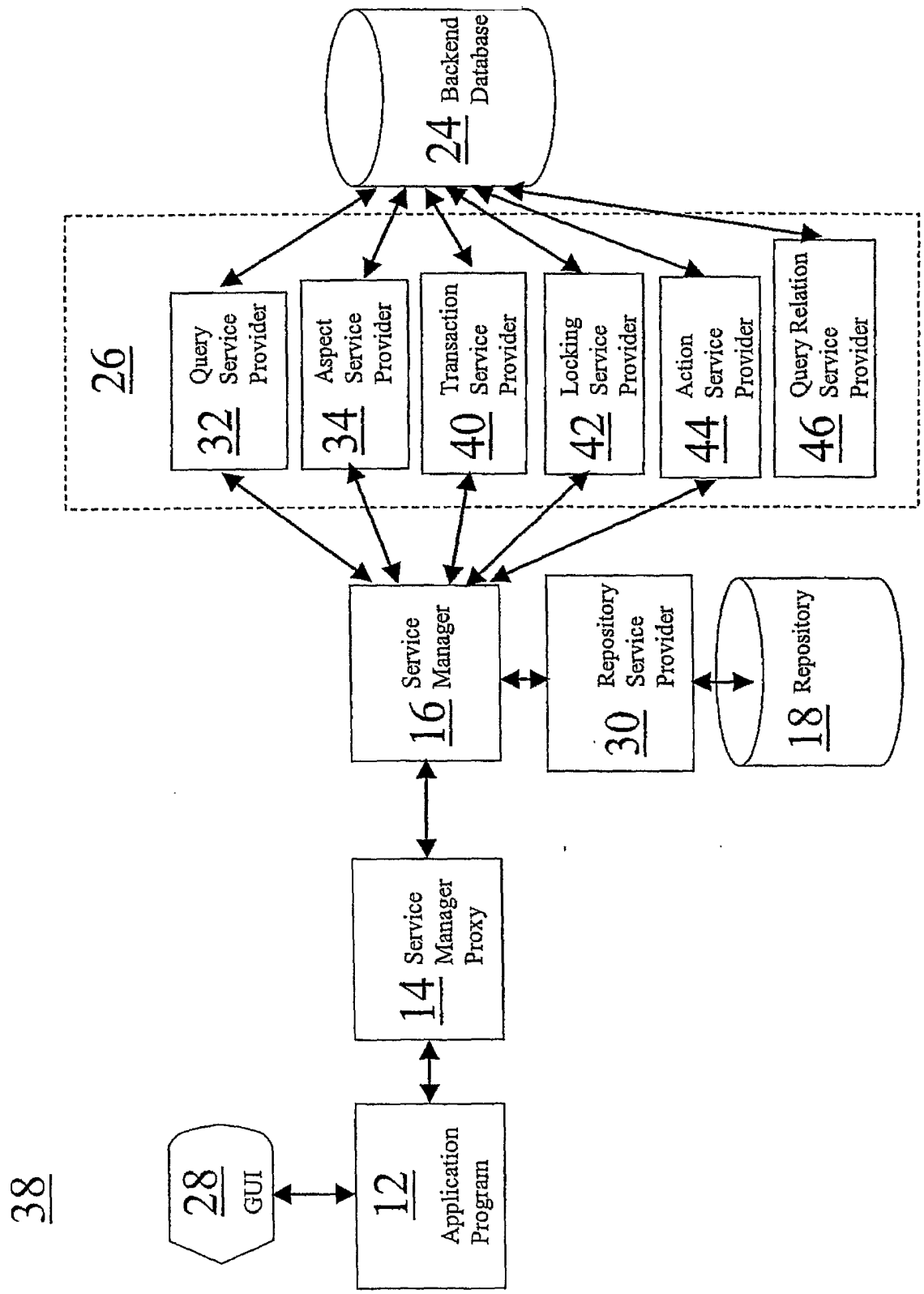
