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(54) **COMPUTER SYSTEM, COMPUTER, STORAGE SYSTEM, AND CONTROL TERMINAL**

(75) Inventors: **Akiyoshi Hashimoto**, Kawasaki (JP); **Masaaki Iwasaki**, Tachikawa (JP)

Correspondence Address:
TOWNSEND AND TOWNSEND AND CREW, LLP
TWO EMBARCADERO CENTER
EIGHTH FLOOR
SAN FRANCISCO, CA 94111-3834 (US)

(73) Assignee: **Hitachi, Ltd.**, Tokyo (JP)

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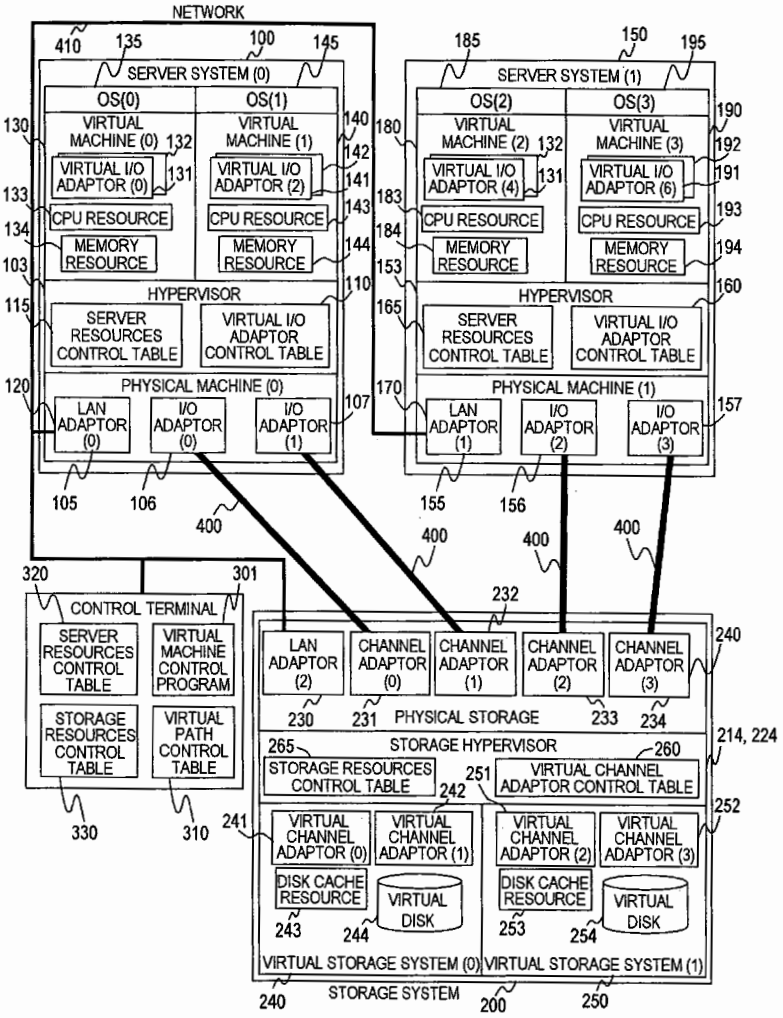
(52) **U.S. Cl.** **711/173**

(57) **ABSTRACT**

To manage physical paths between a server system and a storage system and information about routing between virtual machines and virtual storage systems in an integrated fashion. A computer system of the present invention includes: a computer and a storage system that stores data, in which the computer includes first information for managing the first resource relating to the computer; and the storage system includes second information for managing the second resource provided in the storage system, and in which a relation between the virtual machine and the virtual storage system is defined based on the first information and the second information.



MICROSOFT 1005

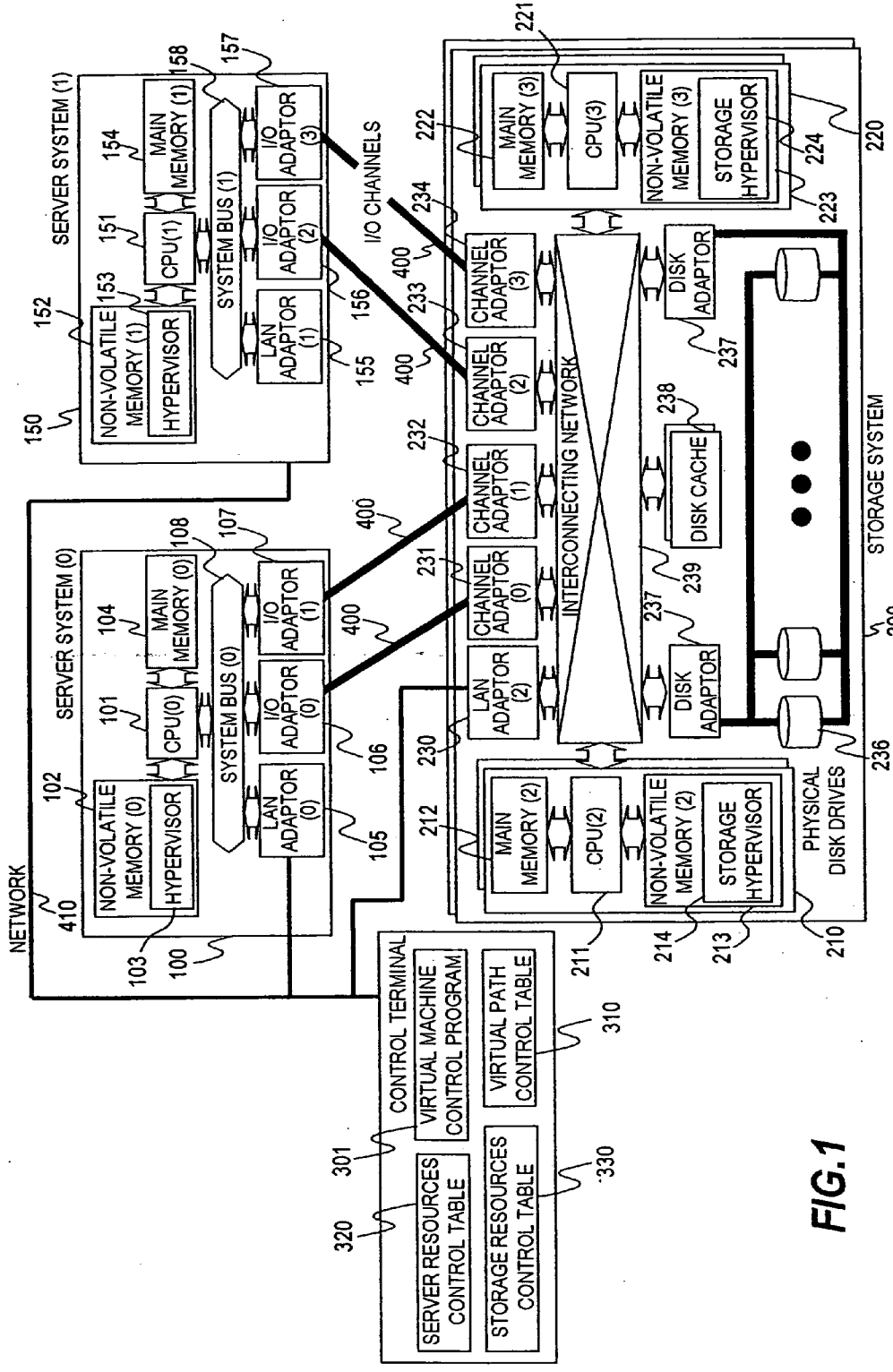

NETWORK
410
SERVER SYSTEM (0)
SERVER SYSTEM (1)
NON-VOLATILE MEMORY (0)
HYPERVISOR
CPU(0)
MAIN MEMORY (0)
SYSTEM BUS (0)
I/O ADAPTOR (0)
I/O ADAPTOR (1)
LAN ADAPTOR (0)
NON-VOLATILE MEMORY (1)
CPU(1)
MAIN MEMORY (1)
SYSTEM BUS (1)
I/O ADAPTOR (2)
I/O ADAPTOR (3)
LAN ADAPTOR (1)
I/O CHANNELS
INTERCONNECTING NETWORK
CHANNEL ADAPTOR (0)
CHANNEL ADAPTOR (1)
CHANNEL ADAPTOR (2)
CHANNEL ADAPTOR (3)
LAN ADAPTOR (2)
MAIN MEMORY (2)
CPU(2)
NON-VOLATILE MEMORY (2)
STORAGE HYPERVISOR
MAIN MEMORY (3)
CPU(3)
NON-VOLATILE MEMORY (3)
STORAGE HYPERVISOR
DISK ADAPTOR
DISK ADAPTOR
DISK CACHE
PHYSICAL DISK DRIVES
STORAGE SYSTEM
CONTROL TERMINAL
VIRTUAL MACHINE CONTROL PROGRAM
VIRTUAL PATH CONTROL TABLE
SERVER RESOURCES CONTROL TABLE
STORAGE RESOURCES CONTROL TABLE

FIG.1

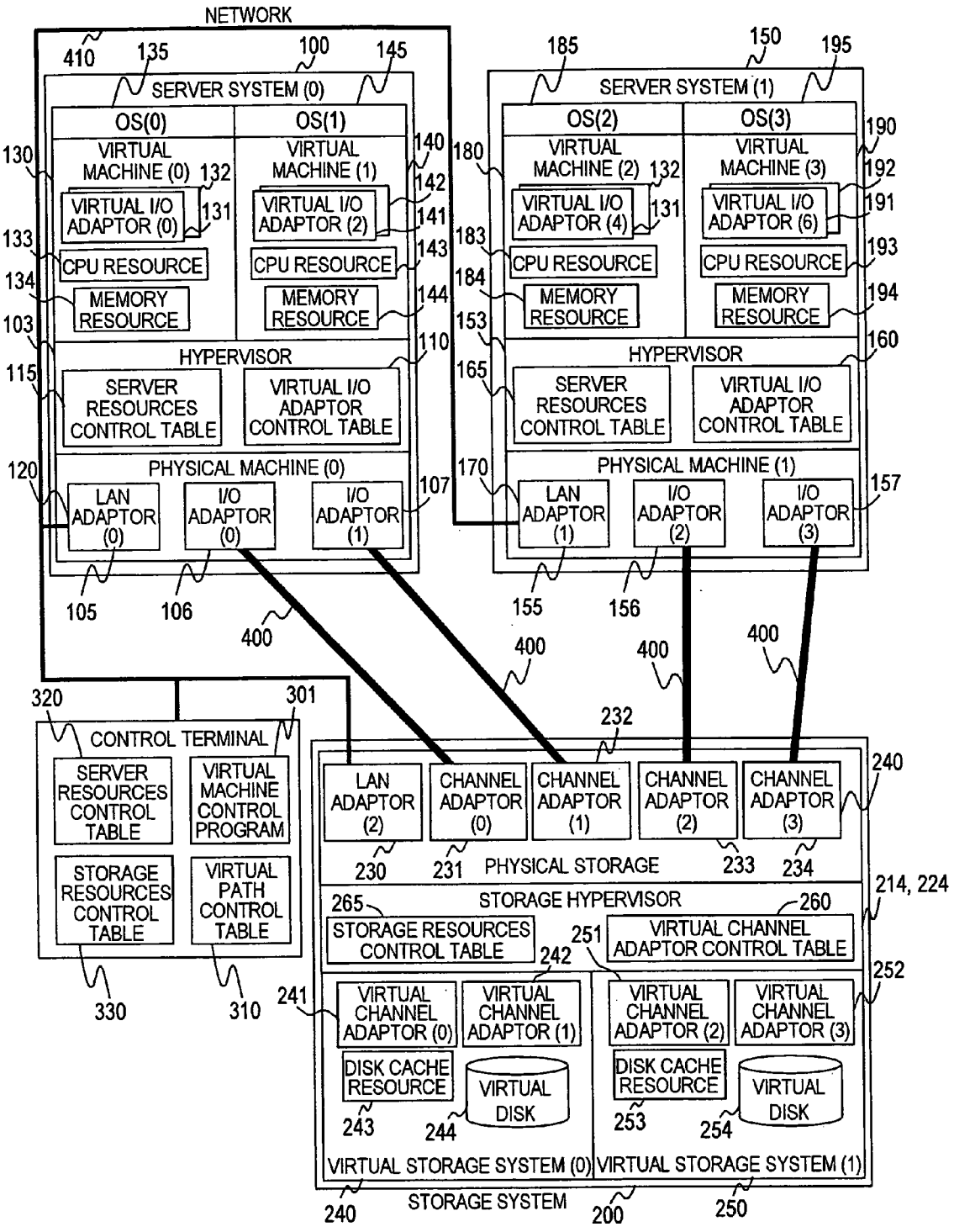

NETWORK
410
135
100
145
SERVER SYSTEM (0)
OS(0)
OS(1)
VIRTUAL MACHINE (0)
VIRTUAL MACHINE (1)
132
VIRTUAL I/O ADAPTOR (0)
131
VIRTUAL I/O ADAPTOR (2)
CPU RESOURCE
MEMORY RESOURCE
HYPERVISOR
SERVER RESOURCES CONTROL TABLE
VIRTUAL I/O ADAPTOR CONTROL TABLE
PHYSICAL MACHINE (0)
LAN ADAPTOR (0)
I/O ADAPTOR (0)
I/O ADAPTOR (1)
130
133
134
103
115
120
140
142
141
143
144
110
107
105
106
400
185
150
195
SERVER SYSTEM (1)
OS(2)
OS(3)
VIRTUAL MACHINE (2)
VIRTUAL MACHINE (3)
VIRTUAL I/O ADAPTOR (4)
VIRTUAL I/O ADAPTOR (6)
180
190
192
191
183
193
184
194
153
160
165
170
157
155
156
CONTROL TERMINAL
SERVER RESOURCES CONTROL TABLE
VIRTUAL MACHINE CONTROL PROGRAM
STORAGE RESOURCES CONTROL TABLE
VIRTUAL PATH CONTROL TABLE
320
301
330
310
232
240
LAN ADAPTOR (2)
CHANNEL ADAPTOR (0)
CHANNEL ADAPTOR (1)
CHANNEL ADAPTOR (2)
CHANNEL ADAPTOR (3)
230
231
PHYSICAL STORAGE
233
234
214, 224
STORAGE HYPERVISOR
265
260
STORAGE RESOURCES CONTROL TABLE
VIRTUAL CHANNEL ADAPTOR CONTROL TABLE
251
242
252
241
VIRTUAL CHANNEL ADAPTOR (0)
VIRTUAL CHANNEL ADAPTOR (1)
VIRTUAL CHANNEL ADAPTOR (2)
VIRTUAL CHANNEL ADAPTOR (3)
DISK CACHE RESOURCE
VIRTUAL DISK
243
244
253
254
VIRTUAL STORAGE SYSTEM (0)
VIRTUAL STORAGE SYSTEM (1)
STORAGE SYSTEM
240
200
250

FIG.2

111 I/O ADAPTOR NUMBER	112 VIRTUAL I/O ADAPTOR NUMBER	113 VIRTUAL MACHINE NUMBER
0	0	0
1	1	0
0	2	1
1	3	1

VIRTUAL I/O ADAPTOR CONTROL TABLE OF SERVER SYSTEM (0) 110

FIG.3A

161 I/O ADAPTOR NUMBER	162 VIRTUAL I/O ADAPTOR NUMBER	163 VIRTUAL MACHINE NUMBER
2	4	2
3	5	2
2	6	3
3	3	3

VIRTUAL I/O ADAPTOR CONTROL TABLE OF SERVER SYSTEM (1) 160

FIG.3B

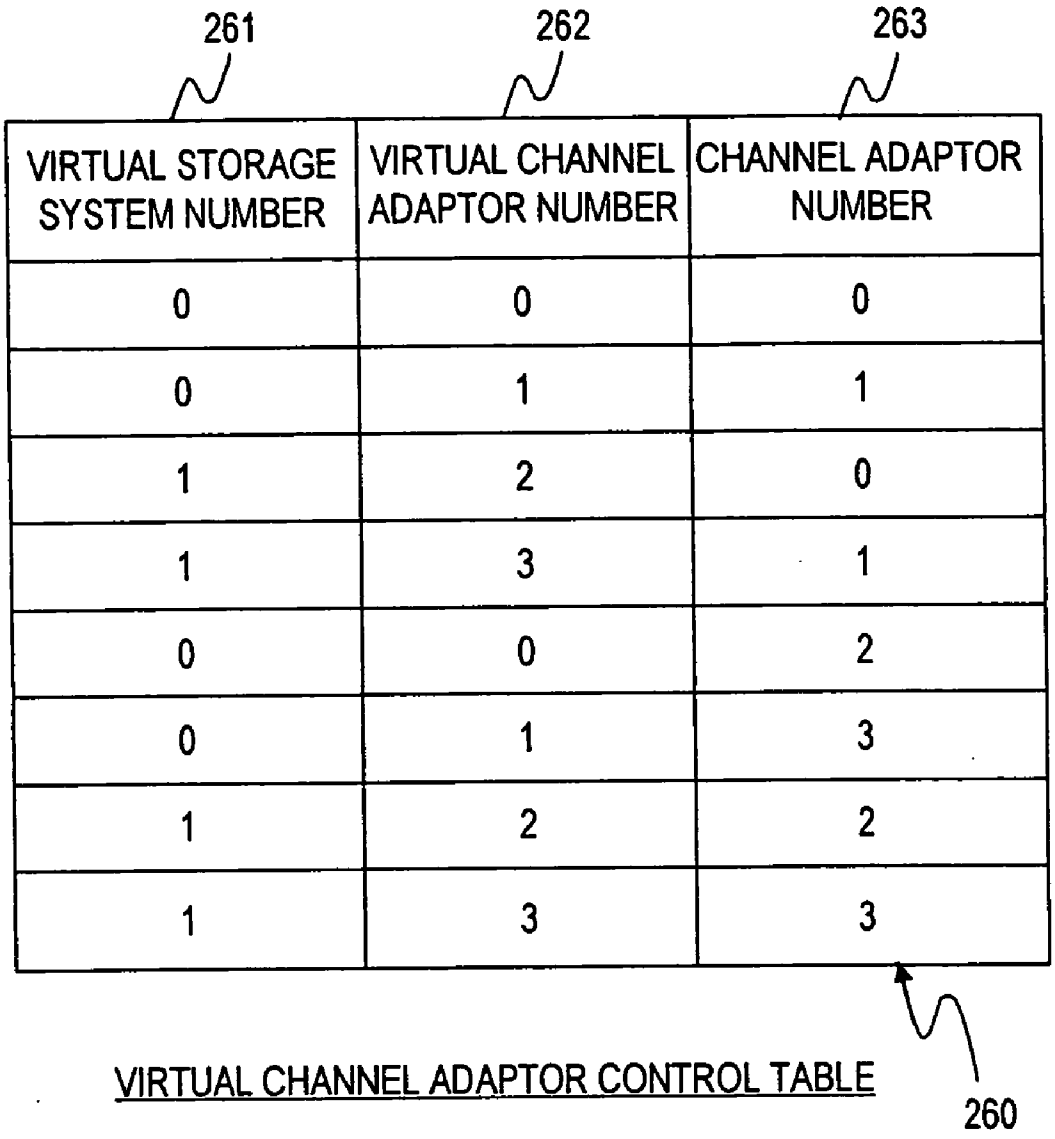

261
262
263
VIRTUAL STORAGE SYSTEM NUMBER
VIRTUAL CHANNEL ADAPTOR NUMBER
CHANNEL ADAPTOR NUMBER
0 0 0
0 1 1
1 2 0
1 3 1
0 0 2
0 1 3
1 2 2
1 3 3
VIRTUAL CHANNEL ADAPTOR CONTROL TABLE
260

FIG.4

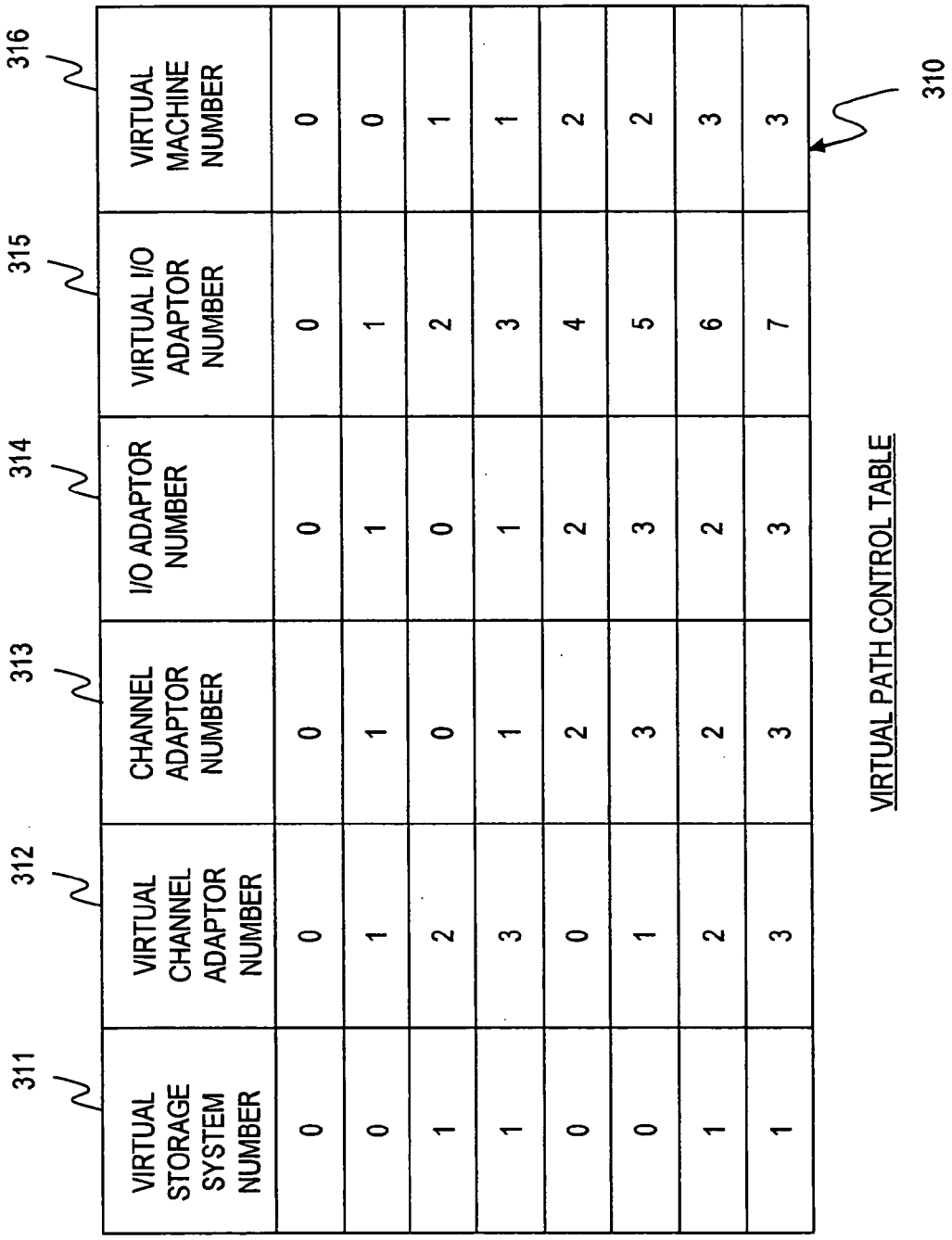

311
312
313
314
315
316
VIRTUAL STORAGE SYSTEM NUMBER
VIRTUAL CHANNEL ADAPTOR NUMBER
CHANNEL ADAPTOR NUMBER
I/O ADAPTOR NUMBER
VIRTUAL I/O ADAPTOR NUMBER
VIRTUAL MACHINE NUMBER
0 0 0 0 0 0
0 1 1 1 1 0
1 2 0 0 2 1
1 3 1 1 3 1
0 0 2 2 4 2
0 1 3 3 5 2
1 2 2 2 6 3
1 3 3 3 7 3
310
VIRTUAL PATH CONTROL TABLE

FIG.5

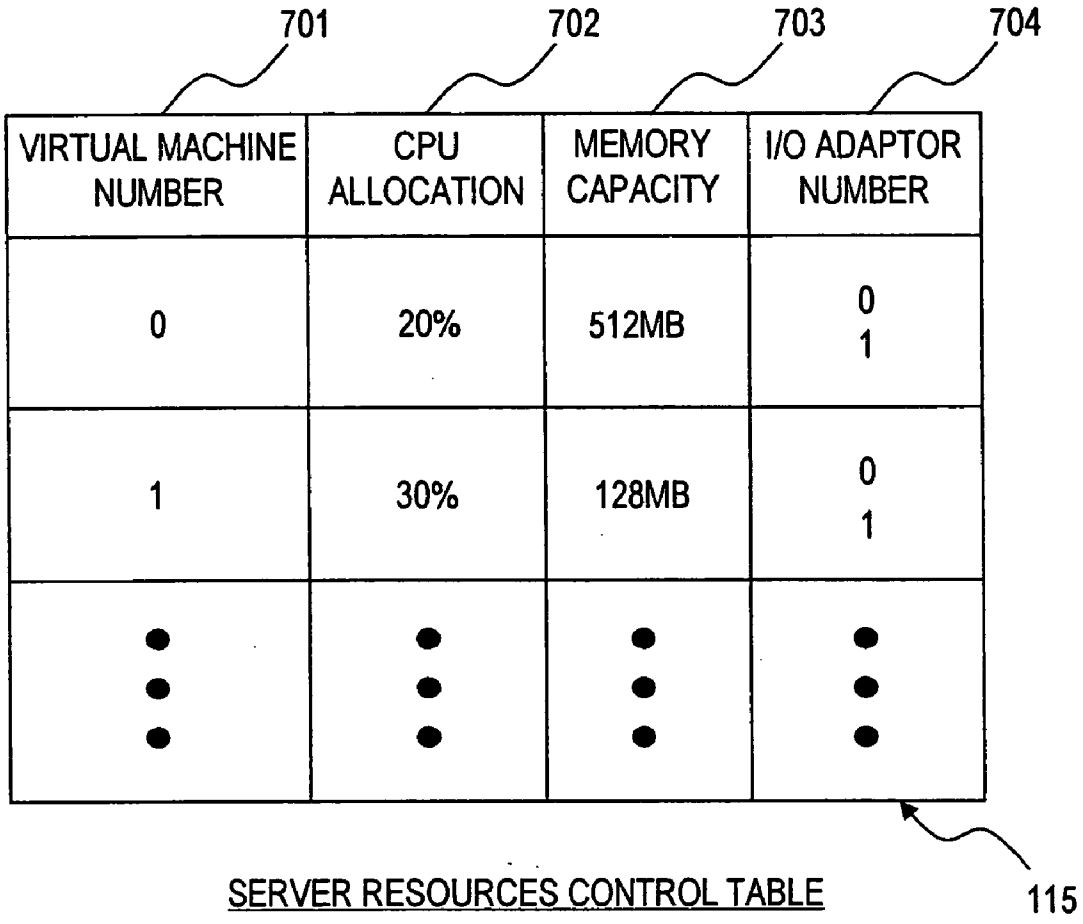

701
702
703
704
VIRTUAL MACHINE NUMBER
CPU ALLOCATION
MEMORY CAPACITY
I/O ADAPTOR NUMBER
0
20%
512MB
0
1
1
30%
128MB
0
1
SERVER RESOURCES CONTROL TABLE
115

