

is connected to the first base and the second base. The runtime system facilitates migration of agents and objects from at least the first base to at least the second base

[0023] In another embodiment, the system may generally comprise at least one agent comprising a protection domain, wherein the protection domain of the at least one agent resides on at least two of the plurality of computer machines. A plurality of objects is contained within the protection domain of the at least one agent, a first object residing on a first of the at least two computer machines and a second object residing on a second of the at least two computer machines. The objects are selectively movable among the at least two computer machines by a programmer of the system. The first object on the first computer machine may access the second object on the second computer machine in a location-transparent or network-transparent manner; that is, without knowledge of the physical address of the second object on the second computer machine and regardless of the selective movement of either the first object or the second object among the first and second computer machines. The agent is mobile and may migrate, in whole or in part, to any other machine in the network. Moreover, the machines in the network may be either homogeneous or heterogeneous.

[0024] The invention further includes a method for implementing a network-centric computer software programming system for a network comprising a plurality of computer machines. The method includes defining a plurality of object-oriented classes including an object class, an agent class, a base class and a task class; defining an object migrate method in the object class that migrates a selected object instance to a location specified with the base class; defining a task migrate method in the task class that migrates a selected task represented in a task instance to a location specified with the base class; defining an agent migrate method in the agent class that migrates a selected agent process to a location specified with the base class, including migration of all object instances and task instances within the agent; instantiating a first agent process according to the agent class, the first agent process including a plurality of task instances and object instances and distributed among the plurality of computer machines; and performing the object migrate method, the task migrate method and the agent migrate method within the first agent process. Thus, the invention provides for partial or total migration of agents which are distributed among various machines of the network.

[0025] Each distributed agent of the present invention may accordingly be distributed among one, several or many of the machines of the network, enabling greater concurrency of operation while simultaneously maintaining a protected, encapsulated software structure which protects tasks and data within the agent (which themselves may be distributed among the machines of

the network) from interference by other tasks and data operating in the network and on the same machines wherein such tasks and data reside, in particular. Migration of such agents, even during process execution, is straightforward and maintains consistency across the network. Specifically, other agents may continue to access a particular agent after it has migrated without any prior notification to the agents themselves.

[0026] Accordingly, a principal object of the present invention is to provide a distributed agent system wherein an agent may have its tasks and state distributed among multiple potentially heterogeneous physical machines within a network.

[0027] Another object of the present invention is to provide a distributed agent system which is network-transparent, wherein references to objects within an agent, including objects residing on distinct physical machines, do not require knowledge of the physical location or address of the object and may instead be made using symbolic references.

[0028] Yet another object of the present invention is to provide a distributed agent system in which references to objects within an agent are resolved by the system transparent to the programmer and to the agent.

[0029] A further object of the present invention is to provide a distributed agent system which provides selectable, location-independent method execution.

[0030] A still further object of the present invention is to provide a distributed agent system which allows easy and efficient runtime process migration, in whole or in part, among distinct machines.

[0031] A still further object of the present invention is to provide a distributed agent system which is easy to program.

[0032] Other objects of the present invention will become more readily apparent in light of the following description in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033]

FIG. 1 is schematic diagram showing basic components of a distributed agent system according to the present invention;

FIG. 2 is a schematic diagram showing communication between objects within the same agent as well as communication between objects in different agents in a distributed agent system according to the present invention;

FIG. 3 is a conceptual diagram showing the operation of an object space in a distributed agent system according to the present invention;

FIG. 4A is a schematic diagram showing an agent on a source base prior to migration to a destination base in a distributed agent system according to the present invention;