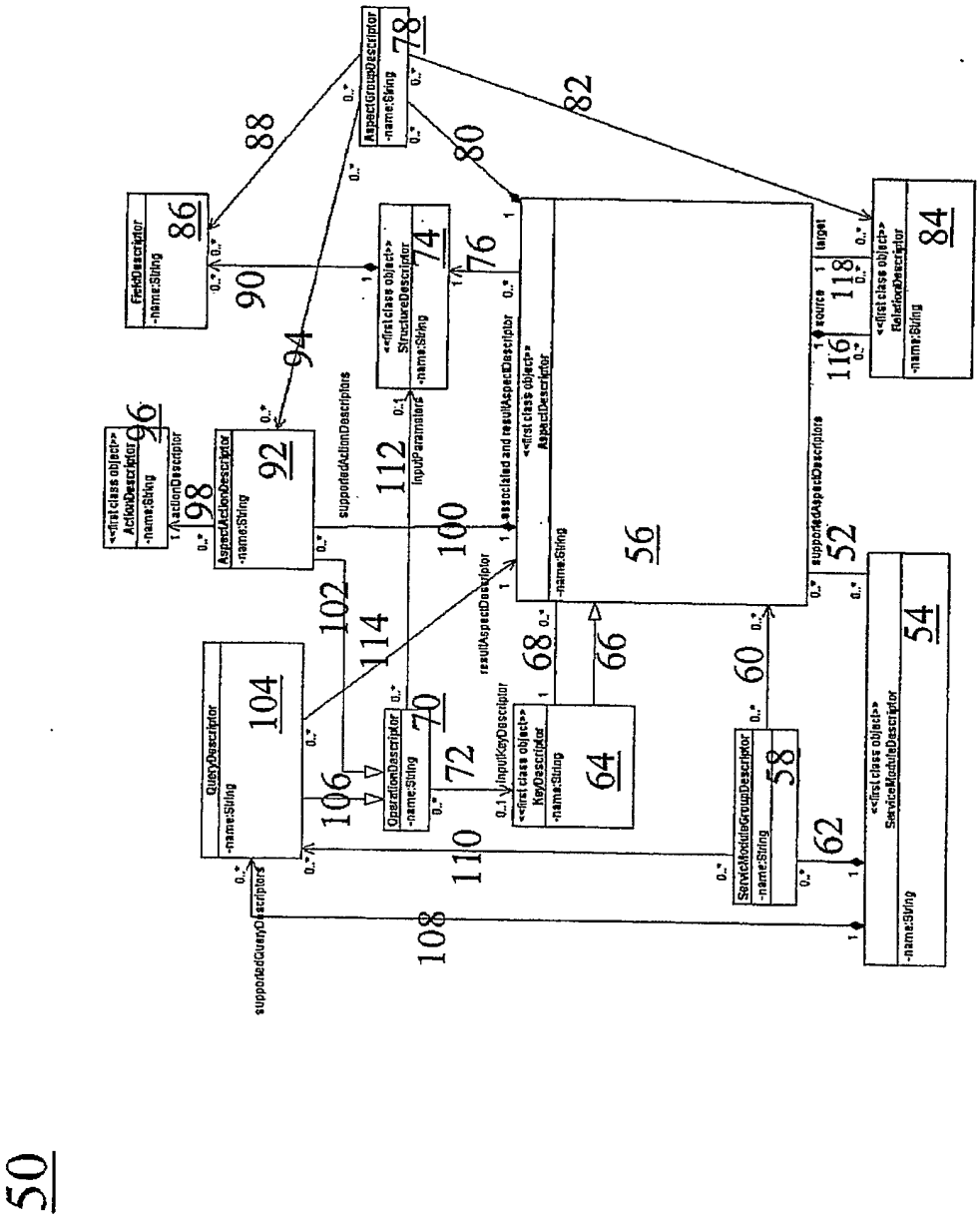