FIG.6

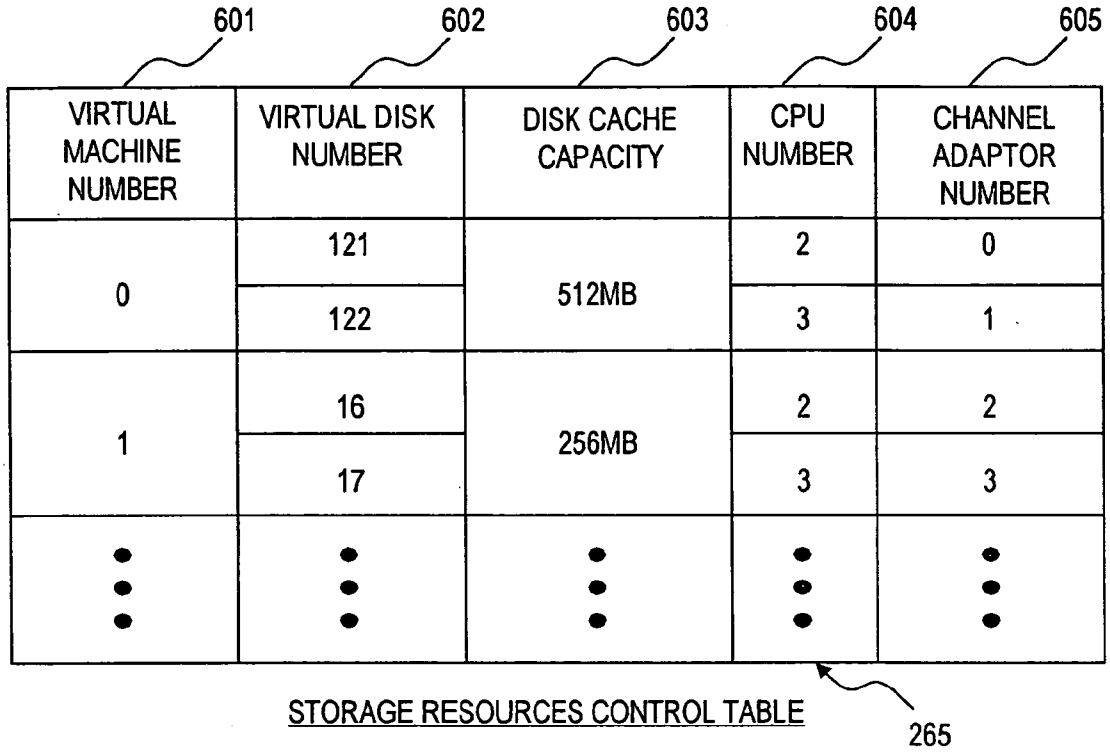

601
602
603
604
605
VIRTUAL MACHINE NUMBER
VIRTUAL DISK NUMBER
DISK CACHE CAPACITY
CPU NUMBER
CHANNEL ADAPTOR NUMBER
0
121
512MB
2
0
122
3
1
1
16
256MB
2
2
17
3
3
STORAGE RESOURCES CONTROL TABLE
265

FIG.7

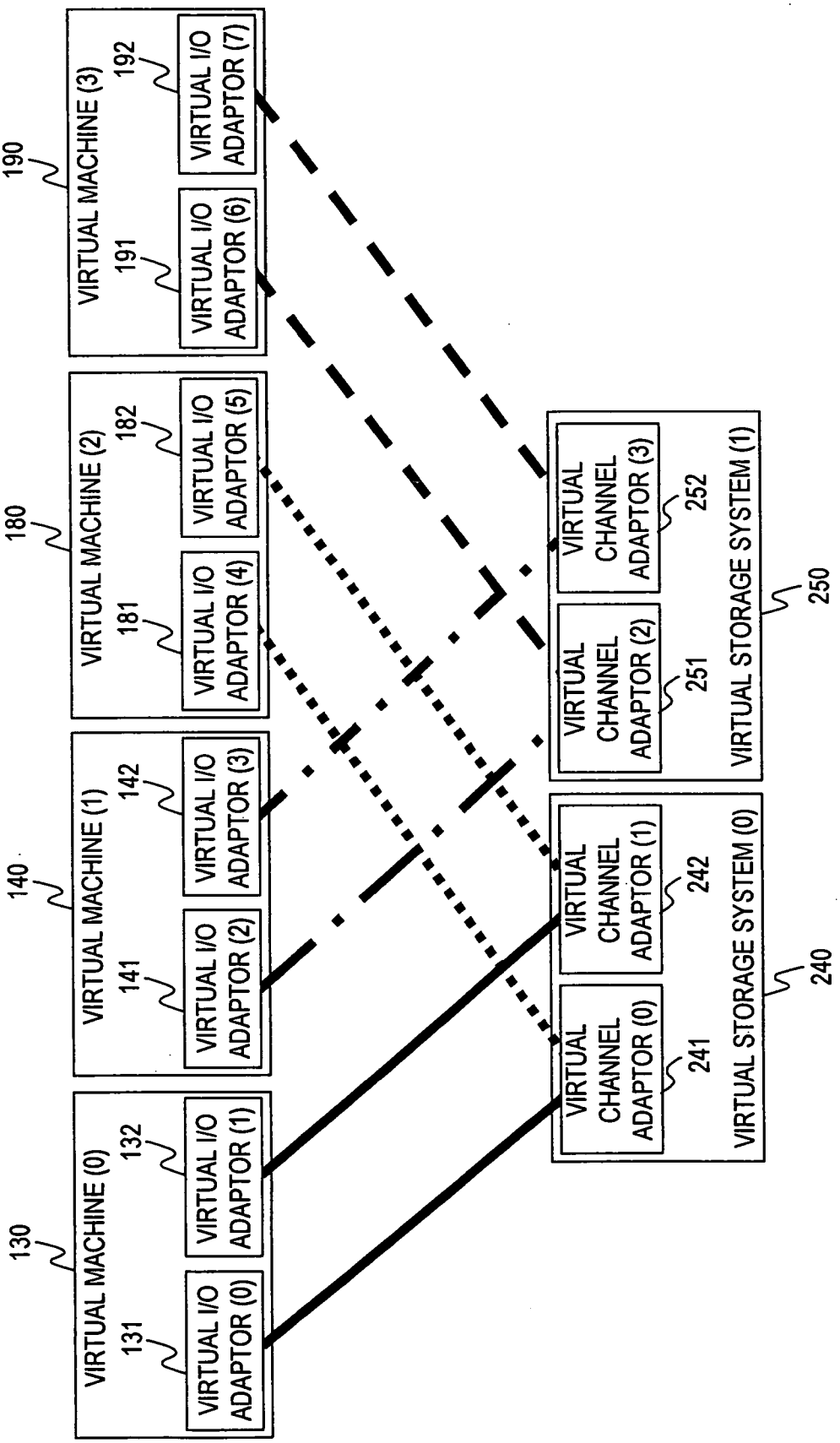

VIRTUAL MACHINE (0)
130
131
VIRTUAL I/O ADAPTOR (0)
132
VIRTUAL I/O ADAPTOR (1)
VIRTUAL MACHINE (1)
140
141
VIRTUAL I/O ADAPTOR (2)
142
VIRTUAL I/O ADAPTOR (3)
VIRTUAL MACHINE (2)
180
181
VIRTUAL I/O ADAPTOR (4)
182
VIRTUAL I/O ADAPTOR (5)
VIRTUAL MACHINE (3)
190
191
VIRTUAL I/O ADAPTOR (6)
192
VIRTUAL I/O ADAPTOR (7)
VIRTUAL STORAGE SYSTEM (0)
240
VIRTUAL CHANNEL ADAPTOR (0)
241
VIRTUAL CHANNEL ADAPTOR (1)
242
VIRTUAL STORAGE SYSTEM (1)
250
VIRTUAL CHANNEL ADAPTOR (2)
251
VIRTUAL CHANNEL ADAPTOR (3)
252

FIG.8

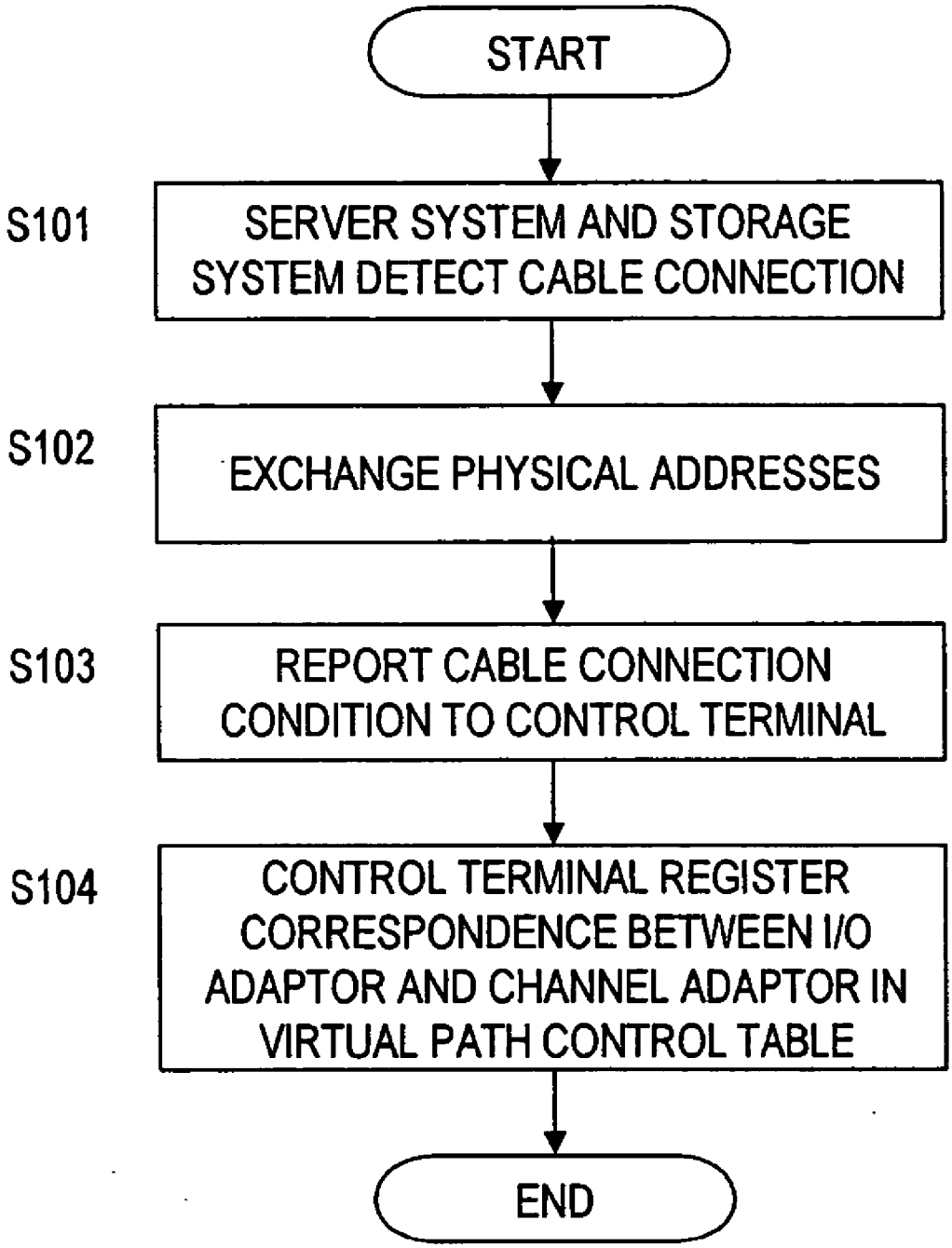

START
S101
SERVER SYSTEM AND STORAGE SYSTEM DETECT CABLE CONNECTION
S102
EXCHANGE PHYSICAL ADDRESSES
S103
REPORT CABLE CONNECTION CONDITION TO CONTROL TERMINAL
S104
CONTROL TERMINAL REGISTER CORRESPONDENCE BETWEEN I/O ADAPTOR AND CHANNEL ADAPTOR IN VIRTUAL PATH CONTROL TABLE
END

FIG.9

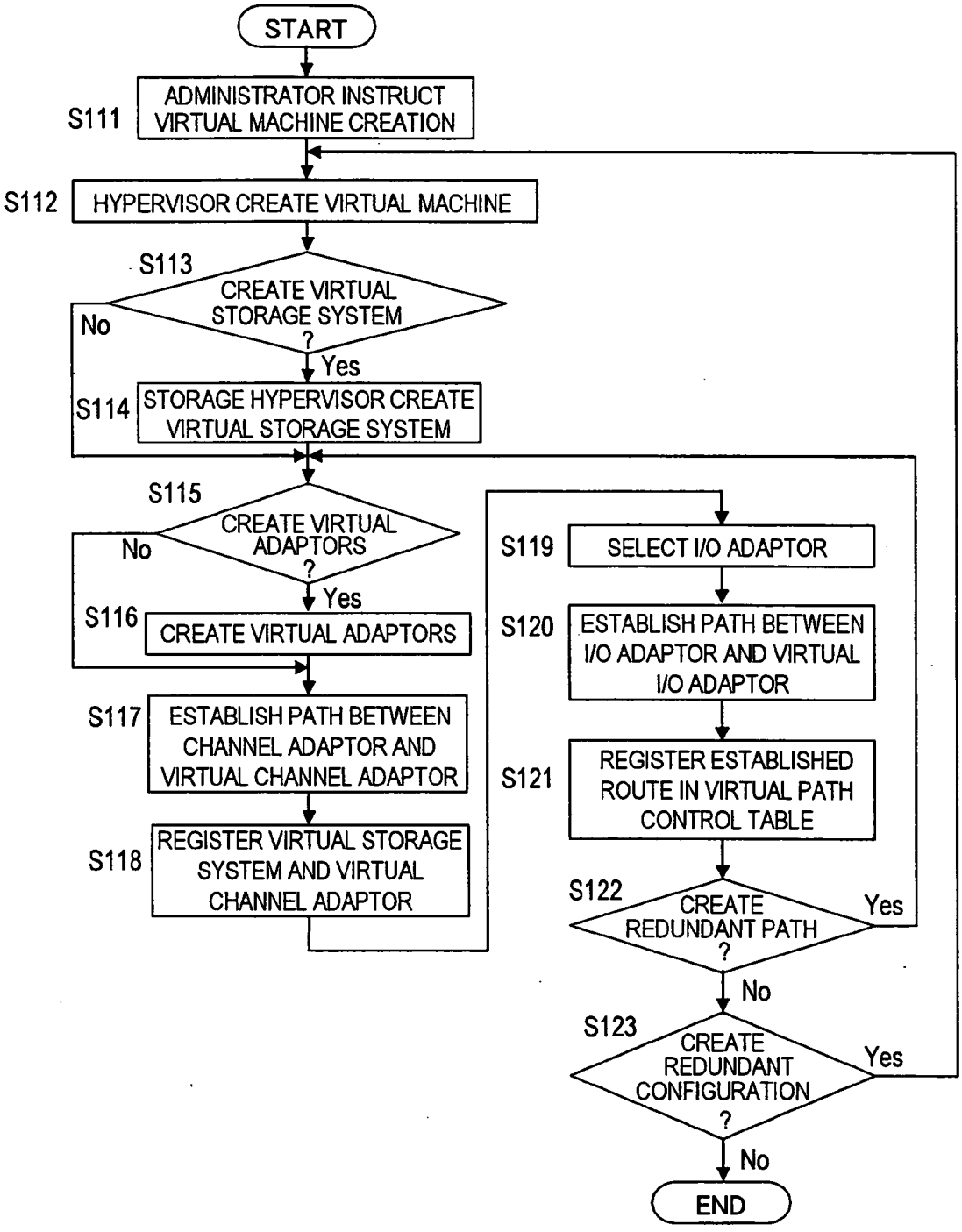

START
S111
ADMINISTRATOR INSTRUCT VIRTUAL MACHINE CREATION
S112
HYPERVISOR CREATE VIRTUAL MACHINE
S113
CREATE VIRTUAL STORAGE SYSTEM ?
No
Yes
S114
STORAGE HYPERVISOR CREATE VIRTUAL STORAGE SYSTEM
S115
CREATE VIRTUAL ADAPTORS ?
No
Yes
S116
CREATE VIRTUAL ADAPTORS
S117
ESTABLISH PATH BETWEEN CHANNEL ADAPTOR AND VIRTUAL CHANNEL ADAPTOR
S118
REGISTER VIRTUAL STORAGE SYSTEM AND VIRTUAL CHANNEL ADAPTOR
S119
SELECT I/O ADAPTOR
S120
ESTABLISH PATH BETWEEN I/O ADAPTOR AND VIRTUAL I/O ADAPTOR
S121
REGISTER ESTABLISHED ROUTE IN VIRTUAL PATH CONTROL TABLE
S122
CREATE REDUNDANT PATH ?
Yes
No
S123
CREATE REDUNDANT CONFIGURATION ?
Yes
No
END

FIG.10

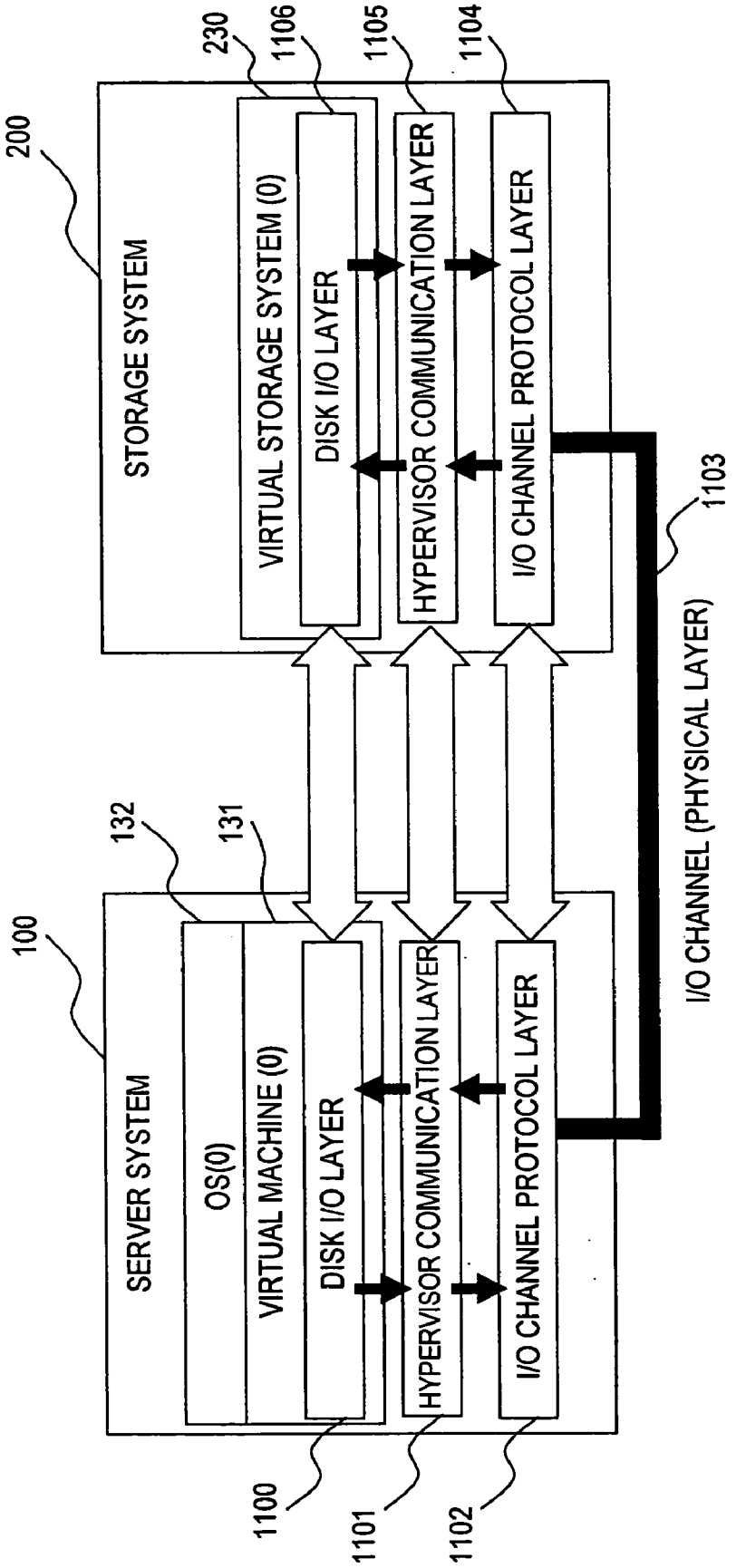

200
STORAGE SYSTEM
230
VIRTUAL STORAGE SYSTEM (0)
1106
DISK I/O LAYER
1105
HYPERVISOR COMMUNICATION LAYER
1104
I/O CHANNEL PROTOCOL LAYER
1103
I/O CHANNEL (PHYSICAL LAYER)
100
SERVER SYSTEM
132
OS(0)
131
VIRTUAL MACHINE (0)
DISK I/O LAYER
HYPERVISOR COMMUNICATION LAYER
I/O CHANNEL PROTOCOL LAYER
1100
1101
1102

FIG.11

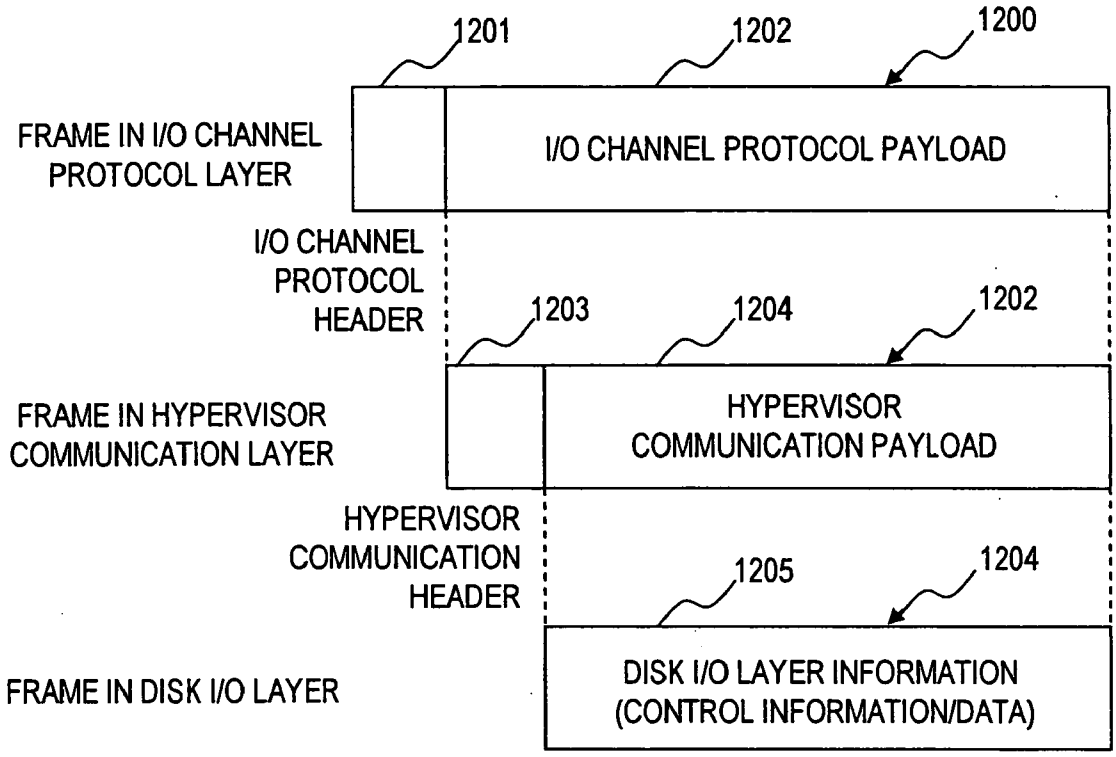

1201
1202
1200
FRAME IN I/O CHANNEL PROTOCOL LAYER
I/O CHANNEL PROTOCOL PAYLOAD
I/O CHANNEL PROTOCOL HEADER
1203
1204
1202
FRAME IN HYPERVISOR COMMUNICATION LAYER
HYPERVISOR COMMUNICATION PAYLOAD
HYPERVISOR COMMUNICATION HEADER
1205
1204
FRAME IN DISK I/O LAYER
DISK I/O LAYER INFORMATION (CONTROL INFORMATION/DATA)

FIG.12

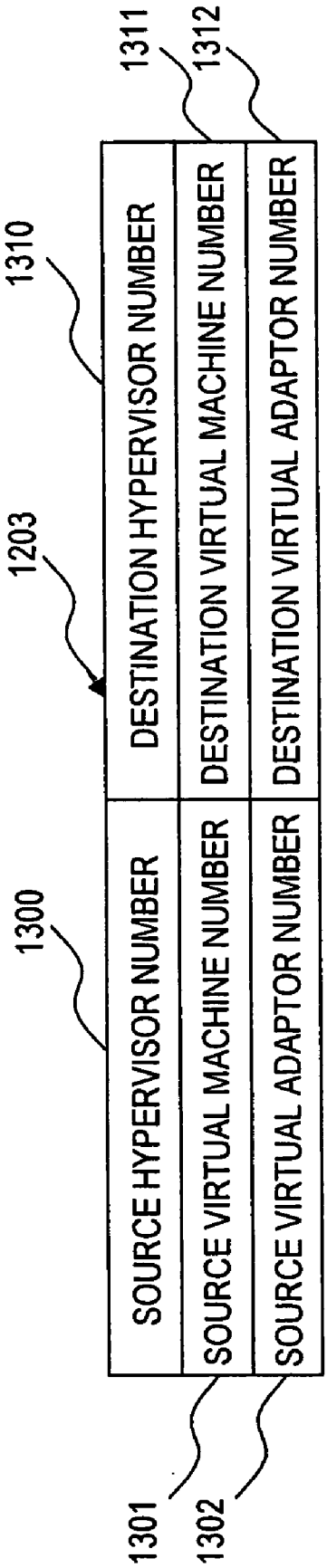

1311
1312
1310
1203
1300
DESTINATION HYPERVISOR NUMBER
DESTINATION VIRTUAL MACHINE NUMBER
DESTINATION VIRTUAL ADAPTOR NUMBER
SOURCE HYPERVISOR NUMBER
SOURCE VIRTUAL MACHINE NUMBER
SOURCE VIRTUAL ADAPTOR NUMBER
1301
1302