38
28 GUI
12 Application Program
14 Service Manager Proxy
16 Service Manager
30 Repository Service Provider
18 Repository
26
32 Query Service Provider
34 Aspect Service Provider
40 Transaction Service Provider
42 Locking Service Provider
44 Action Service Provider
46 Query Relation Service Provider
24 Backend Database

FIG. 3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OperationDescriptor
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ActionDescriptor
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supportedQueryDescriptors
supportedActionDescriptors
inputParameters
resultAspectDescriptor
inputKeyDescriptor
associated and resultAspectDescriptor
supportedAspectDescriptors
source
target
108
110
106
102
114
100
112
94
90
88
80
82
76
68
66
60
62
52
116
118

FIG. 4

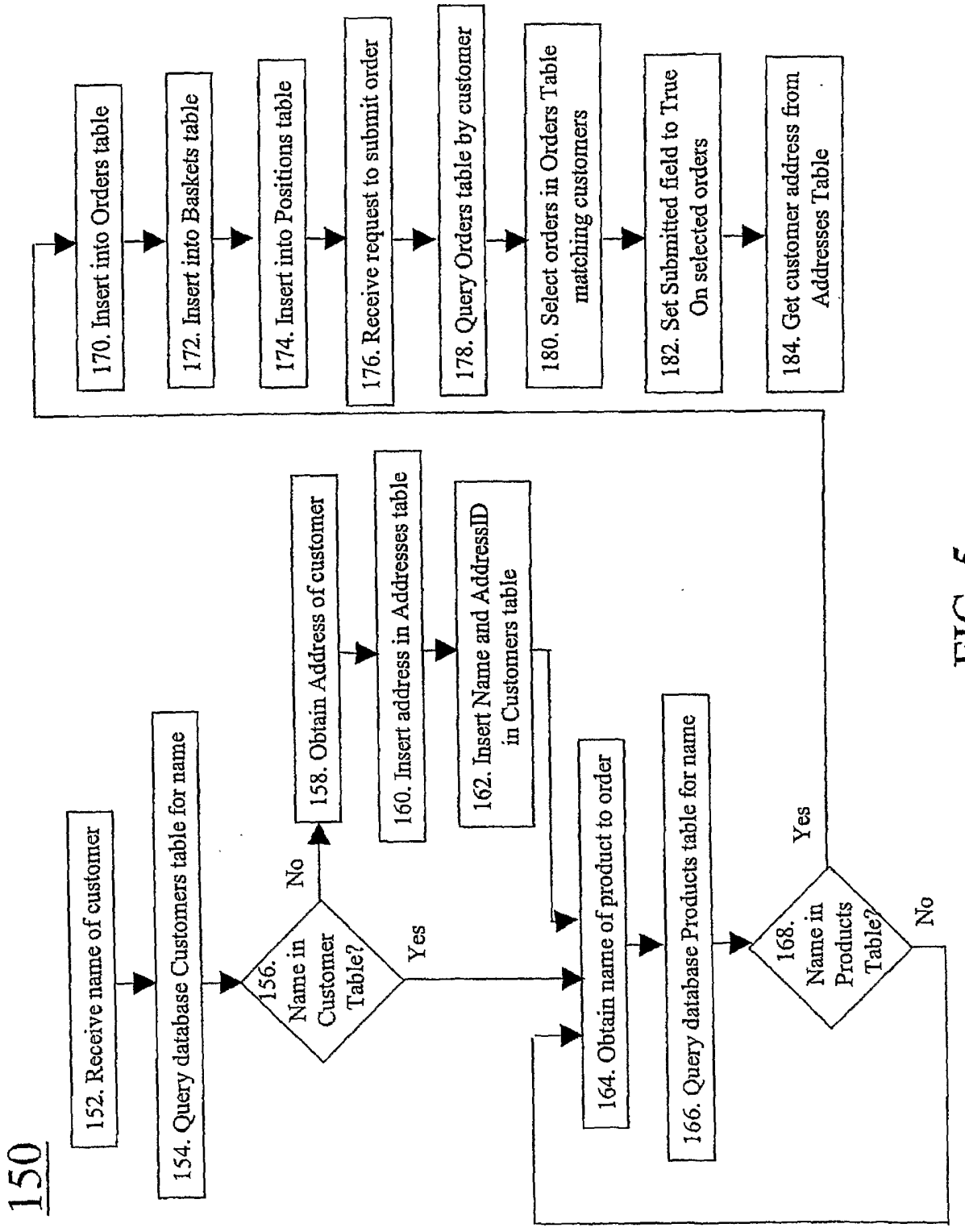
150
152. Receive name of customer
154. Query database Customers table for name
156. Name in Customer Table?
No
158. Obtain Address of customer
160. Insert address in Addresses table
162. Insert Name and AddressID in Customers table
Yes
164. Obtain name of product to order
166. Query database Products table for name
168. Name in Products Table?
Yes
No
170. Insert into Orders table
172. Insert into Baskets table
174. Insert into Positions table
176. Receive request to submit order
178. Query Orders table by customer
180. Select orders in Orders Table matching customers
182. Set Submitted field to True On selected orders
184. Get customer address from Addresses Table