FIG.13

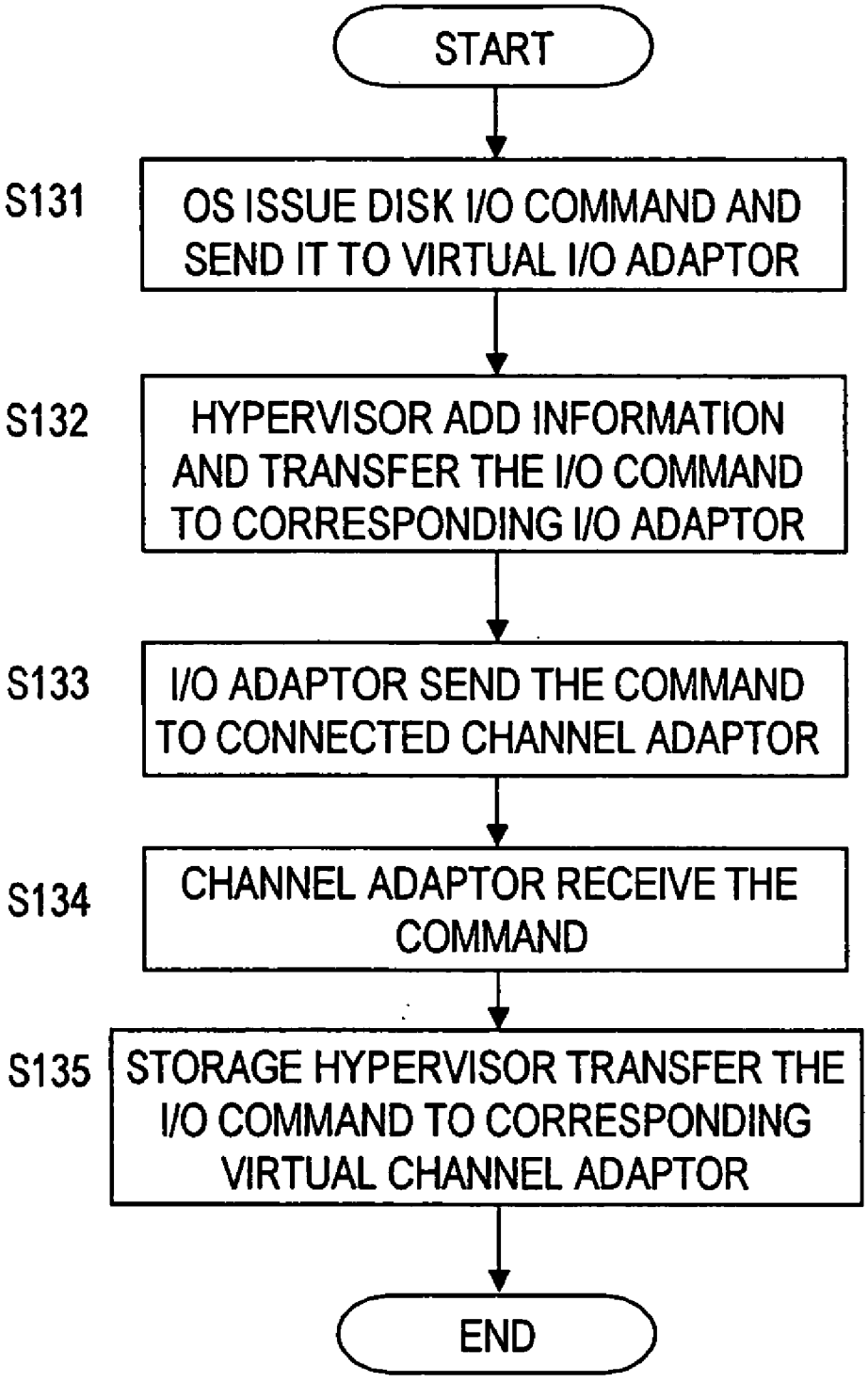

START
S131
OS ISSUE DISK I/O COMMAND AND SEND IT TO VIRTUAL I/O ADAPTOR
S132
HYPERVISOR ADD INFORMATION AND TRANSFER THE I/O COMMAND TO CORRESPONDING I/O ADAPTOR
S133
I/O ADAPTOR SEND THE COMMAND TO CONNECTED CHANNEL ADAPTOR
S134
CHANNEL ADAPTOR RECEIVE THE COMMAND
S135
STORAGE HYPERVISOR TRANSFER THE I/O COMMAND TO CORRESPONDING VIRTUAL CHANNEL ADAPTOR
END

FIG.14

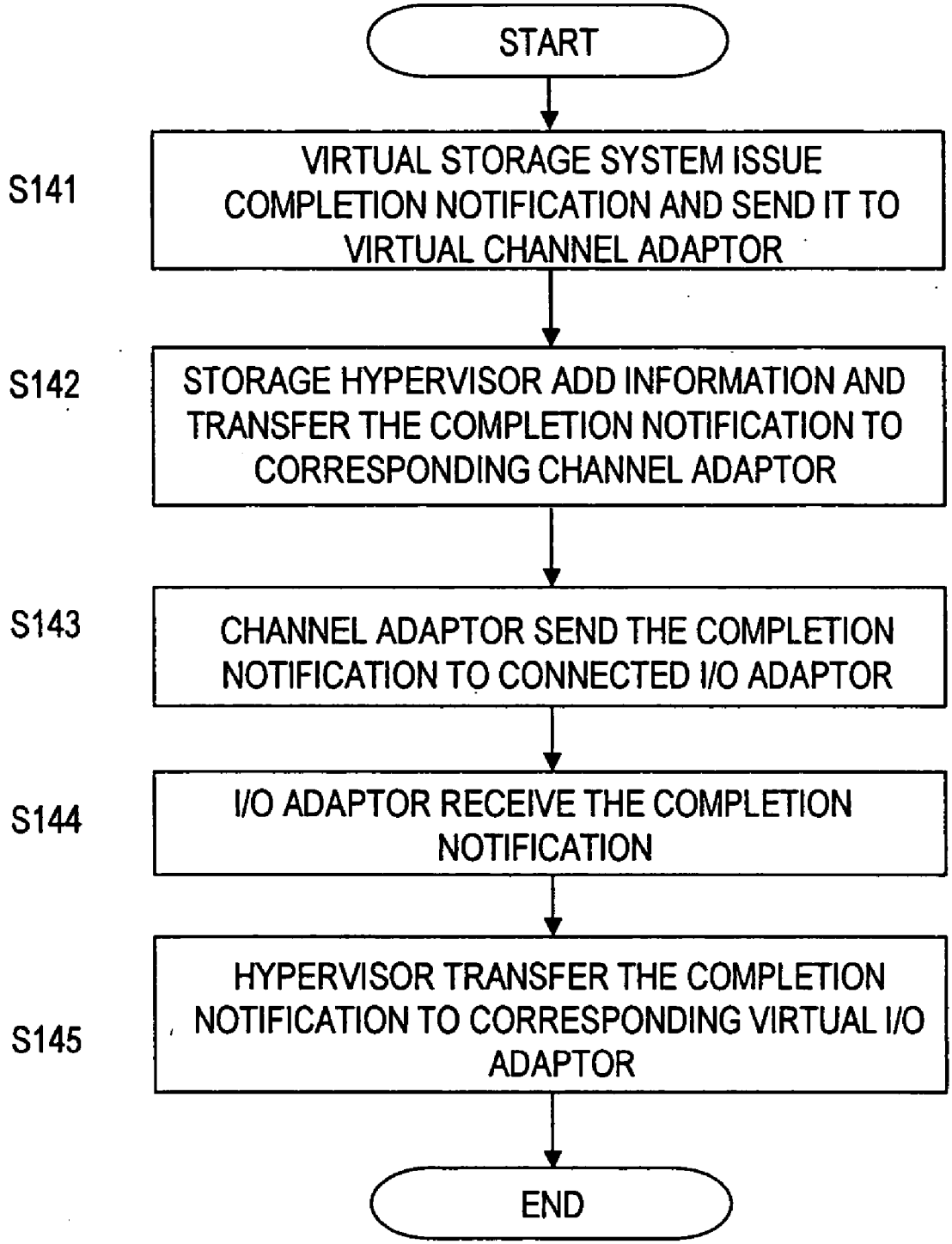

START
S141
VIRTUAL STORAGE SYSTEM ISSUE COMPLETION NOTIFICATION AND SEND IT TO VIRTUAL CHANNEL ADAPTOR
S142
STORAGE HYPERVISOR ADD INFORMATION AND TRANSFER THE COMPLETION NOTIFICATION TO CORRESPONDING CHANNEL ADAPTOR
S143
CHANNEL ADAPTOR SEND THE COMPLETION NOTIFICATION TO CONNECTED I/O ADAPTOR
S144
I/O ADAPTOR RECEIVE THE COMPLETION NOTIFICATION
S145
HYPERVISOR TRANSFER THE COMPLETION NOTIFICATION TO CORRESPONDING VIRTUAL I/O ADAPTOR
END

FIG.15

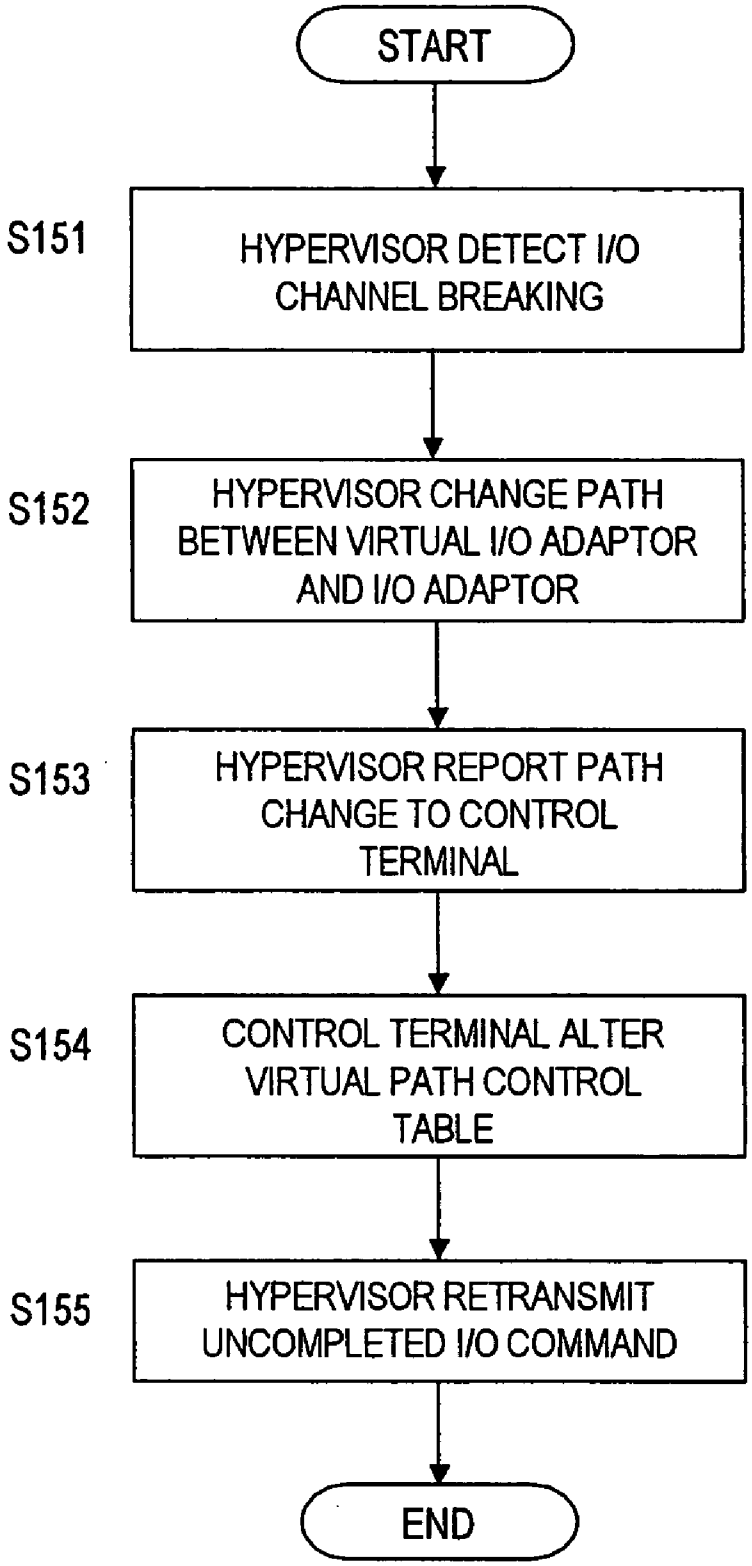

START
S151
HYPERVISOR DETECT I/O CHANNEL BREAKING
S152
HYPERVISOR CHANGE PATH BETWEEN VIRTUAL I/O ADAPTOR AND I/O ADAPTOR
S153
HYPERVISOR REPORT PATH CHANGE TO CONTROL TERMINAL
S154
CONTROL TERMINAL ALTER VIRTUAL PATH CONTROL TABLE
S155
HYPERVISOR RETRANSMIT UNCOMPLETED I/O COMMAND
END

FIG.16

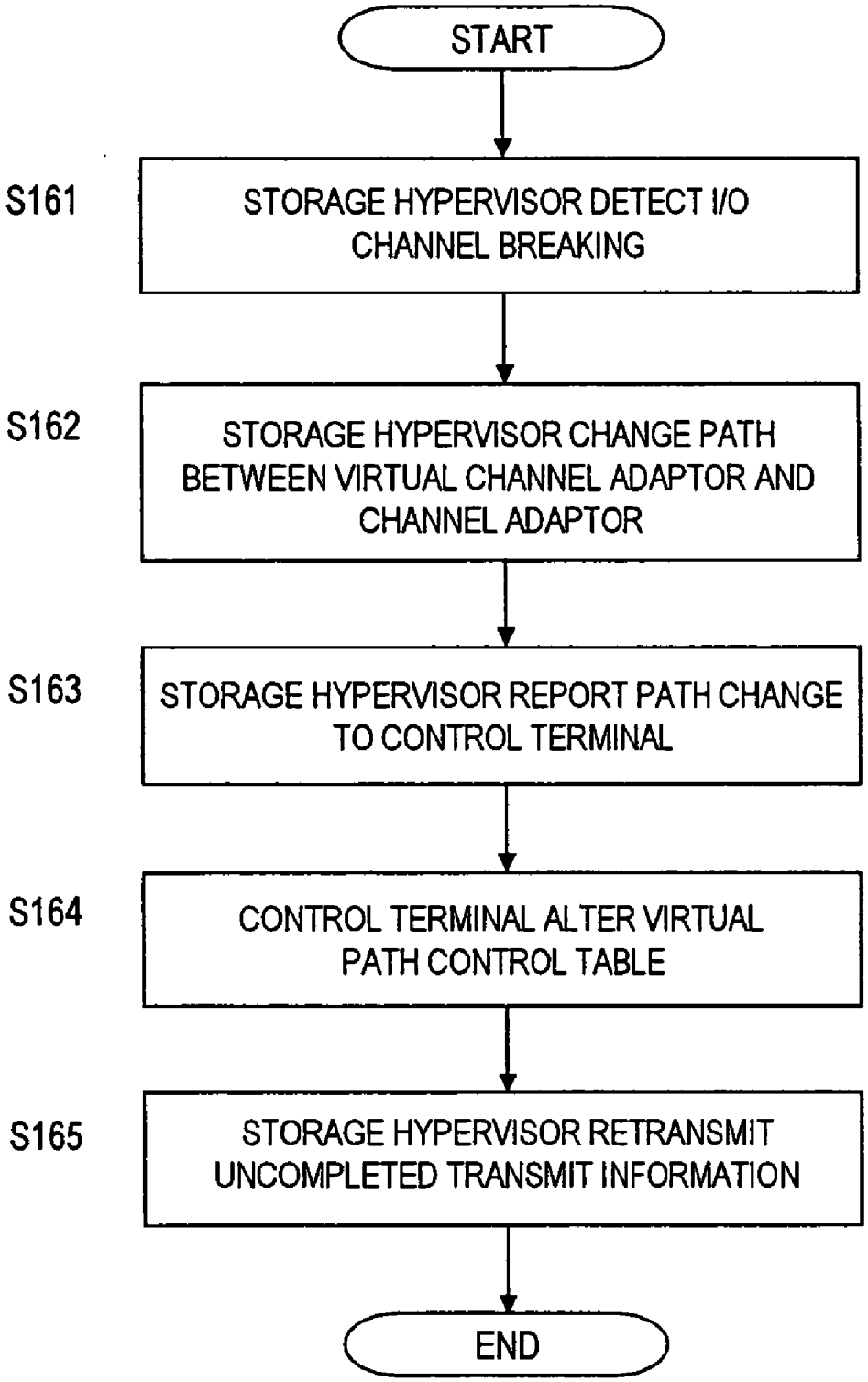

START
S161
STORAGE HYPERVISOR DETECT I/O CHANNEL BREAKING
S162
STORAGE HYPERVISOR CHANGE PATH BETWEEN VIRTUAL CHANNEL ADAPTOR AND CHANNEL ADAPTOR
S163
STORAGE HYPERVISOR REPORT PATH CHANGE TO CONTROL TERMINAL
S164
CONTROL TERMINAL ALTER VIRTUAL PATH CONTROL TABLE
S165
STORAGE HYPERVISOR RETRANSMIT UNCOMPLETED TRANSMIT INFORMATION
END

FIG.17

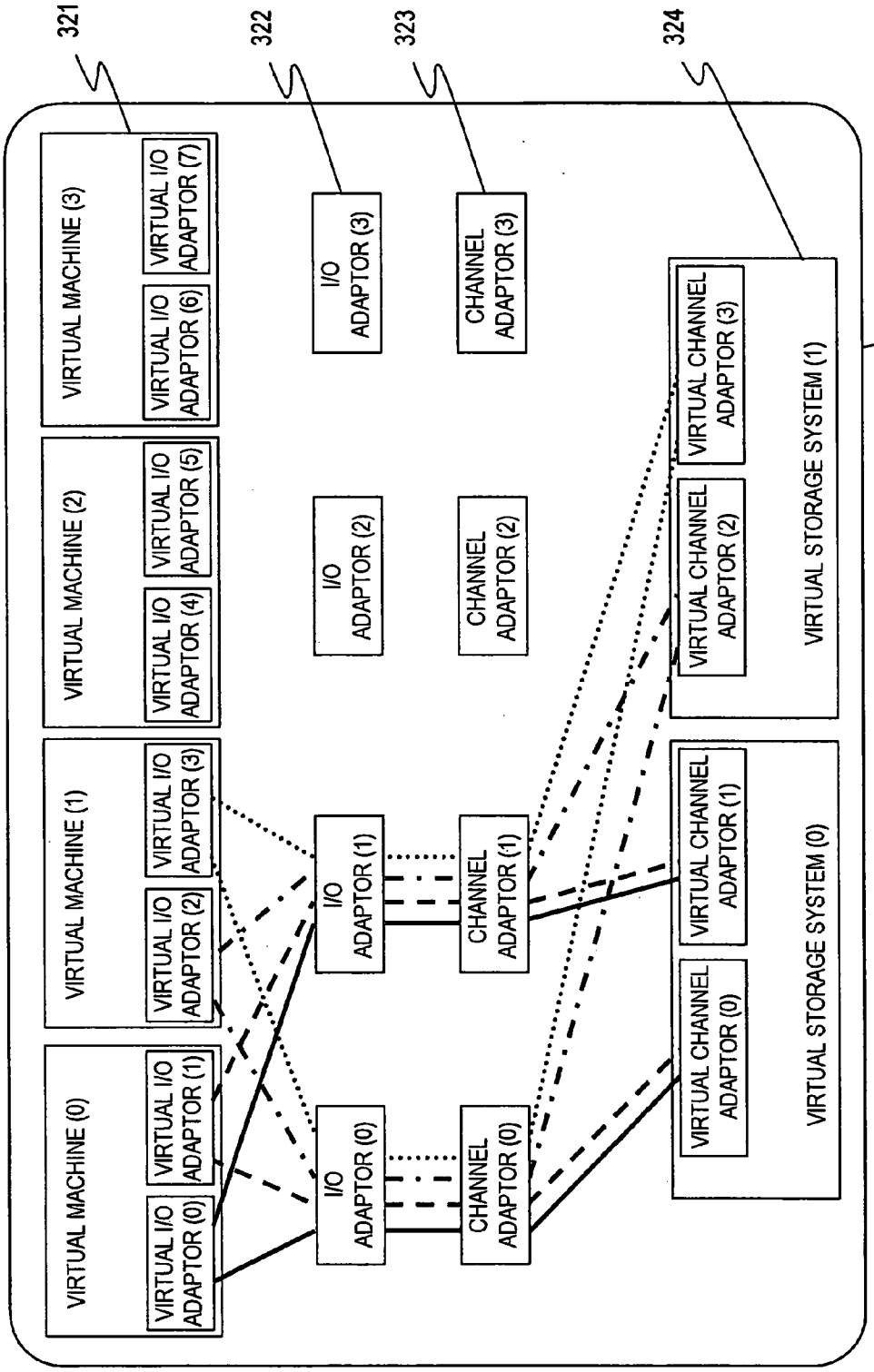

321
322
323
324
320
VIRTUAL MACHINE (3)
VIRTUAL I/O ADAPTOR (6)
VIRTUAL I/O ADAPTOR (7)
VIRTUAL MACHINE (2)
VIRTUAL I/O ADAPTOR (4)
VIRTUAL I/O ADAPTOR (5)
VIRTUAL MACHINE (1)
VIRTUAL I/O ADAPTOR (2)
VIRTUAL I/O ADAPTOR (3)
VIRTUAL MACHINE (0)
VIRTUAL I/O ADAPTOR (0)
VIRTUAL I/O ADAPTOR (1)
I/O ADAPTOR (3)
I/O ADAPTOR (2)
I/O ADAPTOR (1)
I/O ADAPTOR (0)
CHANNEL ADAPTOR (3)
CHANNEL ADAPTOR (2)
CHANNEL ADAPTOR (1)
CHANNEL ADAPTOR (0)
VIRTUAL CHANNEL ADAPTOR (3)
VIRTUAL CHANNEL ADAPTOR (2)
VIRTUAL CHANNEL ADAPTOR (1)
VIRTUAL CHANNEL ADAPTOR (0)
VIRTUAL STORAGE SYSTEM (1)
VIRTUAL STORAGE SYSTEM (0)

FIG.18

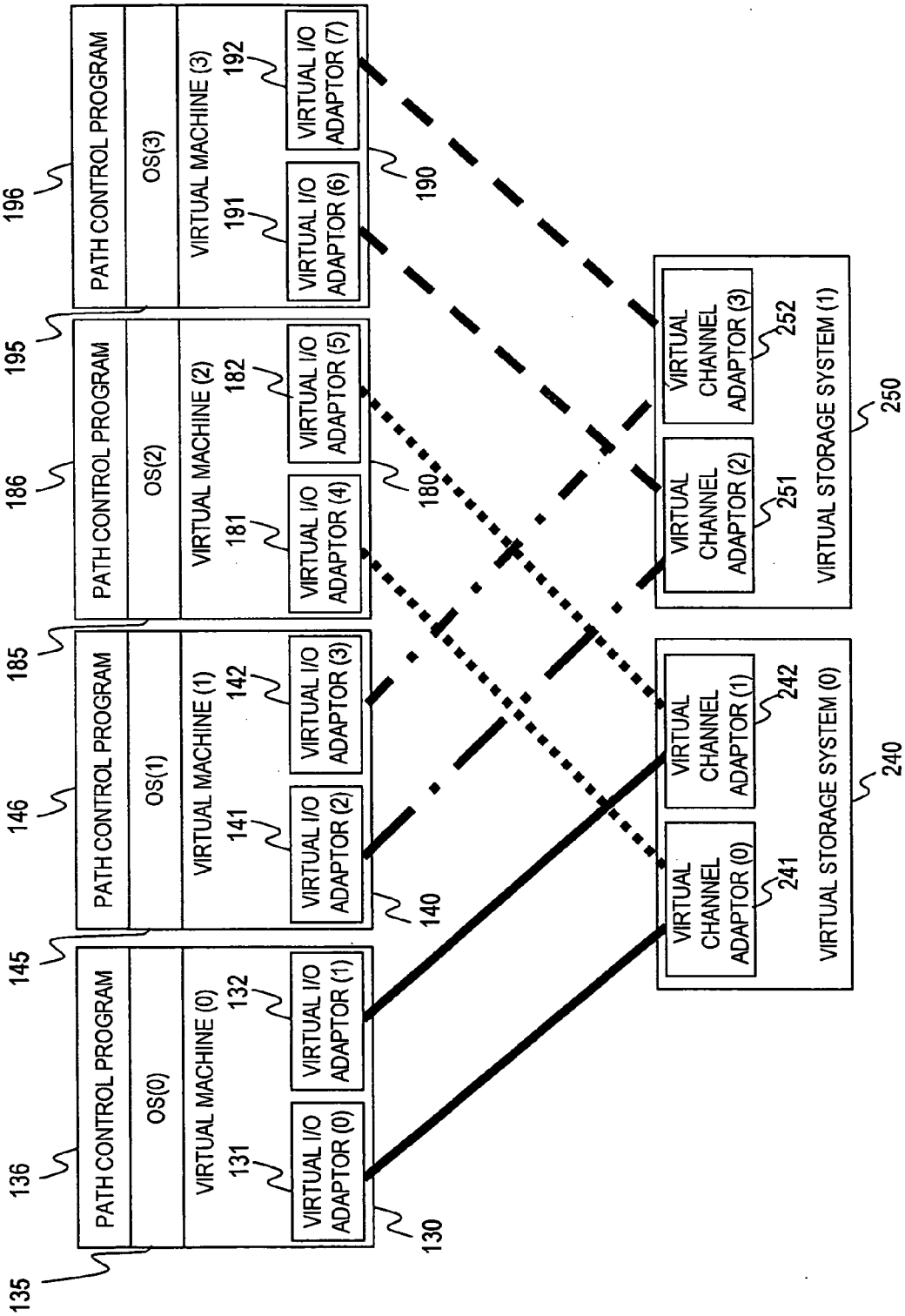

135
136
PATH CONTROL PROGRAM
OS(0)
VIRTUAL MACHINE (0)
131
VIRTUAL I/O ADAPTOR (0)
132
VIRTUAL I/O ADAPTOR (1)
130
145
146
PATH CONTROL PROGRAM
OS(1)
VIRTUAL MACHINE (1)
141
VIRTUAL I/O ADAPTOR (2)
142
VIRTUAL I/O ADAPTOR (3)
140
185
186
PATH CONTROL PROGRAM
OS(2)
VIRTUAL MACHINE (2)
181
VIRTUAL I/O ADAPTOR (4)
182
VIRTUAL I/O ADAPTOR (5)
180
195
196
PATH CONTROL PROGRAM
OS(3)
VIRTUAL MACHINE (3)
191
VIRTUAL I/O ADAPTOR (6)
192
VIRTUAL I/O ADAPTOR (7)
190
VIRTUAL STORAGE SYSTEM (0)
240
VIRTUAL CHANNEL ADAPTOR (0)
241
VIRTUAL CHANNEL ADAPTOR (1)
242
VIRTUAL STORAGE SYSTEM (1)
250
VIRTUAL CHANNEL ADAPTOR (2)
251
VIRTUAL CHANNEL ADAPTOR (3)
252