FIG. 5

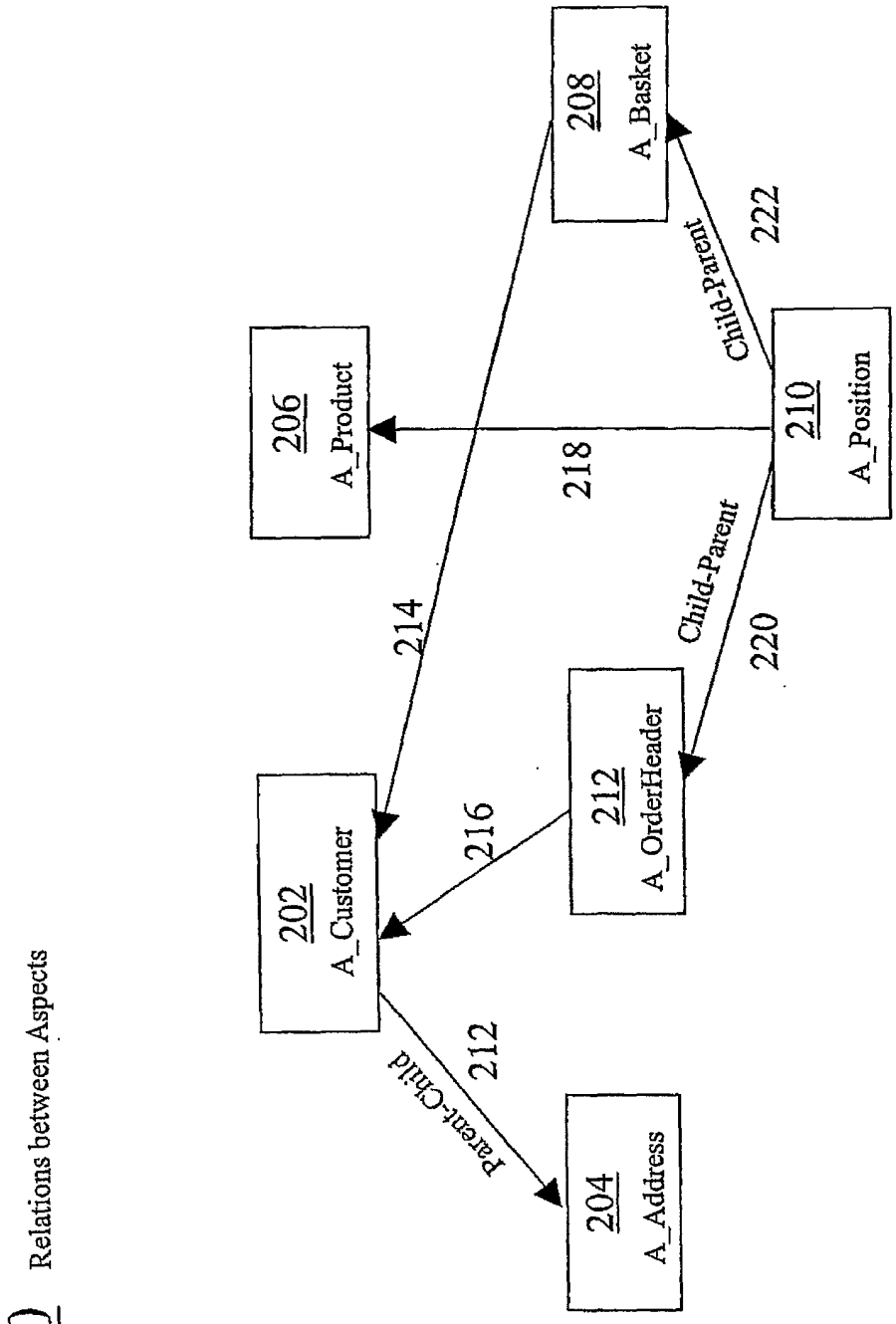
200
Relations between Aspects
208
A_Basket
206
A_Product
210
A_Position
202
A_Customer
212
A_OrderHeader
204
A_Address
214
218
220
222
216
212
Child-Parent
Child-Parent
Parent-Child