FIG.19

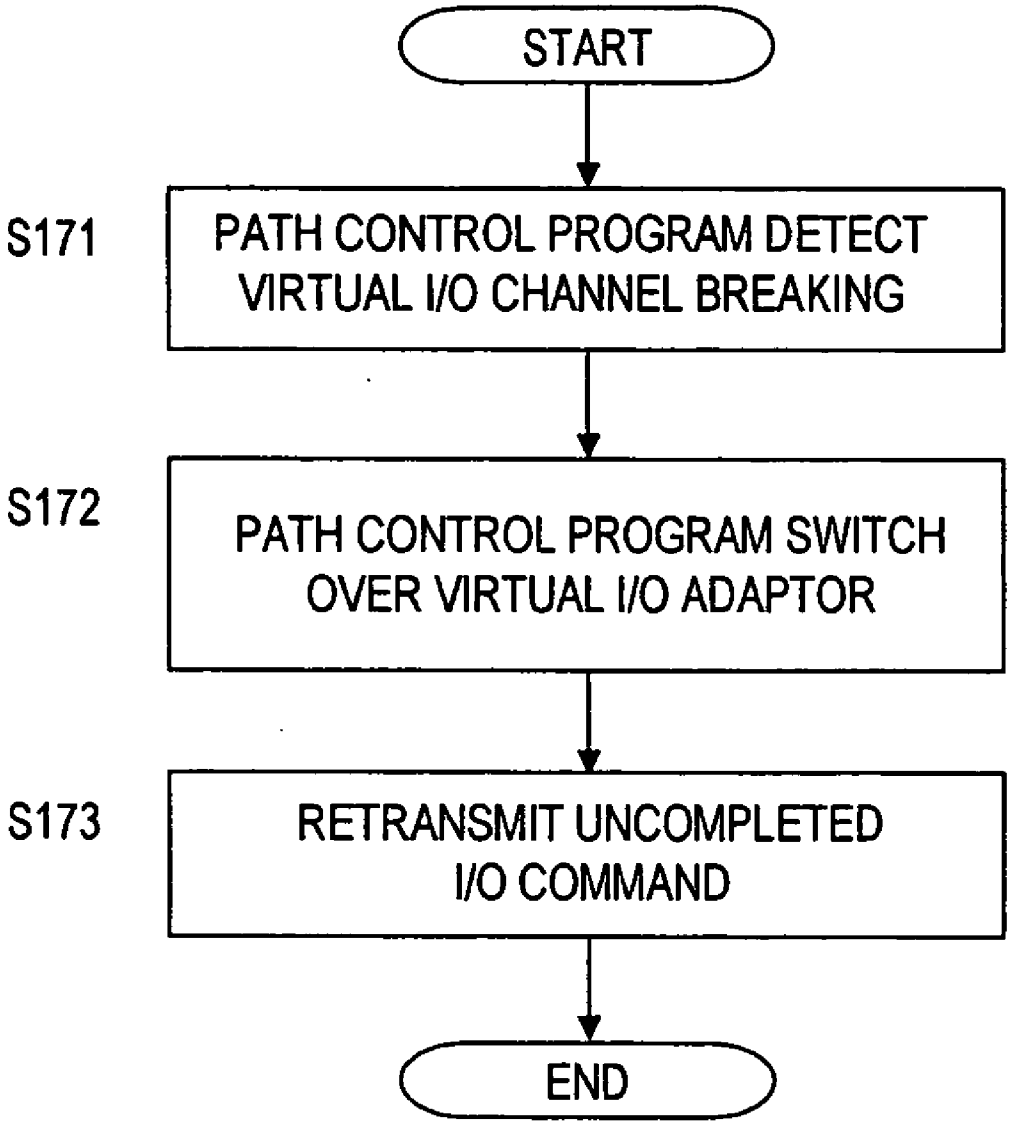

START
S171
PATH CONTROL PROGRAM DETECT VIRTUAL I/O CHANNEL BREAKING
S172
PATH CONTROL PROGRAM SWITCH OVER VIRTUAL I/O ADAPTOR
S173
RETRANSMIT UNCOMPLETED I/O COMMAND
END

FIG.20

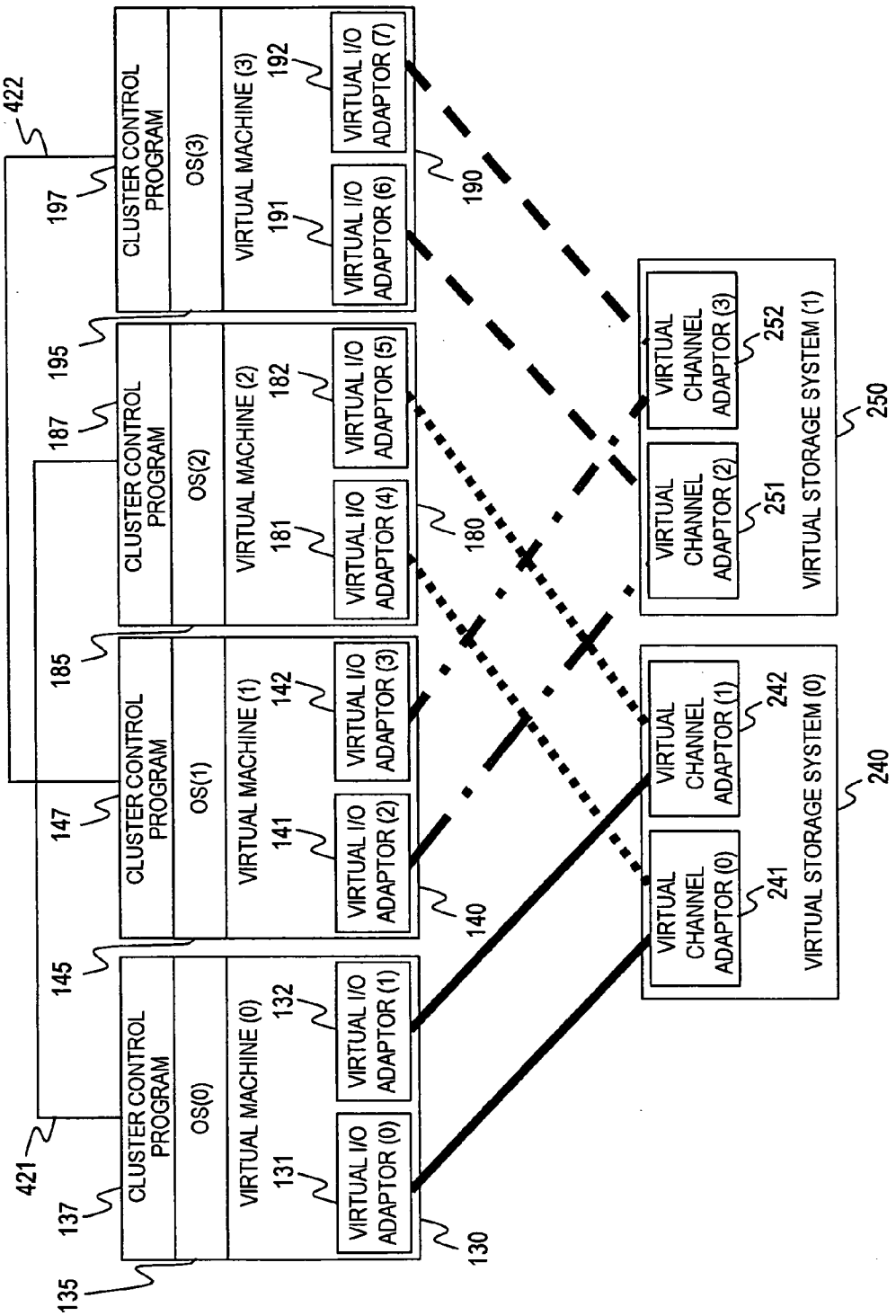

CLUSTER CONTROL PROGRAM
OS(0)
VIRTUAL MACHINE (0)
131
VIRTUAL I/O ADAPTOR (0)
132
VIRTUAL I/O ADAPTOR (1)
CLUSTER CONTROL PROGRAM
OS(1)
VIRTUAL MACHINE (1)
141
VIRTUAL I/O ADAPTOR (2)
142
VIRTUAL I/O ADAPTOR (3)
CLUSTER CONTROL PROGRAM
OS(2)
VIRTUAL MACHINE (2)
181
VIRTUAL I/O ADAPTOR (4)
182
VIRTUAL I/O ADAPTOR (5)
CLUSTER CONTROL PROGRAM
OS(3)
VIRTUAL MACHINE (3)
191
VIRTUAL I/O ADAPTOR (6)
192
VIRTUAL I/O ADAPTOR (7)
VIRTUAL CHANNEL ADAPTOR (0)
241
VIRTUAL CHANNEL ADAPTOR (1)
242
VIRTUAL STORAGE SYSTEM (0)
240
VIRTUAL CHANNEL ADAPTOR (2)
251
VIRTUAL CHANNEL ADAPTOR (3)
252
VIRTUAL STORAGE SYSTEM (1)
250
130
135
137
140
145
147
180
185
187
190
195
197
421
422

FIG.21

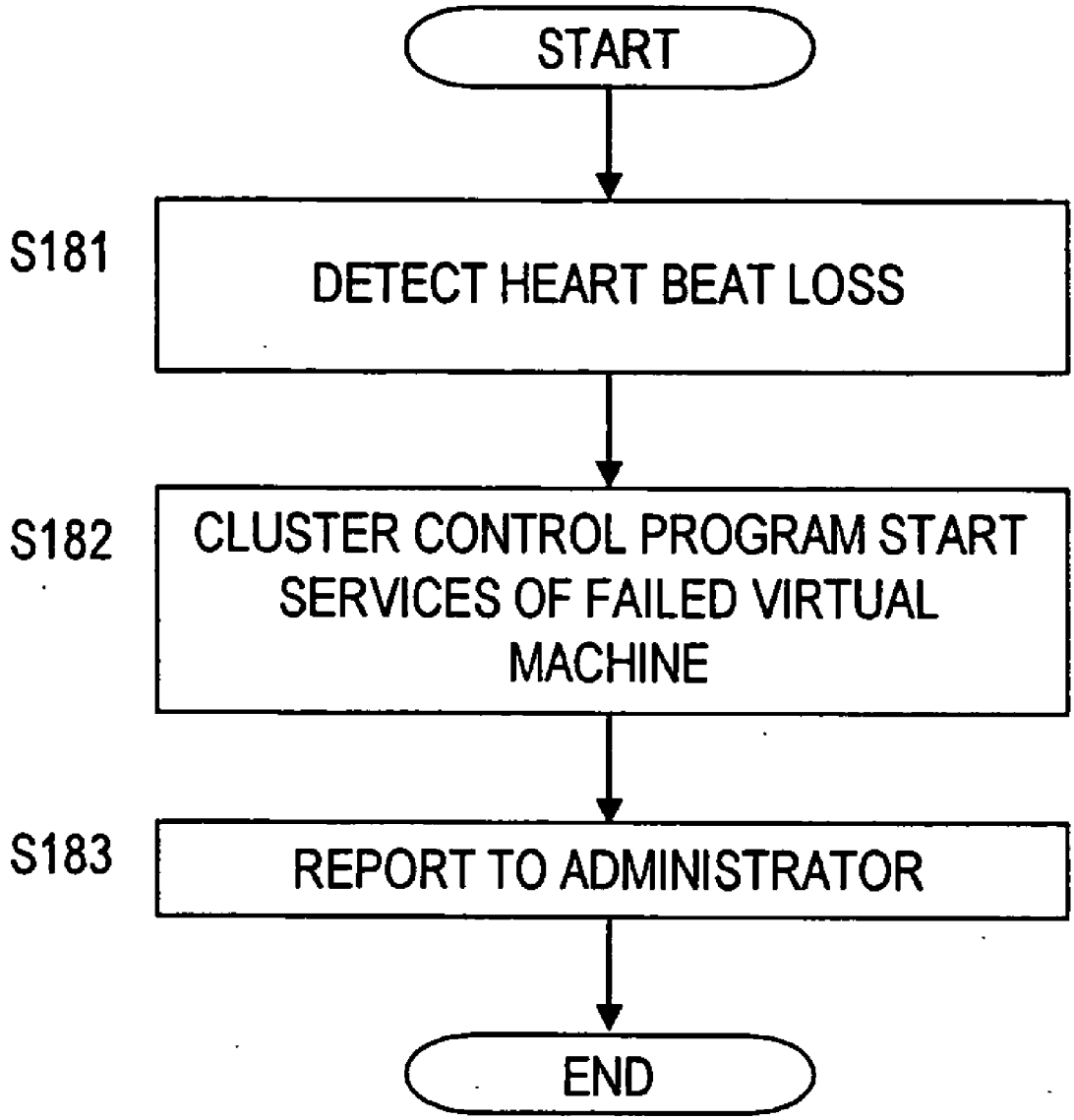

START
S181
DETECT HEART BEAT LOSS
S182
CLUSTER CONTROL PROGRAM START SERVICES OF FAILED VIRTUAL MACHINE
S183
REPORT TO ADMINISTRATOR
END

FIG.22

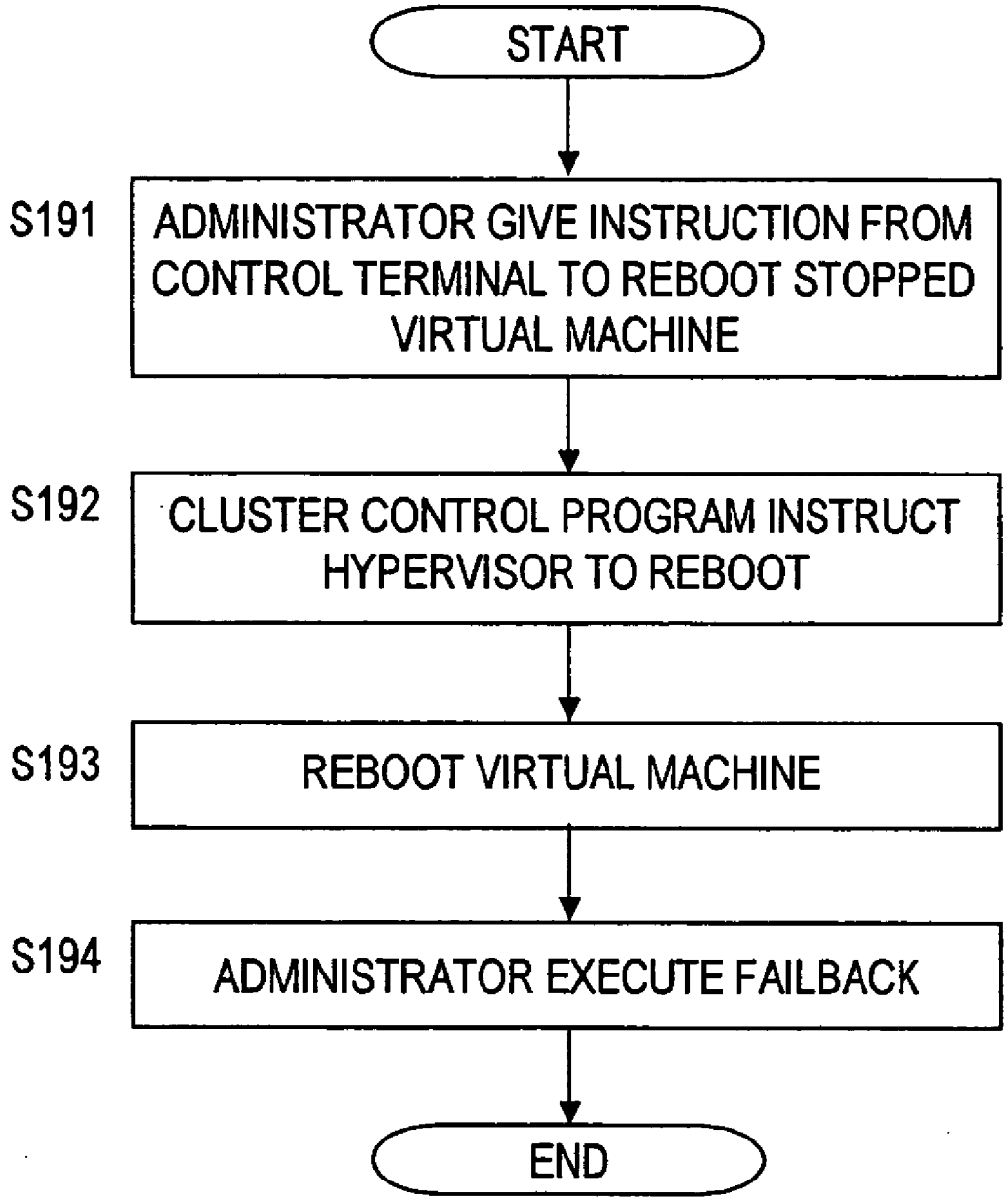

START
S191
ADMINISTRATOR GIVE INSTRUCTION FROM CONTROL TERMINAL TO REBOOT STOPPED VIRTUAL MACHINE
S192
CLUSTER CONTROL PROGRAM INSTRUCT HYPERVISOR TO REBOOT
S193
REBOOT VIRTUAL MACHINE
S194
ADMINISTRATOR EXECUTE FAILBACK
END

FIG.23

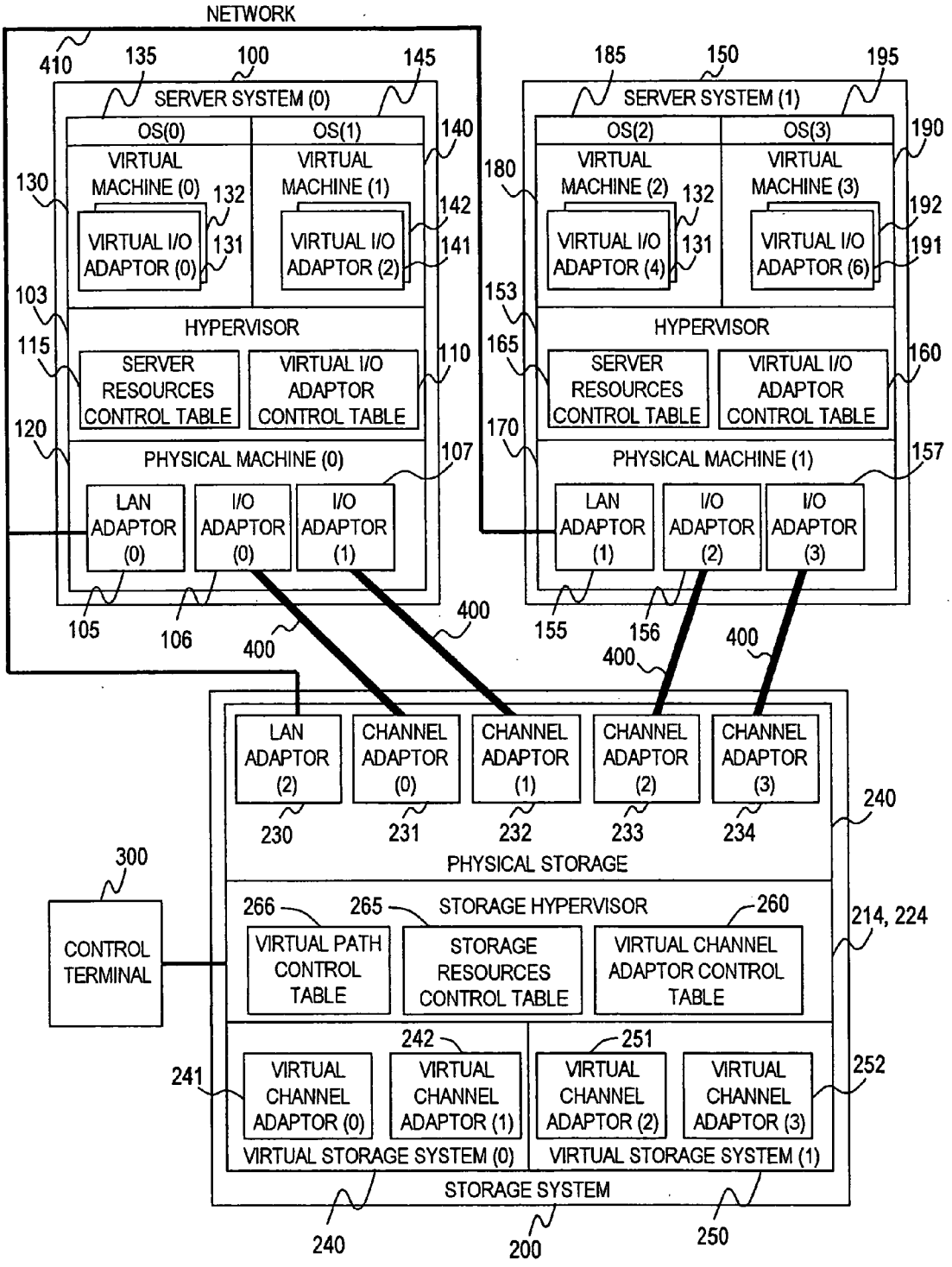

NETWORK
410
135
100
145
SERVER SYSTEM (0)
OS(0)
OS(1)
140
VIRTUAL MACHINE (0)
VIRTUAL MACHINE (1)
130
132
VIRTUAL I/O ADAPTOR (0)
131
VIRTUAL I/O ADAPTOR (2)
142
141
103
HYPERVISOR
115
SERVER RESOURCES CONTROL TABLE
VIRTUAL I/O ADAPTOR CONTROL TABLE
110
120
PHYSICAL MACHINE (0)
107
LAN ADAPTOR (0)
I/O ADAPTOR (0)
I/O ADAPTOR (1)
105
106
400
185
150
195
SERVER SYSTEM (1)
OS(2)
OS(3)
190
180
VIRTUAL MACHINE (2)
VIRTUAL MACHINE (3)
132
VIRTUAL I/O ADAPTOR (4)
131
VIRTUAL I/O ADAPTOR (6)
192
191
153
HYPERVISOR
165
SERVER RESOURCES CONTROL TABLE
VIRTUAL I/O ADAPTOR CONTROL TABLE
160
170
PHYSICAL MACHINE (1)
157
LAN ADAPTOR (1)
I/O ADAPTOR (2)
I/O ADAPTOR (3)
155
156
400
LAN ADAPTOR (2)
CHANNEL ADAPTOR (0)
CHANNEL ADAPTOR (1)
CHANNEL ADAPTOR (2)
CHANNEL ADAPTOR (3)
230
231
232
233
234
240
PHYSICAL STORAGE
300
CONTROL TERMINAL
266
265
STORAGE HYPERVISOR
260
214, 224
VIRTUAL PATH CONTROL TABLE
STORAGE RESOURCES CONTROL TABLE
VIRTUAL CHANNEL ADAPTOR CONTROL TABLE
242
251
241
VIRTUAL CHANNEL ADAPTOR (0)
VIRTUAL CHANNEL ADAPTOR (1)
VIRTUAL CHANNEL ADAPTOR (2)
VIRTUAL CHANNEL ADAPTOR (3)
252
VIRTUAL STORAGE SYSTEM (0)
VIRTUAL STORAGE SYSTEM (1)
STORAGE SYSTEM
240
200
250

FIG.24

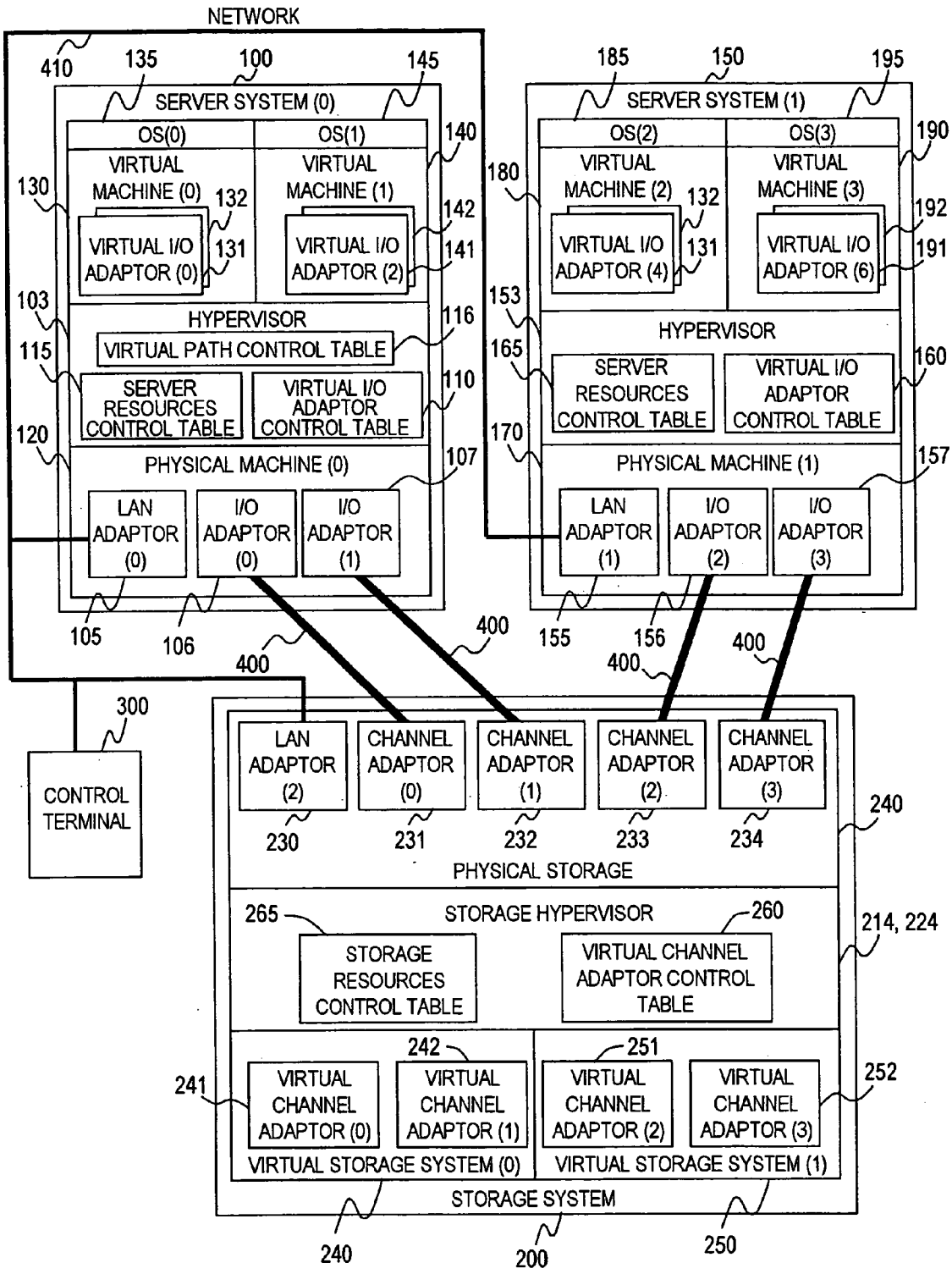

NETWORK
410
135
100
145
SERVER SYSTEM (0)
OS(0)
OS(1)
140
VIRTUAL MACHINE (0)
132
VIRTUAL MACHINE (1)
130
142
VIRTUAL I/O ADAPTOR (0)
131
VIRTUAL I/O ADAPTOR (2)
141
103
HYPERVISOR
116
115
VIRTUAL PATH CONTROL TABLE
SERVER RESOURCES CONTROL TABLE
VIRTUAL I/O ADAPTOR CONTROL TABLE
110
120
PHYSICAL MACHINE (0)
107
LAN ADAPTOR (0)
I/O ADAPTOR (0)
I/O ADAPTOR (1)
105
106
185
150
195
SERVER SYSTEM (1)
OS(2)
OS(3)
190
180
VIRTUAL MACHINE (2)
132
VIRTUAL MACHINE (3)
192
VIRTUAL I/O ADAPTOR (4)
131
VIRTUAL I/O ADAPTOR (6)
191
153
HYPERVISOR
165
160
SERVER RESOURCES CONTROL TABLE
VIRTUAL I/O ADAPTOR CONTROL TABLE
170
PHYSICAL MACHINE (1)
157
LAN ADAPTOR (1)
I/O ADAPTOR (2)
I/O ADAPTOR (3)
155
156
400
400
400
400
300
CONTROL TERMINAL
LAN ADAPTOR (2)
CHANNEL ADAPTOR (0)
CHANNEL ADAPTOR (1)
CHANNEL ADAPTOR (2)
CHANNEL ADAPTOR (3)
230
231
232
233
234
240
PHYSICAL STORAGE
265
STORAGE HYPERVISOR
260
214, 224
STORAGE RESOURCES CONTROL TABLE
VIRTUAL CHANNEL ADAPTOR CONTROL TABLE
242
251
241
VIRTUAL CHANNEL ADAPTOR (0)
VIRTUAL CHANNEL ADAPTOR (1)
VIRTUAL CHANNEL ADAPTOR (2)
VIRTUAL CHANNEL ADAPTOR (3)
252
VIRTUAL STORAGE SYSTEM (0)
VIRTUAL STORAGE SYSTEM (1)
STORAGE SYSTEM
240
200
250

FIG.25

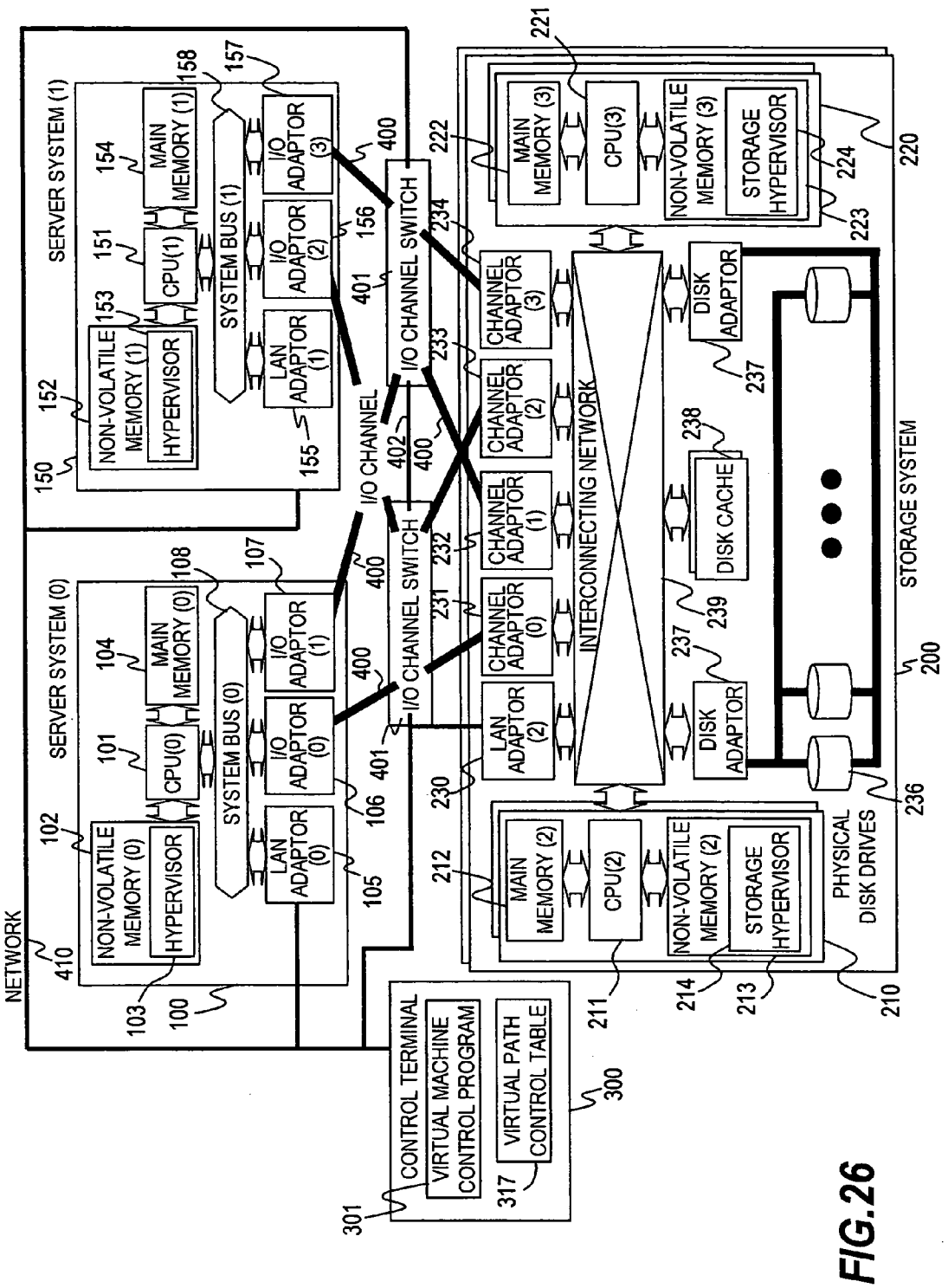
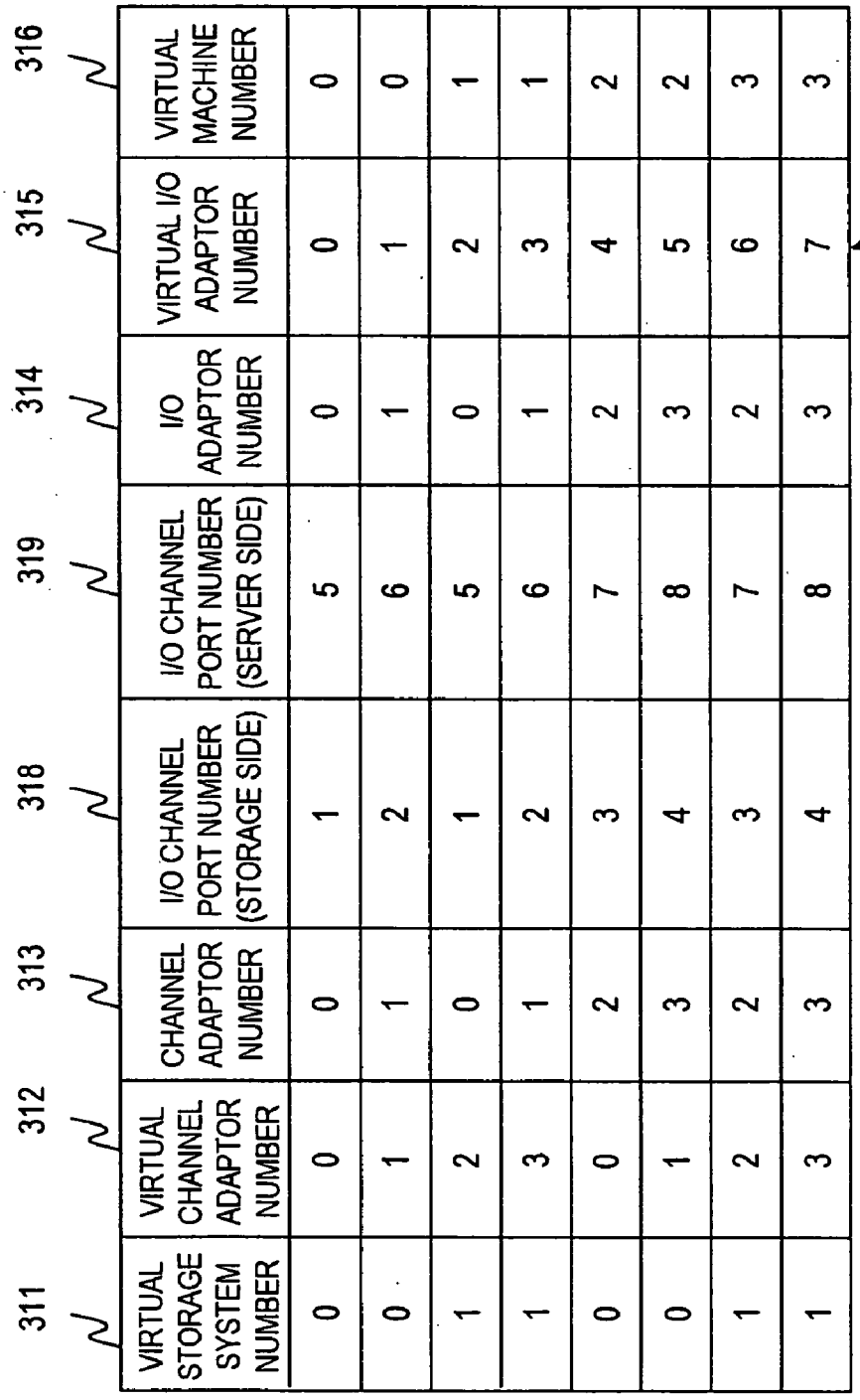

NETWORK
SERVER SYSTEM (0)
SERVER SYSTEM (1)
NON-VOLATILE MEMORY (0)
HYPERVISOR
CPU(0)
MAIN MEMORY (0)
SYSTEM BUS (0)
LAN ADAPTOR (0)
I/O ADAPTOR (0)
I/O ADAPTOR (1)
NON-VOLATILE MEMORY (1)
CPU(1)
MAIN MEMORY (1)
SYSTEM BUS (1)
LAN ADAPTOR (1)
I/O ADAPTOR (2)
I/O ADAPTOR (3)
I/O CHANNEL
I/O CHANNEL SWITCH
I/O CHANNEL SWITCH
LAN ADAPTOR (2)
CHANNEL ADAPTOR (0)
CHANNEL ADAPTOR (1)
CHANNEL ADAPTOR (2)
CHANNEL ADAPTOR (3)
INTERCONNECTING NETWORK
DISK ADAPTOR
DISK ADAPTOR
DISK CACHE
MAIN MEMORY (2)
CPU(2)
NON-VOLATILE MEMORY (2)
STORAGE HYPERVISOR
MAIN MEMORY (3)
CPU(3)
NON-VOLATILE MEMORY (3)
STORAGE HYPERVISOR
PHYSICAL DISK DRIVES
STORAGE SYSTEM
CONTROL TERMINAL
VIRTUAL MACHINE CONTROL PROGRAM
VIRTUAL PATH CONTROL TABLE
100
101
102
103
104
105
106
107
108
150
151
152
153
154
155
156
157
158
200
210
211
212
213
214
220
221
222
223
224
230
231
232
233
234
236
237
238
239
300
301
317
400
401
402
410

FIG.26



311 VIRTUAL STORAGE SYSTEM NUMBER	312 VIRTUAL CHANNEL ADAPTOR NUMBER	313 CHANNEL ADAPTOR NUMBER	318 I/O CHANNEL PORT NUMBER (STORAGE SIDE)	319 I/O CHANNEL PORT NUMBER (SERVER SIDE)	314 I/O ADAPTOR NUMBER	315 VIRTUAL I/O ADAPTOR NUMBER	316 VIRTUAL MACHINE NUMBER
0	0	0	1	5	0	0	0
0	1	1	2	6	1	1	0
1	2	0	1	5	0	2	1
1	3	1	2	6	1	3	1
0	0	2	3	7	2	4	2
0	1	3	4	8	3	5	2
1	2	2	3	7	2	6	3
1	3	3	4	8	3	7	3

317

VIRTUAL PATH CONTROL TABLE

FIG.27

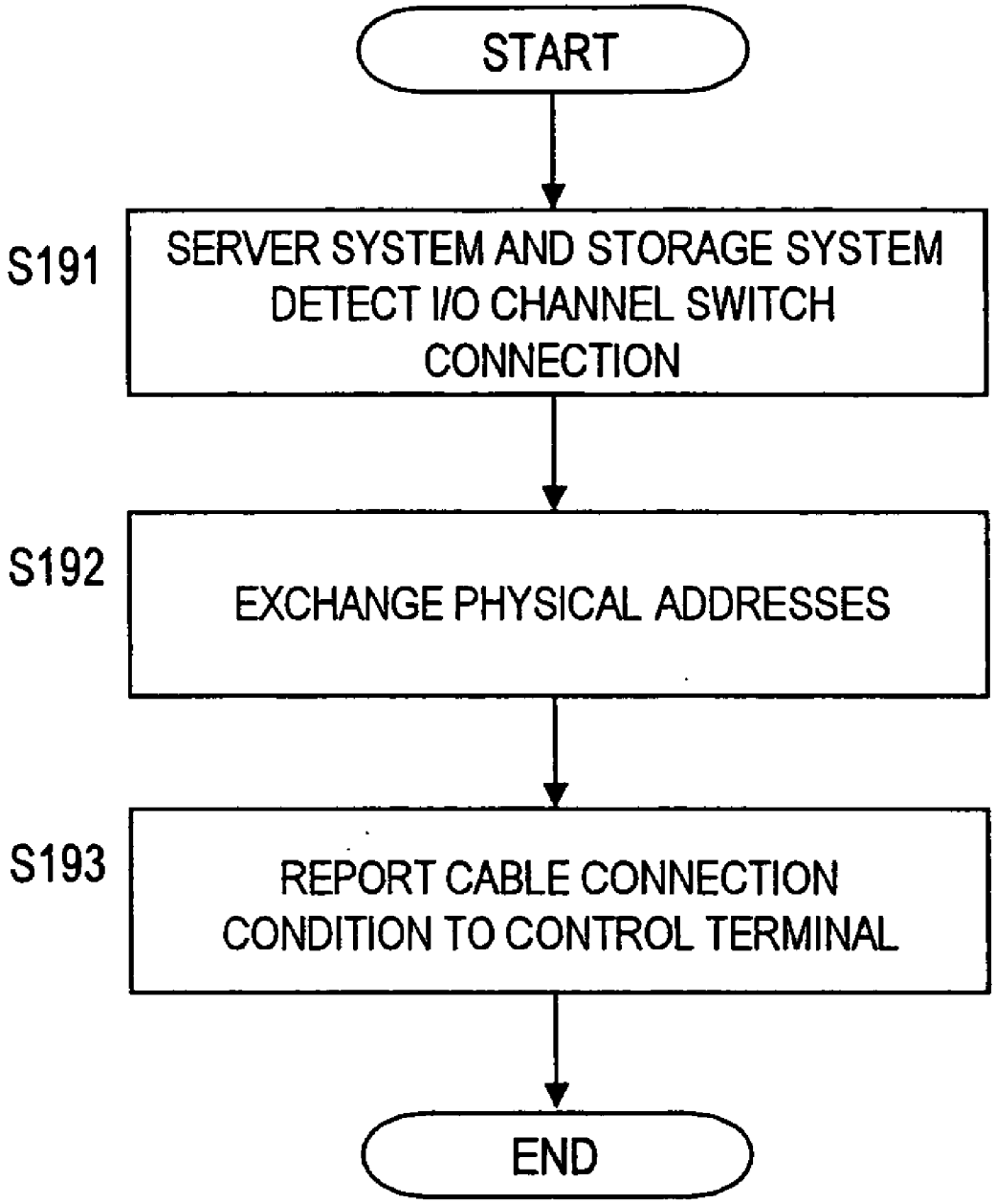

START
S191
SERVER SYSTEM AND STORAGE SYSTEM DETECT I/O CHANNEL SWITCH CONNECTION
S192
EXCHANGE PHYSICAL ADDRESSES
S193
REPORT CABLE CONNECTION CONDITION TO CONTROL TERMINAL
END

FIG.28

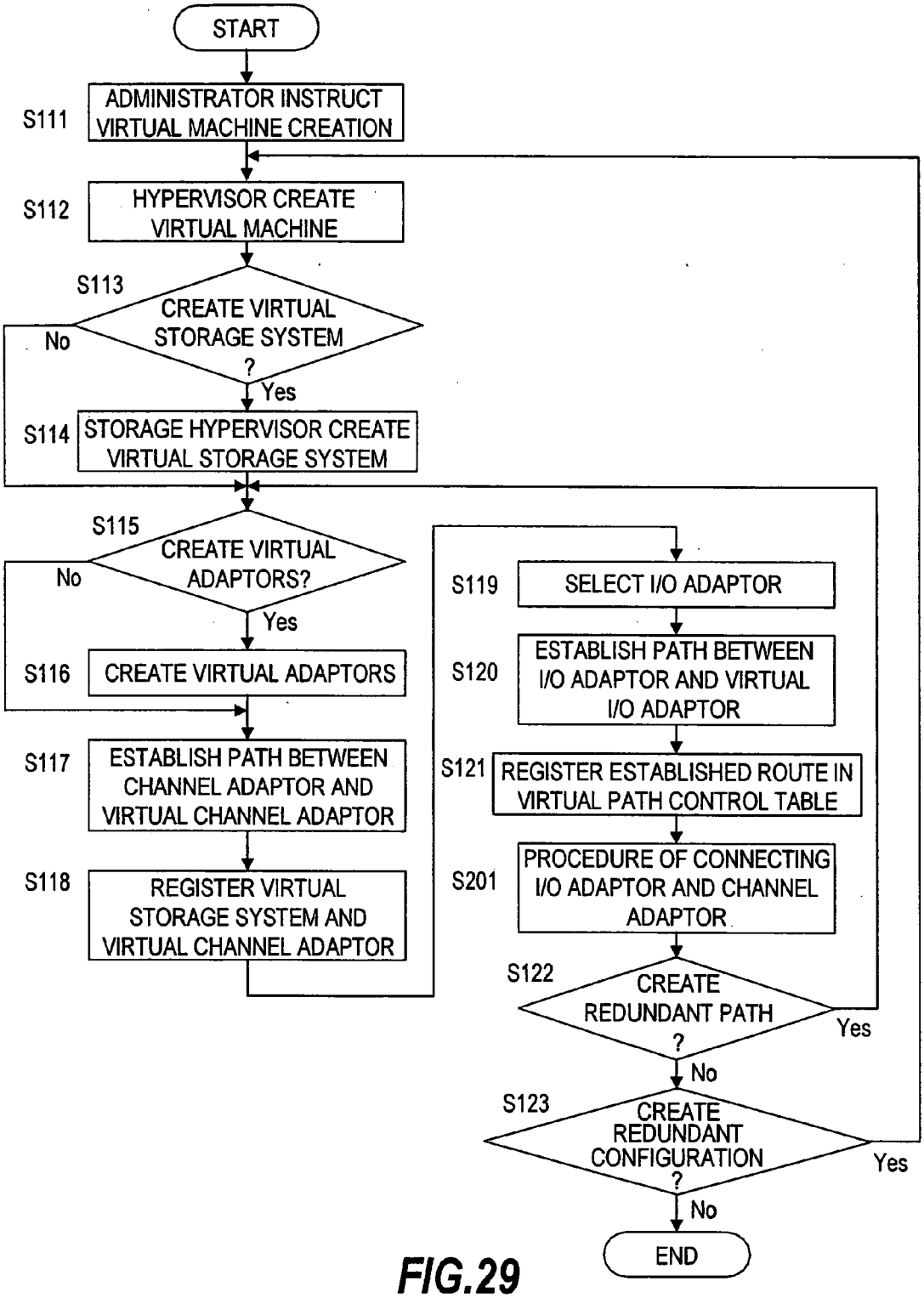

START
S111
ADMINISTRATOR INSTRUCT VIRTUAL MACHINE CREATION
S112
HYPERVISOR CREATE VIRTUAL MACHINE
S113
CREATE VIRTUAL STORAGE SYSTEM ?
No
Yes
S114
STORAGE HYPERVISOR CREATE VIRTUAL STORAGE SYSTEM
S115
CREATE VIRTUAL ADAPTORS?
No
Yes
S116
CREATE VIRTUAL ADAPTORS
S117
ESTABLISH PATH BETWEEN CHANNEL ADAPTOR AND VIRTUAL CHANNEL ADAPTOR
S118
REGISTER VIRTUAL STORAGE SYSTEM AND VIRTUAL CHANNEL ADAPTOR
S119
SELECT I/O ADAPTOR
S120
ESTABLISH PATH BETWEEN I/O ADAPTOR AND VIRTUAL I/O ADAPTOR
S121
REGISTER ESTABLISHED ROUTE IN VIRTUAL PATH CONTROL TABLE
S201
PROCEDURE OF CONNECTING I/O ADAPTOR AND CHANNEL ADAPTOR
S122
CREATE REDUNDANT PATH ?
Yes
No
S123
CREATE REDUNDANT CONFIGURATION ?
Yes
No
END

FIG.29

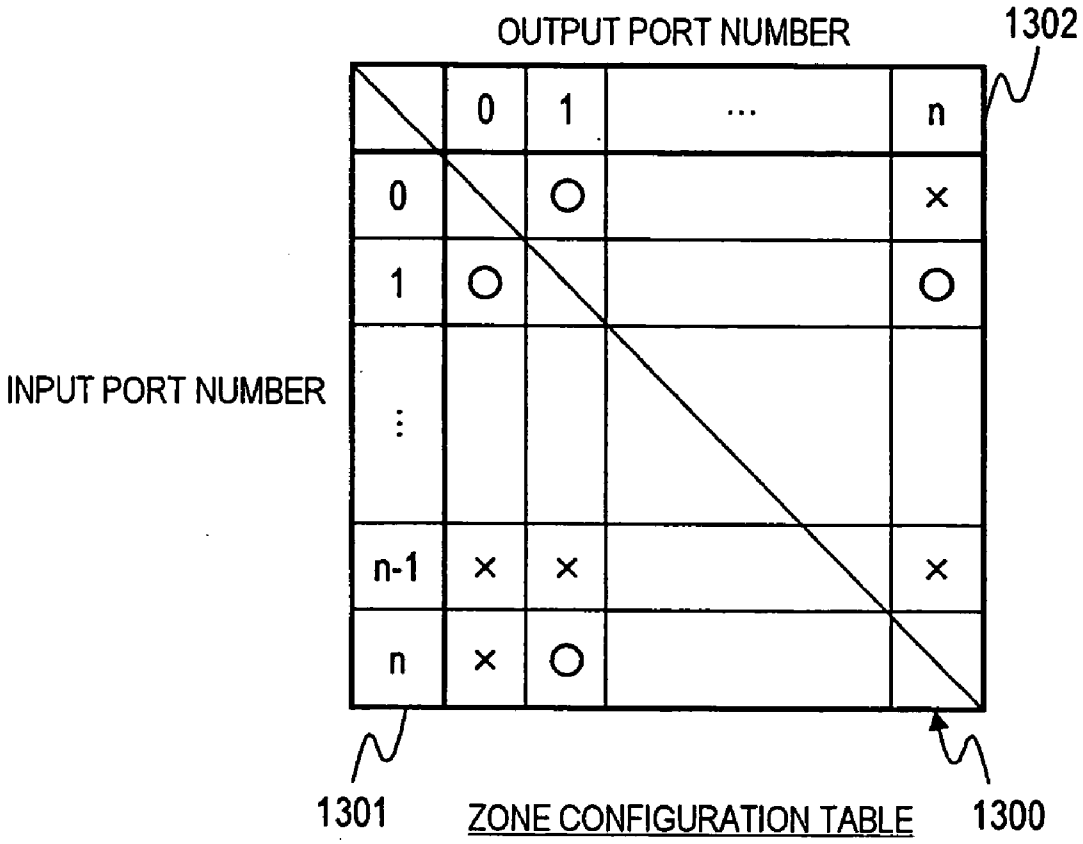

OUTPUT PORT NUMBER
1302
INPUT PORT NUMBER
0
1
...
n
n-1
1301
ZONE CONFIGURATION TABLE
1300

FIG.30

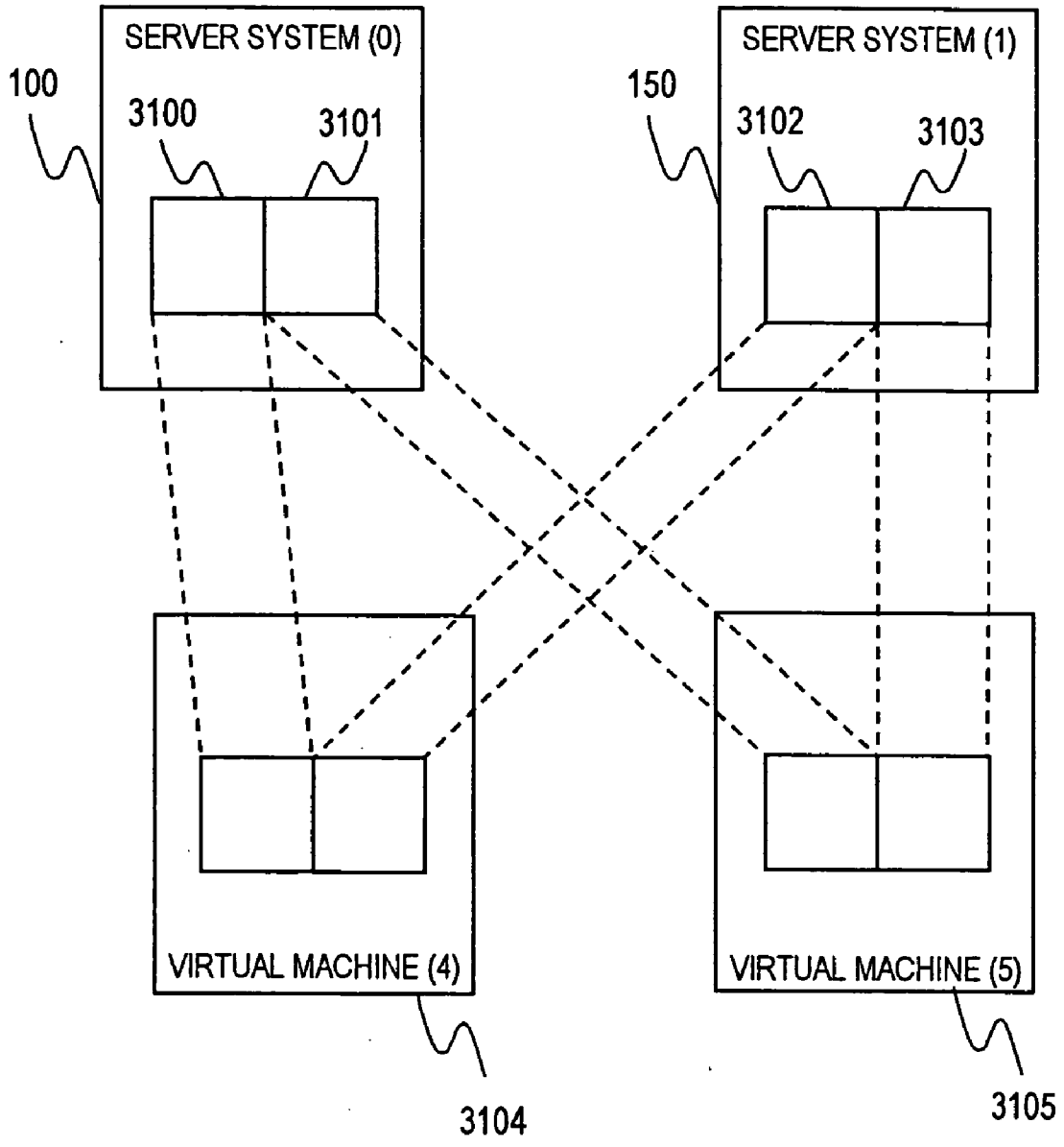

SERVER SYSTEM (0)
100
3100
3101
SERVER SYSTEM (1)
150
3102
3103
VIRTUAL MACHINE (4)
VIRTUAL MACHINE (5)
3104
3105

FIG.31

COMPUTER SYSTEM, COMPUTER, STORAGE SYSTEM, AND CONTROL TERMINAL

CLAIM OF PRIORITY

[0001] The present application claims priority from Japanese patent application P2005-20908 filed on Jan. 28, 2005, the content of which is hereby incorporated by reference into this application.