FIG. 6

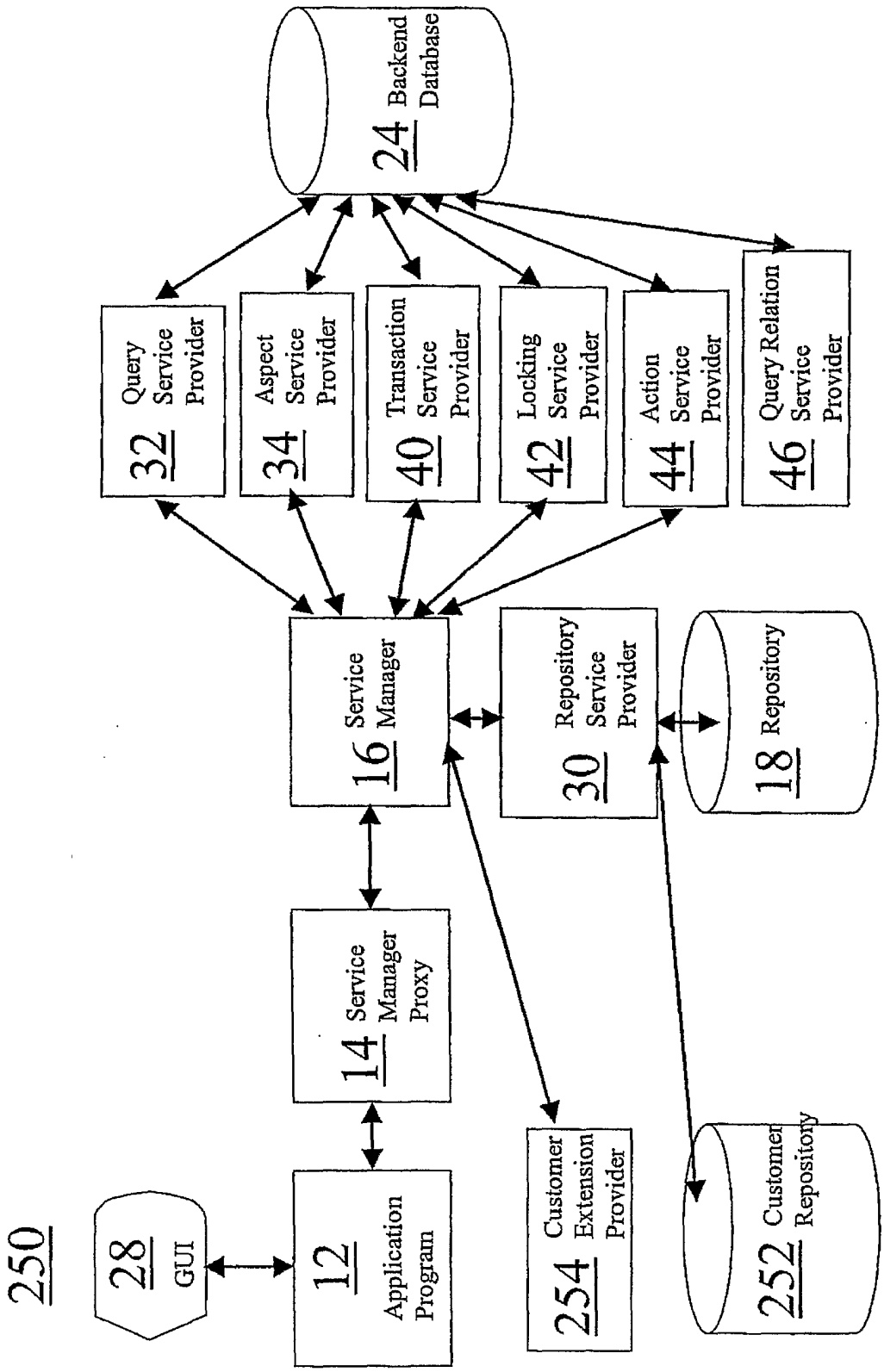
250
28 GUI
12 Application Program
14 Service Manager Proxy
16 Service Manager
18 Repository
24 Backend Database
30 Repository Service Provider
32 Query Service Provider
34 Aspect Service Provider
40 Transaction Service Provider
42 Locking Service Provider
44 Action Service Provider
46 Query Relation Service Provider
252 Customer Repository
254 Customer Extension Provider