BACKGROUND

[0002] This invention relates to a computer system, and more particularly to a technique of logically partitioning a computer system including a storage system.

[0003] One approach to improving the performance of an information processing system is to increase the number of computers in an information processing system. However, the use of many computers in a system poses the following problem: it necessitates a troublesome task of controlling individual computers, requires a larger footprint for the computers and consumes more electric power.

[0004] As a solution to this problem, technology which logically partitions resources of a computer with a large processing capacity (LPAR: Logical Partitioning) and makes it possible to use resulting logical partitions as independent virtual machines has been proposed. This logical partitioning technology can make one computer look like a plurality of virtual machines. When allocation of resources (processor, memory, etc.) to partitions is controlled, the performance of each virtual machine is assured.

[0005] With this technology, different operating systems can be freely installed in virtual machines and each virtual machine can be turned on and off independently. Also faults in a virtual machine can not propagate to other virtual machines and the failed virtual machine can recover from the faults independently. Thus the computer with logical partitioning technology has greater flexibility than that of computer which does not have the technology.

[0006] In addition, the user can consolidate physical machines into fewer physical machines. As a consequence the user benefits from the logical partitioning technology in terms of system management, footprint, and power consumption. This kind of logical partitioning technology is disclosed, for example, in JP 2003-157177 A.

[0007] Also, US 2003-0055933 discloses a technique of accessing a storage system from a logically partitioned virtual machine.

[0008] Also, a storage system logically partitioned by applying a technique of logically partitioning computers is proposed in IBM, "The IBM TotalStorage DS8000 Series: Concepts and Architecture", [online], Internet <URL: http://www.redbooks.ibm.com/redpieces/pdfs/sg246452.pdf>.

SUMMARY

[0009] A technique for preventing system down to improve computer system reliability is also proposed. For this purpose, techniques like clustering, multiplexing, automatic backup, hot swapping, etc. are used to realize high-availability computer systems.

[0010] With conventional techniques of logically partitioning computers, resources in a computer, such as processors and memory, are logically partitioned and allocated to individual virtual machines. Similarly, conventional techniques of logically partitioning storage systems logically partition resources in a storage system, such as cache memory and disk drives, and allocate the partitioned resources to individual virtual storage systems.

[0011] However, with these conventional techniques, the virtualization engine on the server side and the virtualization engine on the storage side do not cooperate with each other.

[0012] Furthermore, virtual paths established between virtual machines and virtual storage systems do not always correspond to physical paths. This requires that the administrator constantly check the relations between the virtual paths and physical paths in making settings of the server and storage systems. In particular, with computer systems having high availability, server and storage systems are so complicatedly related that making settings of the server and storage systems while checking their relations requires advanced skills.

[0013] In other words, with conventional techniques, no information about routing between virtual machines and virtual storage systems exists, because the server-side virtualization engine and the storage-side virtualization engine do not cooperate with each other. This raises a problem in that realizing high availability requires referring to configuration information on both of the server side and the storage side.

[0014] It is therefore an object of this invention to manage physical paths between a server system and a storage system and information about routing between virtual machines and virtual storage systems in an integrated fashion.

[0015] According to an embodiment of this invention, there is provided a computer system including a computer and a storage system that stores data, the computer including a first control unit that logically partitions a first resource provided in the computer to create and run an independent virtual machine; and first information for managing the first resource, and the storage system including a second control unit that logically partitions a second resource provided in the storage system to create and run an independent virtual storage system; and second information for managing the second resource provided in the storage system, in which a relation between the virtual machine and the virtual storage system is defined based on the first information and the second information.

[0016] According to the embodiment of this invention, it is possible to easily realize a high-availability configuration of a computer system including virtual machines and virtual storage systems.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The present invention can be appreciated by the description which follows in conjunction with the following figures, wherein:

[0018] **FIG. 1** is a block diagram showing a hardware configuration of a computer system according to a first embodiment of this invention;

[0019] **FIG. 2** is a functional block diagram of the computer system according to the first embodiment;

[0020] **FIG. 3A** is a diagram illustrating a virtual I/O adaptor control table of a server system (**0**) according to the first embodiment;

[0021] **FIG. 3B** is a diagram illustrating a virtual I/O adaptor control table of a server system (**1**) according to the first embodiment;

[0022] **FIG. 4** is a diagram illustrating a virtual channel adaptor control table according to the first embodiment;

[0023] **FIG. 5** is a diagram illustrating a virtual path control table according to the first embodiment;

[0024] **FIG. 6** is a diagram illustrating a server resources control table according to embodiments of this invention;

[0025] **FIG. 7** is a diagram illustrating a storage resources control table according to embodiments of this invention;

[0026] **FIG. 8** is a diagram illustrating connections in the computer system according to the first embodiment;

[0027] **FIG. 9** is a flowchart of a cable connection process according to the first embodiment;

[0028] **FIG. 10** is a flowchart of a virtual machine creation process according to the first embodiment;

[0029] **FIG. 11** is a diagram illustrating the structure of I/O channel communication protocol layers according to the first embodiment;

[0030] **FIG. 12** is a diagram illustrating information transmitted between the server systems and the storage system according to the first embodiment;

[0031] **FIG. 13** is a diagram illustrating the contents of a hypervisor communication header according to the first embodiment;

[0032] **FIG. 14** is a flowchart of a disk I/O command transmission process according to the first embodiment;

[0033] **FIG. 15** is a flowchart of a disk I/O command completion notification process according to the first embodiment;

[0034] **FIG. 16** is a flowchart of a fault handling process according to the first embodiment;

[0035] **FIG. 17** is a flowchart of a fault handling process according to the first embodiment;

[0036] **FIG. 18** is a diagram illustrating a screen displayed on a control terminal according to the first embodiment;

[0037] **FIG. 19** is a diagram illustrating connections in a computer system according to a second embodiment of this invention;

[0038] **FIG. 20** is a flowchart of a fault handling process according to the second embodiment;

[0039] **FIG. 21** is a diagram illustrating connections in a computer system according to a third embodiment of this invention;

[0040] **FIG. 22** is a flowchart of a fault handling process according to the third embodiment;

[0041] **FIG. 23** is a flowchart of a virtual machine rebooting process according to the third embodiment;

[0042] **FIG. 24** is a functional block diagram showing a computer system according to a fourth embodiment of this invention;

[0043] **FIG. 25** is a functional block diagram showing a computer system according to a fifth embodiment of this invention;

[0044] **FIG. 26** is a block diagram showing a hardware configuration of a computer system according to a sixth embodiment of this invention;

[0045] **FIG. 27** is a diagram illustrating a virtual path control table according to the sixth embodiment;

[0046] **FIG. 28** is a flowchart of a cable connection process in the computer system according to the sixth embodiment;

[0047] **FIG. 29** is a flowchart of a virtual machine creation process in the computer system according to the sixth embodiment:

[0048] **FIG. 30** is a diagram showing a configuration of a zone configuration table according to the sixth embodiment; and

[0049] **FIG. 31** is a diagram showing another configuration of implementation of virtual machines according to the embodiments.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0050] Embodiments of this invention will be described below referring to the drawings.

First Embodiment

[0051] **FIG. 1** is a block diagram showing a hardware configuration of a computer system according to a first embodiment.

[0052] The computer system of the first embodiment includes a server system (**0**) **100**, a server system (**1**) **150**, a storage system **200**, and a control terminal **300**. Application programs run in the server system (**0**) **100** and the server system (**1**) **150**. The storage system **200** stores data required for operations of the server systems **100** and **150**. The control terminal **300** manages information for controlling the computer system and controls operations of the entire computer system. The numbers enclosed in parentheses following the names of physical resources are identifiers of the physical resources.

[0053] The server system (**0**) **100** is a computer having physical resources including a CPU (**0**) **101**, a non-volatile memory (**0**) **102**, a main memory (**0**) **104**, a LAN adaptor (**0**) **105**, an I/O adaptor (**0**) **106**, an I/O adaptor (**1**) **107**, and a system bus **108**.

[0054] The CPU (**0**) **101** performs arithmetic operations related to an operating system (OS) and application programs executed in the server system (**0**) **100**.

[0055] The main memory (**0**) **104** stores programs and data required for the operations of the CPU (**0**) **101**.

[0056] The system bus (0) **108** connects the CPU (0) **101** and the LAN adaptor (0) **105**, the I/O adaptor **106**, and the I/O adaptor **107** to transfer data and control signals.

[0057] The I/O adaptor (0) **106** and the I/O adaptor (1) **107** are connected with the storage system **200** through I/O channels (e.g., fibre channels) **400**. The I/O adaptors **106** and **107** send data input/output requests and output data to the storage system **200** and receive data stored in the storage system **200**. Two I/O adaptors are provided herein. More I/O adaptors may be provided. The two I/O adaptors **106** and **107** operate independently. Thus, the processing system is duplicated so that access from the server system (0) **100** to the storage system **200** will not be stopped even when one I/O adaptor fails.

[0058] The LAN adaptor (0) **105** is connected with the other server system **150**, the storage system **200**, and the control terminal **300**, through a network **410**. The LAN adaptor (0) **105** sends and receives control signals and control information (the contents of various control tables) to and from the systems connected through the network **410**.

[0059] The non-volatile memory (0) **102** stores a hypervisor **103**. The hypervisor **103**, implemented by the execution of processing by the CPU (0) **101**, is a means that enables logical partitioning of physical resources of the server system (0) **100**.

[0060] The hypervisor **103** is a program which is executed by the CPU**101**. The hypervisor **103** is read from the non-volatile memory **102** by the initial boot program such as BIOS (Basic Input Output System) and loaded into main memory (0) **102** when the power to the server system (0) **100** is turned on. And CPU (0) **101** executes the hypervisor **103** as a program. In other words, the hypervisor **103** is a control program that creates logical partitions in the server system (0) **100** to create virtual machines that operate independently.

[0061] Instead of being loaded after the turning on of the server system (0) **100**, the hypervisor **103** may be implemented by the OS of the server system (0) **100** and a virtualization engine program running on the OS. The virtualization engine program may be stored in the non-volatile memory (0) **102**, or may be stored in the storage system **200**. In this case, the OS is loaded when the power to the server system (0) **100** is turned on and the OS reads and executes the virtualization engine program.

[0062] The specification mostly describes operations chiefly in the software perspective, but, in reality, CPUs execute software to run the hypervisor **103** etc. and storage hypervisor **214** etc.

[0063] Alternatively, the hypervisor **103** may be configured not with software but with hardware. For example, a chip specialized for hypervisor may be provided, or a hypervisor block for controlling virtual machines may be provided in the CPU (0) **101**.

[0064] The server system (1) **150** is configured the same as the server system (0) **100** described so far and so its configuration is not described here.

[0065] The storage system **200** has a storage control block **210** including a CPU (2) **211**, a main memory (2) **212**, and a non-volatile memory (2) **213**. The storage system **200** also has a storage control block **220** including a CPU (3) **221**, a main memory (3) **222**, and a non-volatile memory (3) **223**. The plurality of storage control blocks **210** and **220** operate independently. The processing system is thus duplicated so that the storage system **200** does not stop even when one storage control block fails.

[0066] The storage control blocks **210** and **220** control data input/output to and from physical disk drives **236** and manages operations of the storage system **200**. When the storage system **200** is a NAS (Network Attached Storage), file systems operate in the storage control blocks **210** and **220**.

[0067] The CPU (2) **211** performs arithmetic operations related to various control programs executed in the storage system **100**.

[0068] The main memory (2) **212** stores programs and data required for the operations of the CPU (2) **211**.

[0069] The non-volatile memory (2) **213** stores a storage hypervisor **214**. The storage hypervisor **214**, implemented by the execution of processing by the CPUs **211** and **221**, is a means that enables logical partitioning of physical resources of the storage system **200**.

[0070] The storage hypervisor **214** is implemented with a control program that creates logical partitions in the storage system **200** to create virtual storage systems that operate independently. The storage hypervisor **214** can be implemented by adopting various methods as described above about the hypervisor **103** of the server system (0) **100**.

[0071] In the storage control block **220**, the CPU (3) **221**, the main memory (3) **222**, the non-volatile memory (3) **223**, and the storage hypervisor **224** operate in the same ways as the corresponding components of the storage control block **210**.

[0072] The storage system **200** further includes a LAN adaptor (2) **230** and channel adaptors (0) **231** to (3) **234**.

[0073] The channel adaptor (0) **231** and the channel adaptor (1) **232** are connected with the server system (0) **100** through the I/O channels **400**. The channel adaptors **231** and **232** receive data input/output requests and out put data from the server system (0) **100** and sends data stored in the storage system **200**.

[0074] Similarly, the channel adaptor (2) **233** and the channel adaptor (3) **234** are connected with the server system (1) **150** through I/O channels **400**. The channel adaptors **233** and **234** receive data input/output requests and output data from the server system (1) **150** and sends data stored in the storage system **200**.

[0075] The storage system **200** thus has a plurality of channel adaptors. The plurality of channel adaptors **231** to **234** operate independently. The processing system is thus duplicated so that access to the storage system **200** from the server systems **100** and **150** does not stop even when one channel adaptor fails.

[0076] The LAN adaptor (2) **230** is connected with the server systems **100** and **150** and the control terminal **300**, through the network **410**. The LAN adaptor (2) **230** sends and receives control signals and control information (the contents of various control tables) to and from the systems connected through the network **410**.

[0077] The storage system **200** further includes disk adaptors **237**, a disk cache **238**, and physical disk drives **236**.

[0078] The disk adaptors **237** are interfaces to the physical disk drives **236**. The disk adaptors **237** send and receive data and control signals to and from the physical disk drives **236** according to a protocol such as the ATA, SAS (Serial Attached SCSI), Fibre Channel, etc.

[0079] Two disk adaptors **237** are provided herein. More disk adaptors **237** may be provided. The individual disk adaptors **237** are connected with the physical disk drives **236** through different wires. The two disk adaptors **237** operate independently. The processing system is thus duplicated so that access to the physical disk drives **236** does not stop even when one disk adaptor fails.

[0080] The disk cache **238** is a memory that temporarily stores data written to or read from the physical disk drives **236** and so the disk cache **238** improves the performance of access from the server systems **100** and **150** to the storage system **200**.

[0081] The physical disk drives **236** are formed of a storage medium that stores data. The storage medium is usually formed of magnetic disks, but may be formed of other media, e.g., optical disks. The plurality of physical disk drives **236** form a RAID (Redundant Array of Independent Disks) and thus provide the stored data with redundancy. Therefore, the stored data is not lost even when some of the physical disk drives **236** fail.

[0082] The storage system **200** further includes an interconnecting network **239** that interconnects the storage control blocks **210** and **220**, the LAN adaptor **230**, the channel adaptors **231** to **234**, the disk adaptors **237**, and the disk cache **238**. The interconnecting network **239** is formed of a crossbar switch, for example.

[0083] The control terminal **300** is a computer apparatus that manages the computer system and includes a CPU, memory, an input/output device, and a LAN interface in an integrated fashion. A virtual machine control program **301** runs in the CPU of the control terminal **300**.

[0084] The control terminal **300** has a virtual path control table **310** shown in **FIG. 5**, a server resources control table **320**, and a storage resources control table **330**. The virtual machine control program **301** controls virtual configuration of the computer system by using the virtual path control table **310**, the server resources control table **320**, and the storage resources control table **330**. The contents of these tables will be described later. In the first embodiment, the control terminal **300** includes a control unit (not shown) having connection information (the virtual path control table **310**) that defines connection paths between virtual machines and virtual storage systems.

[0085] The LAN interface of the control terminal **300** is connected with the server system **100**, the server system **150**, and the storage system **200**, through the network **410**. The LAN interface sends and receives control signals and control information (the contents of the various control tables) to and from the systems connected through the network **410**.

[0086] The I/O channels **400** are formed of a transmission medium that can make communication according to a protocol suitable for data transfer, e.g., the Fibre Channel protocol. In the first embodiment, the server systems **100** and **150** and the storage system **200** are connected in a one-to-one manner, but they may be connected through a network (SAN) as will be described later in a sixth embodiment.

[0087] The network **410** connects the server system (**0**) **100**, the server system (**1**) **150**, the storage system **200**, and the control terminal **300**. The network **410** is configured to communicate control signals and control information between computers according to, e.g., the TCP/IP protocol, which can be Ethernet (registered trademark).

[0088] While **FIG. 1** shows an example in which two server systems **100** and **150** and one storage system **200** are connected, three or more server systems may be provided and two or more storage systems may be provided.

[0089] **FIG. 2** is a functional block diagram of the computer system according to the first embodiment.

[0090] Functionally, the server system (**0**) **100** can be roughly divided into a physical layer, a hypervisor layer, and a virtual machine layer.

[0091] The physical layer is a physical machine (**0**) **120** having server resources, including the LAN adaptor and the I/O adaptors. The server resources mean the physical resources of the server system, including the CPU, memory, and I/O adaptors. While the physical machine (**0**) **120** includes other server resources (the CPU, memory, etc.) than those shown in **FIG. 2**, they are not shown in **FIG. 2** because not related to the description here.

[0092] The hypervisor layer is implemented by the hypervisor **103** described earlier. The hypervisor **103** controls the server resources of the physical machine (**0**) **120**. The hypervisor **103** has a virtual I/O adaptor control table **110** and a server resources control table **115**.

[0093] The numerals enclosed in parentheses following the names of physical resources are identifiers of the physical resources. The numerals enclosed in parentheses following the names of virtual resources are identifiers of the virtual resources.

[0094] The virtual I/O adaptor control table **110** shown in **FIG. 3A** describes correspondences between the physical I/O adaptors and virtual I/O adaptors.

[0095] The server resources control table **115** shown in **FIG. 6** defines associations between the resources of the server system (**0**) **100** and virtual machines. The server resources control table **115** is used to manage the server resources of the server system (**0**) **100**.

[0096] The virtual I/O adaptor control table **110** and the server resources control table **115** are stored in the main memory **104**. Alternatively, the virtual I/O adaptor control table **110** and the server resources control table **115** may be stored in the non-volatile memory **102**. When these control tables **110** and **115** are stored in the non-volatile memory **102**, the virtual machine control information is retained even when the power to the server system (**0**) **100** is shut off.

[0097] Alternatively, the virtual I/O adaptor control table **110** and the server resources control table **115** may be stored in the storage system **200**, in which case the control tables

110 and 115 will be read from the storage system 200 and stored in the main memory 104 after the server system (0) 100 is booted.

[0098] Alternatively, the virtual I/O adaptor control table 110 and the server resources control table 115 may be stored in the control terminal 300, in which case the control tables 110 and 115 will be read from the control terminal 300 and stored in the main memory 104 after the server system (0) 100 is booted.

[0099] The hypervisor 103 further includes information about other server resources that configure virtual machines.

[0100] The virtual machine layer includes virtual machines 130 and 140 that the hypervisor 103 has created by logically partitioning the server resources of the physical machine (0) 120. The virtual machine (0) 130 includes a virtual I/O adaptor (0) 131, a virtual I/O adaptor (1) 132, a CPU resource 133, and a memory resource 134. Similarly, the virtual machine (1) 140 includes a virtual I/O adaptor (2) 141, a virtual I/O adaptor (3) 142, a CPU resource 143, and a memory resource 144. The virtual machines 130 and 140 further include other server resources of the server system (0) 100, but they are not shown in FIG. 2 because not related to the description here.

[0101] An OS (0) 135 runs on the virtual machine (0) 130. Also, an OS (1) 145 runs on the virtual machine (1) 140. In other words, the OS (0) 135 performs arithmetic operations using the server resources allocated to the virtual machine (0) 130. Similarly, the OS (1) 145 performs arithmetic operations using the server resources allocated to the virtual machine (1) 140.

[0102] Application programs run on the OSs 135 and 145. These application programs provide database services, Web services, etc. to clients (not shown) connected to the server system (0) 100.

[0103] The server system (1) 150 has the same functions as the server system (0) 100 described above. For example, a hypervisor layer is implemented by the hypervisor 153. The hypervisor 153 has a virtual I/O adaptor control table 160 shown in FIG. 3B and a server resources control table 165 shown in FIG. 6. The details of the functions of the server system (1) 150 are therefore not described here.

[0104] The storage system 200 can be roughly divided into a physical layer, a hypervisor layer, and a virtual storage layer.

[0105] The physical layer is a physical storage 240 having storage resources, including the LAN adaptor and the channel adaptors. The storage resources mean the physical resources of the storage system, including the CPU, disk cache, channel adaptors, and physical disk drives. While the physical storage 240 includes other resources (the physical disk drives, disk cache, etc.) than those shown in FIG. 2, they are not shown in FIG. 2 because not related to the description here.

[0106] The hypervisor layer is implemented by the storage hypervisors 214 and 224 described earlier. The hypervisors 214 and 224 control the storage resources of the physical storage 240. The storage hypervisors 214 and 224 have a virtual channel adaptor control table 260 and a storage resources control table 265.

[0107] The virtual channel adaptor control table 260 shown in FIG. 4 describes correspondences between the physical channel adaptors and virtual channel adaptors.

[0108] The storage resources control table 265 shown in FIG. 7 defines associations between the resources of the storage system 200 and virtual machines. The storage resources control table 223 is used to manage the allocation of the storage resources.

[0109] The virtual channel adaptor control table 260 and the storage resources control table 265 are stored in the main memory 212. Alternatively, the virtual channel adaptor control table 260 and the storage resources control table 265 may be stored in the non-volatile memories 213 and 223. When these control tables 260 and 265 are stored in the non-volatile memories, the virtual storage system control information is retained even when the power to the storage system 200 is shut off.

[0110] Alternatively, the virtual channel adaptor control table 260 and the storage resources control table 265 may be stored in the physical disk drives 236, in which case the control tables 260 and 265 will be read from the physical disk drives 236 and stored in the main memories 212 and 222 after the storage system 200 is booted.

[0111] Alternatively, the virtual channel adaptor control table 260 and the storage resources control table 265 may be stored in the control terminal 300, in which case the control tables 260 and 265 will be read from the control terminal 300 and stored in the main memories 212 and 222 after the storage system 200 is booted.

[0112] The storage hypervisors 214 and 224 further include information about other storage resources that configure virtual storage systems.

[0113] The virtual storage layer includes virtual storage systems 240 and 250 that the hypervisors 214 and 224 have created by logically partitioning the storage resources of the physical storage 240. The virtual storage (0) 240 includes a virtual channel adaptor (0) 241, a virtual channel adaptor (1) 242, a disk cache resource 243, and a virtual disk 244. Similarly, the virtual storage (1) 250 includes a virtual channel adaptor (2) 251, a virtual channel adaptor (3) 252, a disk cache resource 253, and a virtual disk 254. The virtual storage systems 240 and 250 further include other storage resources of the storage system 200, but they are not shown in FIG. 2 because not related to the description here.

[0114] In other words, in the virtual storage system (0) 240 and the virtual storage system (1) 250, the storage hypervisors 214 and 224 may partition a physical disk drive 236 into a plurality of virtual disks 244 and 254, or may unite a plurality of physical disk drives 236 into a single virtual disk 244 or 254.

[0115] The storage system 200 selects a single virtual disk or a plurality of virtual disks from the virtual disks 244 and 254 and provides the virtual disk or disks to the virtual machines 100 and 150 as storage areas. The virtual disks thus selected are called logical units (LU). The logical unit indicates a unit that an OS can recognize as a single disk.

[0116] The control terminal 300 has the virtual path control table 310 shown in FIG. 5. The virtual path control table 310 describes relations between the virtual machines and the virtual storage systems. The control terminal 300 generates

the virtual path control table **310** by collecting together the control information contained in the virtual I/O adaptor control table **110** of the server system (**0**) **100**, the control information contained in the virtual I/O adaptor control table **160** of the server system (**1**) **150**, and the control information contained in the virtual channel adaptor control table **260** of the storage system **200**.

[**0117**] **FIGS. 3A and 3B** are diagrams illustrating the virtual I/O adaptor control tables according to the first embodiment. As stated earlier, a virtual I/O adaptor control table is provided for each server system. The virtual I/O adaptor control tables describe the correspondences between the physical I/O adaptors and the virtual I/O adaptors.

[**0118**] **FIG. 3A** is a diagram illustrating the virtual I/O adaptor control table **110** of the server system (**0**) **100**.

[**0119**] The virtual I/O adaptor control table **110** contains I/O adaptor numbers **111**, virtual I/O adaptor numbers **112**, and virtual machine numbers **113**, in correspondence with each other.

[**0120**] The I/O adaptor numbers **111** are the identifiers of the physical I/O adaptors. The virtual I/O adaptor numbers **112** are the identifiers of the virtual I/O adaptors. The virtual machine numbers **113** are the identifiers of the virtual machines residing in the server system (**0**) **100**.

[**0121**] **FIG. 3B** is a diagram illustrating the virtual I/O adaptor control table **160** of the server system (**1**) **150**.

[**0122**] The virtual I/O adaptor control table **160** contains I/O adaptor numbers **161**, virtual I/O adaptor numbers **162**, and virtual machine numbers **163**, in correspondence with each other.