FIG. 7

Extension
304
Repository Object
302

FIG. 8

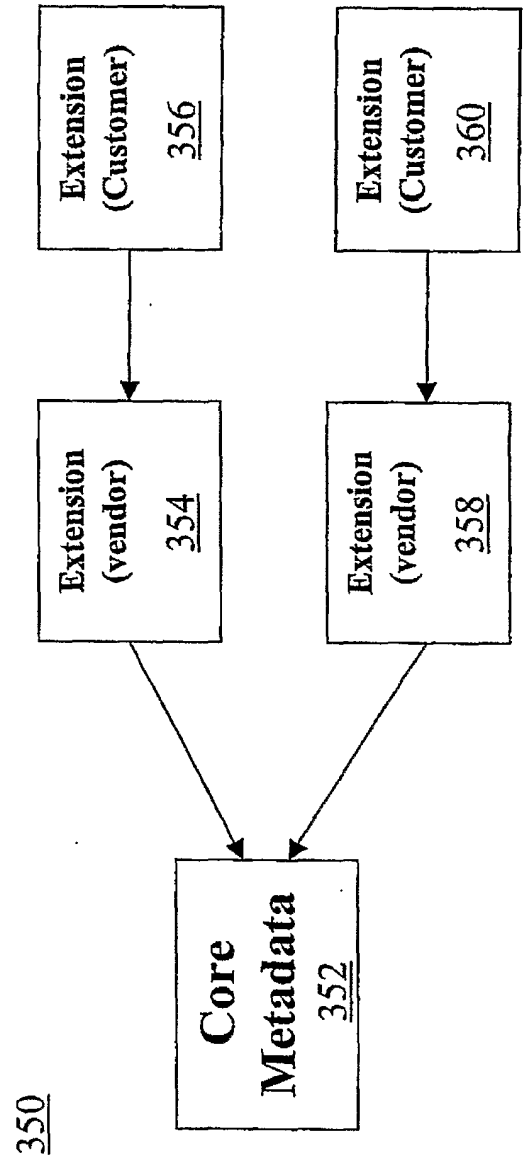
Extension (Customer) 356
Extension (Customer) 360
Extension (vendor) 354
Extension (vendor) 358
Core Metadata 352
350

FIG. 8A

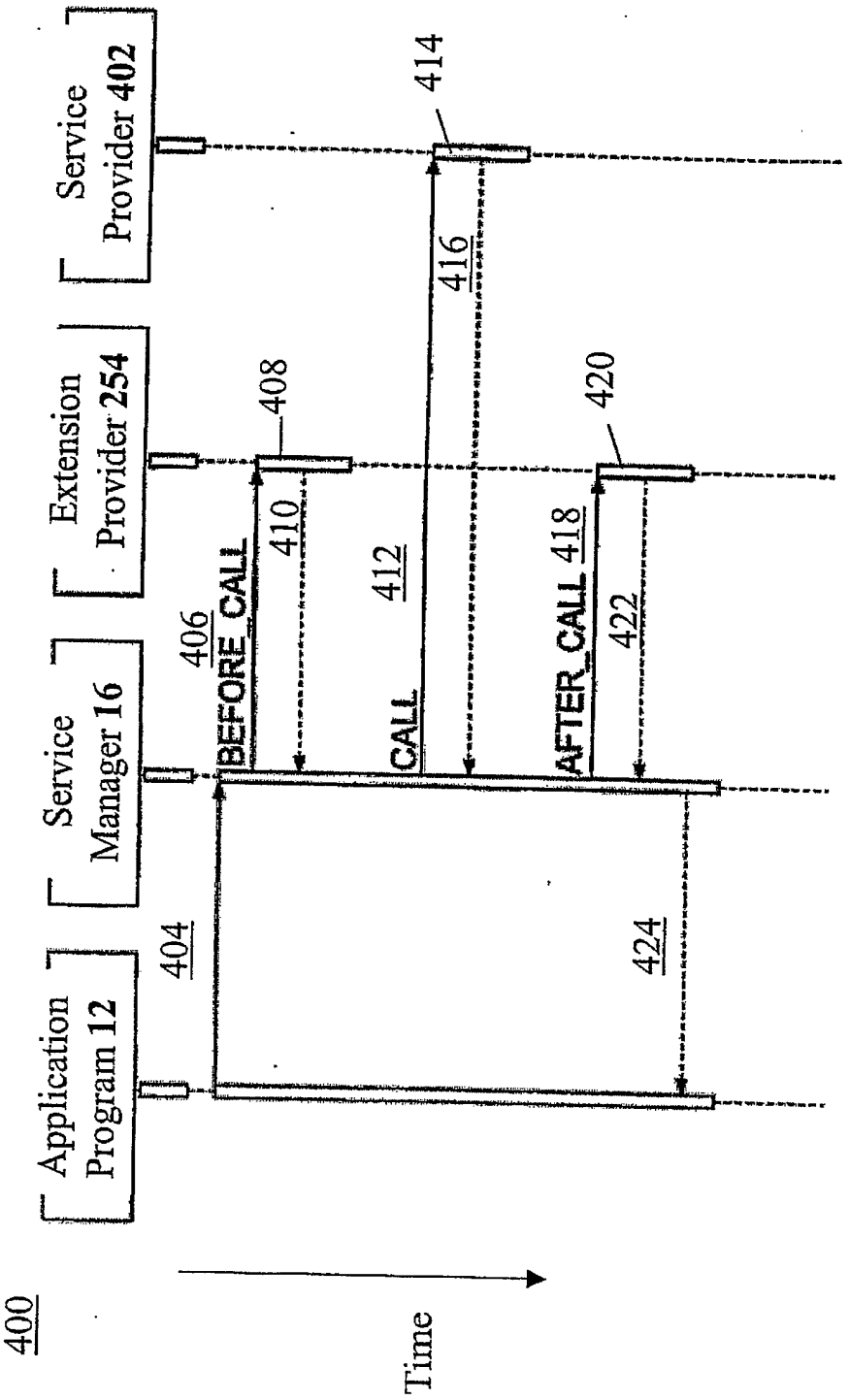
400
Application Program 12
Service Manager 16
Extension Provider 254
Service Provider 402
404
406
BEFORE_CALL
408
410
412
CALL
414
416
AFTER_CALL 418
420
422
424
Time

FIG. 9