[**0123**] The I/O adaptor numbers **161** are the identifiers of the physical I/O adaptors. The virtual I/O adaptor numbers **162** are the identifiers of the virtual I/O adaptors. The virtual machine numbers **163** are the identifiers of the virtual machines residing in the server system (**1**) **150**.

[**0124**] These virtual I/O adaptor control tables **110** and **160** show which virtual machines include which virtual I/O adaptors and which virtual I/O adapters are implemented by which physical I/O adaptors.

[**0125**] For example, according to the first entry of the virtual I/O adaptor control table **110** shown in **FIG. 3A**, the virtual I/O adaptor (**0**) of the virtual machine (**0**) is implemented by server resources of the physical I/O adaptor (**0**). Also, according to the first entry of the virtual I/O adaptor control table **160** shown in **FIG. 3B**, the virtual I/O adaptor (**4**) of the virtual machine (**2**) is implemented by server resources of the physical I/O adaptor (**2**).

[**0126**] **FIG. 4** is a diagram illustrating the virtual channel adaptor control table **260** according to the first embodiment.

[**0127**] The virtual channel adaptor control table **260** describes correspondences between the physical channel adaptors and the virtual channel adaptors. Specifically, the virtual channel adaptor control table **260** contains virtual storage system numbers **261**, virtual channel adaptor numbers **262**, and channel adaptor numbers **263**, in correspondence with each other.

[**0128**] The virtual storage system numbers **261** are the identifiers of the virtual storage systems in the storage system **200**. The virtual channel adaptor numbers **262** are the identifiers of the virtual channel adaptors. The channel adaptor numbers **263** are the identifiers of the physical channel adaptors.

[**0129**] The virtual channel adaptor control table **260** shows which virtual storage systems include which virtual channel adaptors and which virtual channel adaptors are implemented by which physical channel adaptors.

[**0130**] For example, according to the first entry of the virtual channel adaptor control table **260**, the virtual channel adaptor (**0**) of the virtual storage system (**0**) is implemented by storage resources of the physical channel adaptor (**0**). Also, according to the third entry, the virtual channel adaptor (**2**) of the virtual storage system (**1**) is implemented by storage resources of the physical channel adaptor (**0**).

[**0131**] **FIG. 5** is a diagram illustrating the virtual path control table **310** according to the first embodiment.

[**0132**] The virtual path control table **310** describes the relations between the virtual machines and the virtual storage systems. In particular, the correspondence between a physical I/O adaptor and a physical channel adaptor specifies the physical path between the server system and the storage system. In other words, the virtual path control table **310** contains information about path between the virtual machines and the virtual storage systems.

[**0133**] The control terminal **300** generates the virtual path control table **310** by collecting together the information contained in the virtual I/O adaptor control table **110** of the server system (**0**) **100**, the information contained in the virtual I/O adaptor control table **160** of the server system (**1**) **150**, and the information contained in the virtual channel adaptor control table **260** of the storage system **200**. In other words, the virtual path control table **310** is generated by uniting the virtual I/O adaptor control table **110**, the virtual I/O adaptor control table **160**, and the virtual channel adaptor control table **260**, and so the virtual path control table **310** stores the control information in these tables.

[**0134**] Specifically, the virtual path control table **310** contains virtual storage system numbers **311**, virtual channel adaptor numbers **312**, channel adaptor numbers **313**, I/O adaptor numbers **314**, virtual I/O adaptor numbers **315**, and virtual machine numbers **316**, in correspondence with each other.

[**0135**] The virtual storage system numbers **311** correspond to the virtual storage system numbers **261** in the virtual channel adaptor control table **260** shown in **FIG. 4**, and thus the virtual storage system numbers **311** are the identifiers of the virtual storage systems in the storage system **200**.

[**0136**] The virtual channel adaptor numbers **312** correspond to the virtual channel adaptor numbers **262** in the virtual channel adaptor control table **260** shown in **FIG. 4**, and thus the virtual channel adaptor numbers **313** are the identifiers of the virtual channel adaptors.

[**0137**] The channel adaptor numbers **313** correspond to the virtual channel adaptor **263** in the virtual channel adaptor control table **260** shown in **FIG. 4**, and thus the channel adaptor numbers **313** are the identifiers of the physical channel adaptors.

[0138] The I/O adaptor numbers **314** correspond to the I/O adaptor numbers **111** and **161** in the virtual I/O adaptor control tables **110** and **160** shown in **FIGS. 3A and 3B**, and thus the I/O adaptor numbers **314** are the identifiers of the physical I/O adaptors.

[0139] The virtual I/O adaptor numbers **315** correspond to the virtual I/O adaptor numbers **112** and **162** in the virtual I/O adaptor control tables **110** and **160** shown in **FIGS. 3A and 3B**, and thus the virtual I/O adaptor numbers **315** are the identifiers of the virtual I/O adaptors.

[0140] The virtual machine numbers **316** correspond to the virtual machine numbers **113** and **163** in the virtual I/O adaptor control tables **110** and **160** shown in **FIGS. 3A and 3B**, and thus the virtual machine numbers **316** are the identifiers of the virtual I/O adaptors.

[0141] The virtual path control table **310** shows which virtual channel adaptors (the physical channel adaptors that implement the virtual channel adaptors) of which virtual storage systems are connected to which virtual I/O adaptors (the physical I/O adaptors that implement the virtual I/O adaptors) of which virtual machines.

[0142] In other words, the correspondence between a channel adaptor number **313** and an I/O adaptor number **314** defines the connection between the physical I/O adaptor and the physical channel adaptor. The connection shows routing information about the physical path between the server system and the storage system.

[0143] For example, according to the first entry of the virtual path control table **310**, the virtual channel adaptor (**0**) of the virtual storage system (**0**) is implemented by storage resources of the physical channel adaptor (**0**). Also, the virtual I/O adaptor (**0**) of the virtual machine (**0**) is implemented by server resources of the physical I/O adaptor (**0**). The virtual channel adaptor (**0**) implemented by the physical channel adaptor (**0**) corresponds to the virtual I/O adaptor (**0**) implemented by the physical I/O adaptor (**0**).

[0144] Similarly, according to the second entry of the virtual path control table **310**, the virtual channel adaptor (**1**) implemented by the physical channel adaptor (**1**) corresponds to the virtual I/O adaptor (**1**) implemented by the physical I/O adaptor (**1**).

[0145] In other words, the virtual storage system (**0**) and the virtual machine (**0**) are connected by the physical channel adaptor (**0**) and the physical I/O adaptor (**0**), and also by the physical channel adaptor (**1**) and the physical I/O adaptor (**1**).

[0146] **FIG. 6** is a diagram illustrating the server resources control table **115** according to the first embodiment.

[0147] As stated earlier, the server resources control table **115** is provided in the hypervisor **103** (in the server system (**0**) **100**).

[0148] The server resources control table **115** stores virtual machine numbers **701**, CPU allocation **702**, memory capacities **703**, and I/O adaptor numbers **704** in association with each other. The server resources control table **115** thus stores the associations of the resources of the server system (**0**) **100** (the CPU (**0**) **101**, the main memory (**0**) **104**, and the I/O adaptors **106** and **107**).

[0149] The virtual machine numbers **701** indicate the virtual machines in the server system (**0**) **100**. The CPU allocation **702** indicates percentages of areas of the CPU (**0**) **101** in the server system (**0**) **100** that are allocated to the individual virtual machines. The memory capacities **703** indicate capacities of the main memory (**0**) **104** that are allocated to the virtual machines. The I/O adaptor numbers **704** indicate I/O adaptors that handle access from the virtual machines to the storage system **200**.

[0150] The administrator specifies allocation of the server resources by means of the control terminal **300** and the server resources control table **115** is generated as per the administrator's setting.

[0151] The server resources control table **165** in the server system (**1**) **150** (the hypervisor **153**) has the same items as the server resources control table **115** described above, and thus the server resources control table **165** stores the associations of the resources of the server system (**1**) **150**.

[0152] The control terminal **300** possesses the server resources control table **320**. The server resources control table **320** has the same items as the server resources control table **115** described above, and thus the server resources control table **320** stores the associations of the resources of the server system (**0**) **100** and the associations of the resources of the server system (**1**) **150**.

[0153] **FIG. 7** is a diagram illustrating the storage resources control table **265** according to the first embodiment.

[0154] As stated earlier, the storage resources control table **265** is provided in the storage hypervisors **214** and **224** (in the storage system **200**).

[0155] The storage resources control table **265** stores virtual machine numbers **601**, virtual disk numbers **602**, disk cache capacities **603**, CPU numbers **604**, and I/O adaptor numbers **605** in association with each other. The storage resources control table **265** thus stores the associations of the resources of the storage system **200** (the physical disk drives **236**, CPUs **211** and **221**, the channel adaptors **231** to **234**, and the disk cache **238**).

[0156] The virtual machine numbers **601** correspond to the virtual machines in the server systems **100** and **150**. The virtual disk numbers **602** are numbers of the virtual disks **244** and **254** configured by the storage hypervisors **214** and **224**, which indicate virtual disks that are allocated to the virtual machines defined by the virtual machine numbers **601**. In other words, the virtual disk **244** has areas corresponding to virtual disk numbers **121** and **122** and the virtual disk **254** has areas corresponding to virtual disk numbers **16** and **17**. The virtual disks may be logical units.

[0157] The disk cache capacities **603** show capacities of the disk caches **243** and **253** that are allocated to the virtual machines defined by the virtual machine numbers **601**. The CPU numbers **604** show the control CPUs **211** and **221** that control access from the virtual machines defined by the virtual machine numbers **601**.

[0158] The channel adaptor numbers **605** show the channel adaptors **231** to **234** that handle access from the virtual machines defined by the virtual machine numbers **601** (access to the virtual disks defined by the virtual disk numbers **602**).

[0159] In other words, the two virtual disks **121** and **122** are allocated to the virtual machine (**0**) **130**. In order to access the virtual disks **121** and **122**, the virtual machine (**0**) **130** can use **512** megabytes of disk cache. The virtual machine (**0**) **130** accesses the virtual disks **121** and **122** through the two I/O adaptors (**0**) and (**1**). The two CPUs **2** and **3** operate to process the access from the virtual machine (**0**) **130** to the virtual disks **121** and **122**.

[0160] The administrator specifies allocation of the storage resources by means of the control terminal **300** and the storage resources control table **265** is generated as per the administrator's setting.

[0161] Also, the control terminal **300** has the storage resources control table **330**. The storage resources control table **330** contains the same items as the storage resources control table **265** described above, and stores the associations of the resources of the storage system **200**.

[0162] The server resources control table **115** shown in **FIG. 6** describes the CPU allocation, but the CPU numbers may be used. Also, while the storage resources control table **265** shown in **FIG. 7** describes the CPU numbers, CPU allocation may be used.

[0163] **FIG. 8** is a diagram illustrating the connections in the computer system according to the first embodiment. Unlike **FIG. 2** that shows the functions of the computer system in the hardware perspective, **FIG. 8** shows the connections in the software perspective (seen from the virtual world). Therefore, **FIG. 8** does not show the hardware configuration of the computer system (e.g., the I/O adaptors **106** etc. and the channel adaptors **231** etc.).

[0164] The virtual machine (**0**) **130** includes two virtual I/O adaptors (**0**) **131** and (**1**) **132**. The virtual storage system (**0**) **240** has two virtual channel adaptors (**0**) **241** and (**1**) **242**. The virtual I/O adaptor (**0**) **131** is connected with the virtual channel adaptor (**0**) **241** and the virtual I/O adaptor (**1**) **132** is connected with the virtual channel adaptor (**1**) **242**.

[0165] Similarly, the virtual machine (**1**) **140** includes two virtual I/O adaptors (**2**) **141** and (**3**) **142**. The virtual storage system (**1**) **250** has two virtual channel adaptors (**2**) **251** and (**3**) **252**. The virtual I/O adaptor (**2**) **141** is connected with the virtual channel adaptor (**2**) **251** and the virtual I/O adaptor (**3**) **142** is connected with the virtual channel adaptor (**3**) **252**.

[0166] Also, the virtual machine (**2**) **180** includes two virtual I/O adaptors (**4**) **181** and (**5**) **182**. The virtual I/O adaptor (**4**) **181** is connected with the virtual channel adaptor (**0**) **241** and the virtual I/O adaptor (**5**) **182** is connected with the virtual channel adaptor (**1**) **242**.

[0167] Similarly, the virtual machine (**3**) **190** includes two virtual I/O adaptors (**6**) **191** and (**7**) **192**. The virtual I/O adaptor (**6**) **191** is connected with the virtual channel adaptor (**2**) **251** and the virtual I/O adaptor (**7**) **192** is connected with the virtual channel adaptor (**3**) **252**.

[0168] In other words, **FIG. 8** shows the relations among the virtual machine numbers **316**, the virtual I/O adaptor numbers **315**, the virtual channel adaptor numbers **312**, and the virtual storage system numbers **311** in the virtual path control table **310** shown in **FIG. 5**.

[0169] **FIG. 9** is a flowchart of a cable connection process in the computer system according to the first embodiment. This cable connection process is performed in the server system (**0**) **100**. The same process is performed also in the server system (**1**) **150** and the storage system **200**.

[0170] First, an I/O adaptor of the server system (**0**) **100** (a channel adaptor of the storage system **200**) detects a cable connection (S**101**).

[0171] Next, the server system (**0**) **100** exchanges physical addresses with the apparatus coupled by the network **410** (S**102**). For example, when the server device (**0**) **100** is connected to the storage system **200**, the server system (**0**) **100** sends an inquiry to the connected system for a physical address and obtains a physical address of a channel adaptor of the storage system **200**. The physical addresses exchanged in the step S**102** can be any addresses that uniquely identify the ports of adapters to which the cable (I/O channel) is connected.

[0172] For example, World Wide Names (WWNs) are exchanged according to the Fibre Channel protocol. In particular, in this invention, World Wide port Names may be used to specify the ports. With the iSCSI protocol, MAC addresses obtained by an address resolution technique (e.g. ARP) may be exchanged.

[0173] Then, the obtained physical addresses are reported to the hypervisor **103**.

[0174] Next, the hypervisor **103** notifies the control terminal **300** of the obtained cable connection state (the physical address of the I/O adaptors and the physical address of the channel adaptors) through the network **410** (S**103**).

[0175] The control terminal **300** receives the physical address of the I/O adaptor and the physical addresses of the channel adaptor and then waits for a notification of a physical address from the storage system that includes the connected channel adaptors.

[0176] Then, having received the physical addresses from both of the connected systems, the control terminal **300** registers the correspondence between the I/O adaptors and the channel adaptors in the virtual path control table **310** (S**104**). In other words, in the virtual path control table **310**, the control terminal **300** registers channel adaptor numbers **313** and I/O adaptor numbers **314** of the same number as the detected cables.

[0177] **FIG. 10** is a flowchart of a process of creating a virtual machine in the computer system according to the first embodiment. The virtual machine creation process is performed in the server system (**0**) **100**. The same process is performed also in the server system (**1**) **150**.

[0178] First, the administrator operates the control terminal **300** to set allocation of server resources of the server system (**0**) **100** and gives an instruction to create a virtual machine (S**111**). The control terminal **300** sends the resource allocation to the server system (**0**) **100**.

[0179] The server system (**0**) **100** receives the virtual machine creation instruction from the control terminal **300** and then the hypervisor **103** creates a virtual machine by allocating server resources of the server system (**0**) **100**, other than I/O adaptors, according to the received virtual machine creation instruction (S**112**).

[0180] Then, when completing the virtual machine creation, the hypervisor **103** notifies the control terminal **300** of the completion of the virtual machine creation.

[0181] The control terminal **300** receives the notification of the completion of the virtual machine creation from the server system (**0**) **100** and then checks whether a virtual storage system should be created in the storage system **200** (S**113**).

[0182] Then, when the control terminal **300** judges that a virtual storage system should be created, the flow moves to a step S**114**. On the other hand, when the control terminal **300** judges that there is no need to create a virtual storage system, the flow moves to a step S**115**.

[0183] For example, when a virtual machine is created for the first time in the server system (**0**) **100**, it is necessary to create a virtual storage system that the virtual machine accesses. On the other hand, when the created virtual machine uses a virtual storage system already created, then there is no need to newly create a virtual storage system.

[0184] In the step S**114**, the control terminal **300** sends allocation of storage resources of the storage system **200** to the storage system **200** and gives an instruction to create a virtual storage system. The storage system **200** receives the virtual storage system creation instruction from the control terminal **300** and then the storage hypervisor **214**, **224** creates a virtual storage system by allocating the storage resources of the storage system **200**, other than channel adaptors, according to the received virtual storage system creation instruction (S**114**).

[0185] Then, when completing the virtual storage system creation, the storage hypervisor **214**, **224** notifies the control terminal **300** of the completion of the virtual storage system creation.

[0186] The control terminal **300** receives the notification of the completion of the virtual storage system creation from the storage system **200** and then checks whether virtual adaptors (virtual channel adaptors and virtual I/O adaptors) should be created (S**115**).

[0187] Then, when the control terminal **300** judges that virtual adaptors should be created, the flow moves to a step S**116**. On the other hand, when the control terminal **300** judges that there is no need to create virtual adaptors, the flow moves to a step S**117**.

[0188] For example, when a virtual machine is created for the first time in the server system (**0**) **100**, it is necessary to create virtual adaptors for use by the virtual machine. On the other hand, there is no need to create virtual adaptors when already created virtual adaptors are used, or when redundant ports are used.

[0189] In the step S**116**, the resources of an I/O adaptor (or a channel adaptor) are allocated to create a virtual adaptor (S**116**). Virtual I/O adaptors are created by the hypervisor **103**, **153**, and virtual channel adaptors are created by the storage hypervisor **214**, **224**.

[0190] After creating a virtual I/O adaptor, the hypervisor **103** adds an entry to the virtual I/O adaptor control table **110**. In this process, the virtual I/O adaptor number **112** and the virtual machine number **113** are registered in the virtual I/O adaptor control table **110**. In the step S**112**, the I/O adaptor number **111** is blank because I/O adaptor resources have not been allocated.

[0191] Also, the storage hypervisor **214**, after creating a virtual channel adaptor, adds an entry to the virtual channel adaptor control table **260**. In this process, the virtual storage system number **261** and the virtual channel adaptor number **262** are registered in the virtual channel adaptor control table **260**. In the step S**114**, the channel adaptor number **263** is blank because channel adaptor resources have not been allocated.

[0192] After that, a path is established between the channel adaptor and the virtual channel adaptor (S**117**). In other words, the channel adaptor number **263** corresponding to the virtual channel adaptor number **262** is registered in the virtual channel adaptor control table **260**. Thus, the virtual channel adaptor control table **260** is completed and a path in the server system (**0**) **100** is established.

[0193] Next, the storage hypervisor **214**, **244** sends, to the control terminal **300**, the virtual storage system number **261**, the virtual channel adaptor number **262**, and the channel adaptor number **263** in the virtual channel adaptor control table **260**. The control terminal **300** receives the information contained in the virtual channel adaptor control table **260** and then searches and retrieves an entry corresponding to the channel adaptor number **313** in the virtual path control table **310**. Then, the control terminal **300** registers the received information in the virtual storage system number **311** and the virtual channel adaptor number **312** of the retrieved entry (S**118**). The control terminal **300** is now capable of managing the relation from the virtual storage system to the channel adaptor.

[0194] Next, using the control terminal **300**, the administrator selects an I/O adaptor that is connected to the target channel adaptor (S**119**). In this process, the virtual machine control program **301** may indicate one or a plurality of I/O adaptors that are physically connected to the target channel adaptor so that the administrator can select one. The control terminal **300** sends information about the selected I/O adaptor to the hypervisor **103**.

[0195] The hypervisor **103** receives the information about the selected I/O adaptor and creates a path between the I/O adaptor and the virtual I/O adaptor (S**120**). In other words, the channel adaptor number **263** corresponding to the virtual channel adaptor number **262** is registered in the virtual channel adaptor control table **260**. Thus, the virtual I/O adaptor control table **110** is completed and a path in the server system is established.

[0196] Next, the hypervisor **103** sends, to the control terminal **300**, the I/O adaptor number **111**, the virtual I/O adaptor number **112**, and the virtual machine number **113** in the virtual I/O adaptor control table **110**. The control terminal **300** receives the information contained in the virtual I/O adaptor control table **110** and then searches and retrieves an entry corresponding to the I/O adaptor number. Then, the control terminal **300** registers the received information in the virtual I/O adaptor number **315** and the virtual machine number **316** of the retrieved entry (S**121**). Thus, the route from the virtual storage system to the virtual machine has been registered in the virtual path control table **310**. The control terminal **300** is now capable of managing the relation from the virtual storage system to the virtual machine.

[0197] After that, whether a redundant path should be created is checked (S**122**). When it is judged that a redundant path should be created, the flow returns to the step S**115** and checks whether virtual adaptors used for the redundant

path should be created. Subsequently, a redundant path is created through the process steps S116 to S122.

[0198] When adaptors are newly created for the creation of a redundant path (when there is no redundant adaptors), the flow may return to the step S116. When new adaptors are not created for the creation of a redundant path (when there are redundant adaptors), the flow may return to the step S117.

[0199] After the completion of redundant path creation, whether a redundant configuration should be created is checked (S123). When it is judged that a redundant configuration should be created, the flow returns to the step S112 and virtual machines used in the redundant configuration is created through the process steps S112 to S122.

[0200] **FIG. 11** is a diagram illustrating the structure of communication protocol layers for the I/O channels **400** of the computer system according to the first embodiment.

[0201] When accessing a logical unit in the storage system **200**, the OS (**0**) **135** on the virtual machine (**0**) **130** processes input/output according to a disk I/O protocol (e.g. the SCSI standard). In this embodiment, the disk I/O protocol layer is referred to as "disk I/O layer"**1100**, **1106**.

[0202] While a disk I/O command issued by the OS (**0**) **135** is received by the hypervisor **103**, a communication protocol layer exists also between the hypervisor **103** and the storage hypervisors **214** and **224**. This communication protocol layer is referred to as "hypervisor communication layer"**1101**, **1105**.

[0203] Also, in this embodiment, a layer that handles general communication by the I/O channels **400** is referred to as "I/O channel protocol layer"**1102**, **1104**. Also, a layer of hardware, such as a physical communication medium, is referred to as "physical layer"**1103**.

[0204] When the communication protocol of the I/O channels **400** has such a layered structure, the disk I/O layers **1101** and **1106** and the hypervisor communication layers **1101** and **1105** are not affected even when the communication medium forming the I/O channels **400** is changed.

[0205] The disk I/O command issued by the OS (**0**) **135** is sent to the virtual machine (**0**) **130**. The virtual machine (**0**) **130** issues that I/O command to the virtual storage system (**0**) **240**. In reality, this I/O command is received by the hypervisor **103**.

[0206] The hypervisor **103** adds information to the disk I/O command (see **FIG. 12**) and sends the disk I/O command to the storage hypervisors **214** and **224**. The storage hypervisors **214** and **224** receive the command, extract the disk I/O command, and send it to the virtual storage system (**0**) **240**.

[0207] Communication with such a layered structure makes the OS (**0**) **135** recognize as if it were communicating directly with the virtual storage system (**0**).

[0208] **FIG. 12** is a diagram illustrating the information transmitted between the server system (**0**) **100** and the storage system **200** according to the first embodiment.

[0209] The I/O channels **400** of this embodiment conduct communication using a frame **1200** as a unit. This is the same in common standards like the Fibre Channel and Ethernet. The frame **1200** is formed of an I/O channel protocol header **1201** and an I/O channel protocol payload **1202**.

[0210] The I/O channel protocol header **1201** contains control information required for communication in the I/O channel protocol layers **1102** and **1104**. Specifically, the I/O channel protocol header **1201** contains an identifier of the source and an identifier of the destination. The I/O channel protocol payload **1202** is information transmitted in the I/O channel protocol layers **1102** and **1104**, and the I/O channel protocol layers **1102** and **1104** have no concern with the contents.

[0211] The I/O channel protocol payload **1202** is formed of a hypervisor communication header **1203** and a hypervisor communication payload **1204**.

[0212] The hypervisor communication header **1203** contains control information required for communication in the hypervisor communication layers **1101** and **1105**. The contents of the hypervisor communication header **1203** will be fully described later with **FIG. 13**. The hypervisor communication payload **1204** is data transmitted in the hypervisor communication layers **1101** and **1105**, and the hypervisor communication layers **1101** and **1105** have no concern with the contents.

[0213] In this embodiment, the hypervisor communication payload **1204** is formed of information required for communication in the disk I/O layers **1100** and **1106**. Specifically, the information includes a disk I/O command and transferred data. In this embodiment, the hypervisor communication payload **1204** contains information in the disk I/O layers **1100** and **1106** because the disk I/O layers reside above the hypervisor communication layers **1101** and **1105**. However, in communication between the hypervisor and storage hypervisor, information of a type other than disk I/O is contained. In other words, when communication for a purpose other than disk I/O is made between the hypervisor and storage hypervisor, a protocol other than the disk I/O protocol is defined for the communication. The information of a type other than disk I/O is information conforming to the protocol.

[0214] **FIG. 13** is a diagram illustrating the contents of the hypervisor communication header **1203** according to the first embodiment.

[0215] The hypervisor communication header **1203** contains a source hypervisor number **1300**, a source virtual machine number **1301**, a source virtual adaptor number **1302**, a destination hypervisor number **1310**, a destination virtual machine number **1311**, and a destination virtual adaptor number **1312**. In this embodiment, the hypervisors and the storage hypervisors are provided with unique identifiers so that systems including a plurality of server systems **100** and **150** and a plurality of storage systems **200** can be dealt with.

[0216] The source hypervisor number **1300** is an identifier of the hypervisor or storage hypervisor that has sent this frame.

[0217] The destination hypervisor number **1310** is an identifier of the hypervisor or storage hypervisor that should receive this frame.

[0218] The source virtual machine number **1301** is an identifier of the virtual machine or virtual storage system that has sent this frame.

[0219] The destination virtual machine number **1311** is an identifier of the virtual machine or virtual storage system that should receive this frame.

[0220] The source virtual adaptor number **1302** is an identifier of the virtual I/O adaptor or virtual channel adaptor that has sent this frame.

[0221] The destination virtual adaptor number **1312** is an identifier of the virtual I/O adaptor or virtual channel adaptor that should receive this frame.

[0222] **FIG. 14** is a flowchart of a process of sending a disk I/O command according to the first embodiment. While the flowchart describes an example in which the virtual machine (**0**) **130** accesses the virtual storage system (**0**) **240** through the I/O adaptor (**0**) **106** and the channel adaptor (**0**) **231**, the same process can be performed also with other virtual machines **140**, **180**, and **190** and virtual storage system **250**.

[0223] When a disk I/O command is issued, the OS (**0**) **135** sends the disk I/O command to the virtual machine (**0**) **130** (the virtual I/O adaptor (**0**) **131**) (S**131**). In reality, the disk I/O command sent to the virtual I/O adaptor (**0**) **131** is received by the hypervisor **103**.

[0224] The hypervisor **103** then adds information to the disk I/O command (see **FIG. 12**) and transfers the disk I/O command to the physical I/O adaptor (**0**) **106** (S**132**).

[0225] The I/O adaptor (**0**) **106** sends the disk I/O command to the connected channel adaptor (**0**) **231** (the virtual storage system (**0**) **240**) (S**133**).

[0226] Then, the channel adaptor (**0**) **231** receives the disk I/O command sent from the I/O adaptor (**0**) **106** (S**134**). In reality, the disk I/O command received by the channel adaptor (**0**) **231** is received by the storage hypervisor **214**.

[0227] The storage hypervisor **214** extracts the destination virtual adaptor number **1312** contained in the hypervisor communication header **1203** of the received disk I/O command. Then, the storage hypervisor **214** transfers the disk I/O command to the extracted virtual channel adaptor (**0**) **241** (S**135**).

[0228] **FIG. 15** is a flowchart of a process of completion notification of a disk I/O command according to the first embodiment. While the flowchart describes an example in which the virtual storage system (**0**) **240** accesses the virtual machine (**0**) **130** through the channel adaptor (**0**) **231** and the I/O adaptor (**0**) **106**, the same process can be performed also with other virtual storage system **250** and virtual machines **140**, **180**, and **190**.

[0229] When the virtual storage system (**0**) **240** receives a disk I/O command from the virtual machine (**0**) **130**, the virtual storage system (**0**) **240** obtains the virtual disk number that is the target of the access by the disk I/O command to specify the accessed virtual disk and reads/writes data to/from the corresponding virtual disk **244**.

[0230] In this process, the storage hypervisor **214** translates the virtual block address of the accessed virtual disk **244** to a physical block address of the physical disk drive **236**. The access to the virtual disk **244** is then converted to access to the physical disk drive **236**. Then, the storage hypervisor **214** accesses the physical disk drive **236** and reads/writes data.

[0231] When completing the data read from or data write to the physical disk, the virtual storage system (**0**) **240** issues a disk I/O completion notification. The virtual storage system (**0**) **240** then sends the disk I/O completion notification to the virtual channel adaptor (**0**) **241** (S**141**). In reality, the disk I/O completion notification sent to the virtual channel adaptor (**0**) **241** is received by the storage hypervisor **214**.

[0232] The storage hypervisor **214** then adds information to the disk I/O completion notification (see **FIG. 12**) and transfers the disk I/O completion notification to the physical channel adaptor (**0**) **231** (S**142**).

[0233] The channel adaptor (**0**) **231** sends the disk I/O completion notification to the connected I/O adaptor (**0**) **106** (the virtual machine (**0**) **130**) (S**143**).

[0234] Then, the I/O adaptor (**0**) **106** receives the disk I/O completion notification sent from the channel adaptor (**0**) **231** (S**144**). In reality, the disk I/O completion notification received by the I/O adaptor (**0**) **106** is received by the hypervisor **103**.

[0235] The hypervisor **103** extracts the destination virtual adaptor number **1312** contained in the hypervisor communication header **1203** of the received disk I/O completion notification. Then, the hypervisor **103** transfers the disk I/O completion notification to the extracted virtual I/O adaptor (**0**) **131** (S**145**).

[0236] **FIG. 16** is a flowchart of a process of handling a fault according to this embodiment. While the flowchart describes an example in which the hypervisor **103** detects a fault of the I/O channels **400**, the hypervisor **153** can detect faults in the same way.

[0237] First, the hypervisor **103** detects a breaking of I/O channel **400** (S**151**). This fault handling process is not performed when no breaking of I/O channels **400** is detected.

[0238] As for the breaking of I/O channels **400**, an I/O channel **400** is judged to be broken when, for example, the virtual machine **130** of the server system (**0**) **100** has issued a disk I/O command but does not receive a disk I/O completion notification before a timeout occurs. A breaking detecting circuit for detecting breaking of I/O channels **400** may be provided in the server system (**0**) **100** to monitor for breaking.

[0239] In other words, this fault handling process may be executed at the moment of an occurrence of a disk I/O, or may be executed otherwise.

[0240] Next, in order to keep the connection between the virtual machine (**0**) **130** and the virtual storage system (**0**) **240**, the hypervisor **103** changes the connection path between the virtual I/O adaptor (**0**) **131** and the physical I/O adaptor (**0**) **106** (the connection path in the server system (**0**) **100**) (S**152**). For example, the hypervisor **103** sets up a connection path between the virtual I/O adaptor (**0**) **131** and the I/O adaptor (**1**) **107**.

[0241] Then, the contents of the virtual I/O adaptor control table **110** are altered accordingly. In this embodiment, the

I/O adaptor number **111** is changed to "1" in the entry in which the I/O adaptor number **111** is "0", the virtual I/O adaptor number **112** is "0" and the virtual machine number **113** is "0".

[**0242**] Alternatively, instead of changing the contents of the entry of the detected fault, an entry may be added for the newly established path.

[**0243**] Subsequently, the hypervisor **103** notifies the control terminal **300** of the change of the connection path between the virtual I/O adaptor and the physical I/O adaptor (the connection path in the server system (**0**) **100**) (S**153**).

[**0244**] The control terminal **300** receives the path change notification from the hypervisor **103** and alters the virtual path control table **310** (S**154**). Specifically, the I/O adaptor number **314** is changed to "1" in the entry with the I/O adaptor number **314** of "0", the virtual I/O adaptor number **315** of "0", and the virtual machine number **316** of "0".

[**0245**] Then, the control terminal **300** notifies the hypervisor **103** of the completion of the alteration of the virtual path control table **310**.

[**0246**] The hypervisor **103** receives the alteration completion notification from the control terminal **300** and retransmits uncompleted transmit information (e.g., an issued disk I/O command for which completion notification has not been received) to the I/O adaptor that forms the new path (S**155**).

[**0247**] **FIG. 17** is a flowchart of a process of handling a fault according to this embodiment. While the flowchart describes an example in which the storage hypervisor **214** detects a fault of the I/O channels **400** in the I/O channel protocol layer **1104**, the storage hypervisor **224** can detect faults in the same way.

[**0248**] First, the storage hypervisor **214** detects a breaking of I/O channel **400** (S**161**). This fault handling process is not performed when no breaking of I/O channels **400** is detected.

[**0249**] As for the breaking of I/O channels **400**, an I/O channel **400** is judged to be broken when, for example, the virtual storage system **210** of the storage system **200** has issued a disk I/O completion notification but does not receive a confirmation signal with respect to the disk I/O completion notification before a timeout occurs. A breaking detecting circuit for detecting breaking of I/O channels **400** may be provided in the storage system **200** to monitor for breaking.

[**0250**] In other words, this fault handling process may be executed at the moment of an occurrence of a disk I/O, or may be executed otherwise.

[**0251**] Next, in order to keep the connection between the virtual storage system (**0**) **240** and the virtual machine (**0**) **130**, the storage hypervisor **214** changes the connection path between the virtual channel adaptor (**0**) **241** and the physical channel adaptor (**0**) **231** (the connection path in the storage system **200**) (S**162**). For example, the storage hypervisor **214** sets up a connection path between the virtual channel adaptor (**0**) **241** and the channel adaptor (**1**) **232**.

[**0252**] Then, the contents of the virtual channel adaptor control table **260** are altered accordingly. In this embodiment, the channel adaptor number **263** is changed to "1" in the entry in which the virtual storage system number **261** is "0", the virtual channel adaptor number **262** is "0" and the channel adaptor number **263** is "0".

[**0253**] Alternatively, instead of changing the contents of the entry of the detected fault, an entry may be added for the newly established path.

[**0254**] Subsequently, the storage hypervisor **214** notifies the control terminal **300** of the change of the connection path between the virtual I/O adaptor and the physical I/O adaptor (the connection path in the server system (**0**) **100**) (S**163**).

[**0255**] The control terminal **300** receives the path change notification from the storage hypervisor **214** and alters the virtual path control table **310** (S**164**). Specifically, the channel adaptor number **313** is changed to "1" in the entry with the virtual storage system number **311** of "0", the virtual channel adaptor number **312** of "0", and the channel adaptor number **313** of "0".

[**0256**] Then, the control terminal **300** notifies the storage hypervisor **214** of the completion of the alteration of the virtual path control table **310**.

[**0257**] The storage hypervisor **214** receives the alteration completion notification from the control terminal **300** and retransmits uncompleted transmit information to the I/O adaptor that forms the new path (S**165**).

[**0258**] Information thus transmitted includes a completion notification about a disk I/O command. There are a plurality of communication protocols for I/O channels. According to the Fibre Channel, which is one of such communication protocols, an I/O adaptor or channel adaptor that has received some information may report the reception (acknowledgement) to the source. The step S**165** retransmits information transmitted to the I/O adaptor but for which no acknowledgement has been received.

[**0259**] As described so far, by the fault handling process on the virtual machine side shown in **FIG. 16** and the fault handling process on the virtual storage system side shown in **FIG. 17**, the virtual path control table **310** is altered and the path between the virtual machine (**0**) **130** and the virtual storage system (**0**) **230** is recovered, whereby communication is enabled between the two parties. Because this process of changing a path is performed by the hypervisor **103** and the storage hypervisor **214**, the OS (**0**) **135**, the OS (**1**) **145**, the OS (**2**) **185**, and the OS (**3**) **195** are unable to detect faults. This provides an advantage that there is no need to handle a fault on the OS side.

[**0260**] **FIG. 18** is a diagram illustrating a screen displayed on the control terminal **300** according to the first embodiment.

[**0261**] A monitor screen **320** of the control terminal **300** displays control information required for the administrator to control the computer system. In other words, the monitor screen **320** of the control terminal **300** visually displays the relations among the pieces of information stored in the virtual path control table **310** shown in **FIG. 5** (the virtual machine numbers **316**, the virtual I/O adaptor numbers **315**, the I/O adaptor numbers **314**, the channel adaptor numbers **313**, the virtual channel adaptor numbers **312**, and the virtual storage system numbers **311**).

[**0262**] Specifically, the monitor screen **320** includes virtual machine display areas **321**, I/O adaptor display areas **322**, channel adaptor display areas **323**, and storage system display areas **324**.

[0263] The virtual machine display areas **321** display the virtual machines (**0**) to (**3**) of this computer system. The virtual I/O adaptors are displayed in each virtual machine.

[0264] The I/O adaptor display areas **322** display the physical I/O adaptors (**0**) to (**3**) of the server systems of the computer system.

[0265] The channel adaptor display areas **323** display the physical channel adaptors (**0**) to (**3**) of the storage system of the computer system.

[0266] The storage system display areas **324** display the virtual storage systems (**0**) and (**1**) of the computer system. The virtual channel adaptors are displayed in each virtual storage system.

[0267] The monitor screen **320** also displays the paths established between the virtual machines (virtual I/O adaptors) and the virtual storage systems (virtual channel adaptors). The monitor screen **320** visually shows which I/O adaptors and which channel adaptors the paths pass through. Furthermore, different paths are indicated by different kinds of lines (or in different colors) so that the routing of the paths can be seen easily.

[0268] The monitor screen **320** of the control terminal **300** thus visually displays the routing of paths to show that the paths connecting the virtual machines and the virtual storage systems are physically separated into different paths and thus form a redundant configuration. The administrator can see the correspondence between the physical connections and virtual connections between the virtual machines and the virtual storage systems.

[0269] In other words, between the virtual machine (**0**) and the virtual storage system (**0**), two paths are routed via different virtual I/O adaptors and different virtual channel adaptors. Physically, too, the two paths pass via different I/O adaptors and different channel adaptors, thus forming a redundant configuration both virtually and physically.

[0270] As described so far, in creating a virtual machine according to the first embodiment of this invention, a virtual machine control program sets the configuration of the computer system while confirming correct relations among physical resources (physical paths) and virtual resources (virtual paths) according to a virtual path control table. In other words, in logically partitioning server and storage systems in cooperation, the relations among the physical resources and logical resources can be confirmed. This makes it possible to easily set a high-availability configuration of a computer system using virtual machines.

Second Embodiment

[0271] According to a second embodiment of this invention, path control programs run on virtual machines. The path control programs control the paths set up between the virtual machines and the virtual storage systems and also handle faults of the I/O channels.

[0272] **FIG. 19** is a diagram illustrating connections in a computer system according to the second embodiment. Like **FIG. 8**, **FIG. 19** shows the connections in the computer system in the software perspective (seen from the virtual world). **FIG. 19** therefore does not show the hardware configuration of the computer system (e.g., the I/O adaptors **106** etc. and the channel adaptors **231** etc.).

[0273] In the virtual machine (**0**) **130**, an OS (**0**) **135** and a path control program **136** run. The path control program **136** is stored in the storage system **200**, and when the virtual machine (**0**) **130** is booted, the path control program **136** is read from the storage system **200**, loaded into a main memory **104**, and executed by a CPU **101**. Alternatively, the path control program **136** may be stored in a non-volatile memory in the server system and loaded from the non-volatile memory. The path control program **136** manages the paths set up between the virtual I/O adaptors related to the virtual machine (**0**) **130** and the virtual channel adaptors related to the virtual storage system (**0**) **240**.

[0274] Similarly, an OS**145** and a path control program **146** run in a virtual machine **140**. An OS**185** and a path control program **186** run in a virtual machine **180**. Also, an OS**195** and a path control program **196** run in a virtual machine **190**. The path control programs **156**, **186**, and **196** manage the paths set up for the respective virtual machines.

[0275] Like **FIG. 8** described earlier, **FIG. 19**, too, shows the relations among the virtual machine numbers **316**, the virtual I/O adaptor numbers **315**, the virtual channel adaptor numbers **312**, and the virtual storage system numbers **311** in the virtual path control table **310** shown in **FIG. 5**. The connections between the virtual machines and the virtual storage systems are the same as those shown in **FIG. 8** described earlier and therefore not described here again.

[0276] **FIG. 20** is a flowchart of a fault handling process according to the second embodiment. While the flowchart shows an example in which the path control program **136** in the virtual machine (**0**) **130** detects a fault of I/O channels **400**, the other path control programs **146**, **186**, and **196** are also capable of detecting faults in the same way.

[0277] First, the path control program **136** detects a breaking of an I/O channel **400** (S**171**). This fault handling process is not executed when no breaking of I/O channels **400** is detected.

[0278] As for the breaking of I/O channels **400**, an I/O channel **400** is judged to be broken when, for example, the virtual machine **130** of the server system (**0**) **100** has issued a disk I/O command but does not receive a disk I/O completion notification before a timeout occurs. A breaking detecting circuit for detecting breaking of I/O channels **400** may be provided in the server system (**0**) **100** and the path control program **136** may monitor for breaking.

[0279] In other words, this fault handling process may be executed at the moment of an occurrence of a disk I/O, or may be executed otherwise.

[0280] Next, the path control program **136** switches the virtual I/O adaptor that the virtual machine (**0**) **130** uses to access the virtual storage system (**0**) **240** (S**172**). Specifically, the path control program **136** switches the I/O from the virtual I/O adaptor (**0**) **131** to the virtual I/O adaptor (**1**) **132**.

[0281] Subsequently, the path control program **136** retransmits uncompleted transmit information (e.g., an issued disk I/O command for which completion notification has not been received) to the corresponding I/O adaptor (S**173**).

[0282] In this way, according to the second embodiment, when an I/O channel fails, the path control program switches over the virtual I/O adaptor that the virtual machine uses.

This makes it possible to recover from the fault without altering the virtual path control table **310** of the control terminal **300**.

Third Embodiment

[**0283**] According to a third embodiment of this invention, cluster control programs run on virtual machines. The cluster control programs control the cluster configuration with the virtual machines forming a pair.

[**0284**] **FIG. 21** is a diagram illustrating connections in a computer system according to the third embodiment. Like **FIG. 8**, **FIG. 21** shows the connections in the computer system in the software perspective (seen from the virtual world). **FIG. 21** therefore does not show the hardware configuration of the computer system (e.g., the I/O adaptors **106** etc. and the channel adaptors **231** etc.).

[**0285**] In the virtual machine (**2**) **180**, an OS (**2**) **185** and a cluster control program **187** run. The cluster control program **187** is stored in the storage system **200**, and when the virtual machine (**2**) **180** is booted, the cluster control program **187** is read from the storage system **200**, loaded into a main memory (**1**) **154**, and executed by a CPU **151**. Alternatively, the cluster control program **187** may be stored in a non-volatile memory in the server system and loaded from the non-volatile memory.

[**0286**] In this embodiment, the virtual machine (**0**) **130** and the virtual machine (**2**) **180** configured on different hardware systems (server systems) form a cluster. The virtual machines forming a cluster pair are connected through a communication path **421**. The communication path **421** may be formed of a specialized line connecting the server system (**0**) **100** and the server system (**1**) **150**. Alternatively, the network **410** may be used.

[**0287**] The virtual machines forming a cluster pair issue a control I/O for fault detection (e.g., a heart beat signal) through the communication path **421** with given timing (e.g., periodically). Then, when one virtual machine does not receive the control I/O issued by the other virtual machine of the cluster pair, that one virtual machine judges that a fault has occurred in the other virtual machine.

[**0288**] The virtual machines forming a cluster pair have virtual I/O adaptors of the same configuration because, in the event of a failover, they have to provide services using the same data stored in the virtual storage system **240** and the like, and the virtual I/O adaptors forming pairs in the cluster are connected to the virtual storage system in the same way.

[**0289**] Similarly, the virtual machine (**1**) **140** and the virtual machine (**3**) **190** are connected through a communication path **422** and form a cluster.

[**0290**] Like **FIG. 8** described earlier, **FIG. 21**, too, shows the relations among the virtual machine numbers **316**, the virtual I/O adaptor numbers **315**, the virtual channel adaptor numbers **312**, and the virtual storage system numbers **311** in the virtual path control table **310** shown in **FIG. 5**. The connections between the virtual machines and the virtual storage systems are the same as those shown in **FIG. 8** described earlier and therefore not described again here.

[**0291**] **FIG. 22** is a flowchart of a fault handling process according to the third embodiment. The flowchart describes an example in which the hypervisor **103** reboots the virtual machine (**0**) **130**, but other hypervisors and other virtual machines are capable of performing the same rebooting process.

[**0292**] First, when the cluster control program **137** does not receive a heart beat signal from the virtual machine (**0**) **130** for a predetermined time period, the heart beat is judged to be lost (S**181**). This fault handling process is not executed when loss of heart beat signal is not detected.

[**0293**] Specifically, for example, the heart beat signal is judged to be lost when periodically sent heart beat signals are not received for a predetermined time period for plural times. In other words, it is judged that a fault has occurred in the virtual machine (**0**) **130**.

[**0294**] Next, the cluster control program **187** makes preparations for a failover by loading, in the virtual machine (**2**) **180**, the programs for services that the failed virtual machine (**0**) **130** had been providing (S**182**). Then, the virtual machine (**0**) **130** is separated off from the computer system. Then, access from clients (not shown) to the virtual machine (**0**) **130** is stopped.

[**0295**] Subsequently, the cluster control program **187** notifies the administrator that a fault has occurred in the virtual machine (**0**) **130** and that preparation for taking over the work have been completed (S**183**).

[**0296**] Then, with an instruction from the administrator, the service is taken over from the virtual machine (**0**) **130** to the virtual machine (**2**) **180**.

[**0297**] **FIG. 23** is a flowchart of a process of rebooting a virtual machine according to the third embodiment. The flowchart describes an example in which the hypervisor **103** reboots the virtual machine (**0**) **130**, but other hypervisors and other virtual machines are capable of executing the same rebooting process.

[**0298**] First, the administrator gives an instruction from the control terminal **300** to reboot the stopped virtual machine (**0**) **130** (S**191**).

[**0299**] The virtual machine (**0**) **130** receives the reboot instruction from the control terminal **300** through the network **410** Actually, the hypervisor **103** receives the reboot instruction. (S**192**).

[**0300**] Subsequently, the hypervisor **103** reboots the virtual machine (**0**) **130** (S**193**).

[**0301**] After that, the administrator gives an instruction for a failback from the control terminal **300** (S**194**). With this failback instruction, the work taken over to the virtual machine (**2**) **180** is restarted in the virtual machine (**0**) **130**. Specifically, the program of services that the rebooted virtual machine had been providing is started in the virtual machine (**0**) **130**. Then, the virtual machine (**0**) **130** is connected to the computer system. Thus, access to the virtual machine (**0**) **130** from clients restarts.

Fourth Embodiment

[**0302**] A fourth embodiment of this invention differs from the first embodiment in that the control terminal **300** does not have a virtual path control table but the storage system **200** has a virtual path control table **266**.

[0303] **FIG. 24** is a functional block diagram of a computer system according to the fourth embodiment.

[0304] The computer system of the fourth embodiment includes a server system (**0**) **100**, a server system (**1**) **150**, a storage system **200**, and a control terminal **300**. The same components as those described in the first embodiment are shown at the same reference numerals and not described here again.

[0305] Functionally, the server system (**0**) **100** and the server system (**1**) **150** can be roughly divided into a physical layer, a hypervisor layer, and a virtual machine layer. The configuration and functions of parts of each layer are the same as those described in the first embodiment.

[0306] Also, functionally, the storage system **200** can be roughly divided into a physical layer, a hypervisor layer, and a virtual storage layer. The configuration and functions of parts of each layer are the same as those described in the first embodiment.

[0307] The storage system **200** of this embodiment has the virtual path control table **266**. The storage hypervisors **214** and **224** control the virtual configuration of the storage system **200** using the virtual path control table **266**. In other words, in the fourth embodiment, the storage system **200** having the virtual path control table **266** includes a control unit (not shown) containing connection information that defines connections between the virtual machines and the virtual storage systems (the virtual path control table **266**).

[0308] The virtual path control table **266** describes the relations between the virtual machines and the virtual storage systems. Specifically, the virtual path control table **266** has the same configuration and contains the same control information as the virtual path control table **310**, shown in **FIG. 5**, of the first embodiment.

[0309] The storage hypervisors **214** and **224** generate the virtual path control table **266** by collecting together the control information contained in the virtual I/O adaptor control table **110** of the server system (**0**) **100**, the control information contained in the virtual I/O adaptor control table **160** of the server system (**1**) **150**, and the control information contained in the virtual channel adaptor control table **260** of the storage system **200**.

[0310] The control terminal **300** is a computer apparatus that manages the computer system and includes a CPU, a memory, an input/output device, and an interface in an integrated fashion. The control terminal **300** is a service processor (SVP). The administrator can manage the computer system by operating the control terminal **300**.

[0311] The interface of the control terminal **300** is connected to the storage system **200**. Alternatively, instead of being connected directly to the storage system **200**, the control terminal **300** may be connected to the storage system **200** via the network **410**.

[0312] While **FIG. 24** describes an example in which two server systems **100** and **150** and one storage system **200** are connected, three or more server systems may be provided, and two or more storage systems may be provided. In such a case, the control terminal **300** may be connected to any of the storage systems, but is preferably connected to a storage system that possesses the virtual path control table **266**. A plurality of storage systems may possess virtual path control tables **266**. The table can thus be duplicated in case of a fault.

Fifth Embodiment

[0313] A fifth embodiment of this invention differs from the first embodiment in that the control terminal **300** does not have a virtual path control table but the server system (**0**) **100** has a virtual path control table **116**.

[0314] **FIG. 25** is a functional block diagram of a computer system according to the fifth embodiment.

[0315] The computer system of the fifth embodiment includes a server system (**0**) **100**, a server system (**1**) **150**, a storage system **200**, and a control terminal **300**. The same components as those described in the first embodiment are shown at the same reference numerals and not described here again.

[0316] Functionally, the server system (**0**) **100** and the server system (**1**) **150** can be roughly divided into a physical layer, a hypervisor layer, and a virtual machine layer. The configuration and functions of parts of each layer are the same as those described in the first embodiment.

[0317] The server system (**0**) **100** of this embodiment has the virtual path control table **116**. The hypervisor **103** controls the virtual configuration of the computer system using the virtual path control table **116**. In other words, in the fifth embodiment, the server system (**0**) **100** having the virtual path control table **116** includes a control unit (not shown) containing connection information that defines connections between the virtual machines and the virtual storage systems (the virtual path control table **116**).

[0318] The virtual path control table **116** describes the relations between the virtual machines and the virtual storage systems. Specifically, the virtual path control table **116** has the same configuration and contains the same control information as the virtual path control table **310** shown in **FIG. 5** of the first embodiment.

[0319] The hypervisor **103** generates the virtual path control table **116** by collecting together the control information contained in the virtual I/O adaptor control table **110** of the server system (**0**) **100**, the control information contained in the virtual I/O adaptor control table **160** of the server system (**1**) **150**, and the control information contained in the virtual channel adaptor control table **260** of the storage system **200**.

[0320] Functionally, the storage system **200** can be roughly divided into a physical layer, a hypervisor layer, and a virtual storage layer. The configuration and functions of parts of each layer are the same as those described in the first embodiment.

[0321] The control terminal **300** is a computer apparatus that manages the computer system and includes a CPU, a memory, an input/output device, and an interface in an integrated fashion. The control terminal **300** is a service processor (SVP). The administrator can manage the computer system by operating the control terminal **300**.

[0322] The interface of the control terminal **300** is connected with the server systems **100** and **150** and with the storage system **200** through the network **410**. This interface sends and receives control signals and control information (the contents of the various control tables) to and from the

systems connected through the network **410**. The control terminal **300** may be connected directly to the server system (**0**) **100**.

[**0323**] While **FIG. 25** describes an example in which two server systems **100** and **150** and one storage system **200** are connected, three or more server systems may be provided, and two or more storage systems may be provided. In such a case, the control terminal **300** may be connected to any of the server systems, but is preferably connected to a server system that possesses the virtual path control table **116**. A plurality of server systems may possess virtual path control tables **116**. The table can thus be duplicated in case of a fault.

Sixth Embodiment

[**0324**] A sixth embodiment of this invention differs from the first embodiment described earlier in that the I/O adaptors and the channel adaptors are not directly connected by the I/O channels **400** but are connected via I/O channel switches **401**.

[**0325**] **FIG. 26** is a block diagram showing the hardware configuration of a computer system according to the sixth embodiment.

[**0326**] The computer system according to the sixth embodiment includes a server system (**0**) **100**, a server system (**1**) **150**, a storage system **200**, a control terminal **300**, and the I/O channel switches **401**. The same components as those described in the first embodiment are shown at the same reference numerals and are not described again here.

[**0327**] Application programs run on the server system (**0**) **100** and the server system (**1**) **150**. The configurations and functions of parts of the server system (**0**) **100** and the server system (**1**) **150** are the same as those described in the first embodiment.

[**0328**] An I/O adaptor (**0**) **106** and an I/O adaptor (**1**) **107** are connected with the I/O channel switches **401** through the I/O channels **400**.

[**0329**] When the I/O adaptor **106** or **107** sends a data input/output request and output data to the storage system **200**, the I/O channel switch **401** receives the data input/output request and output data. Then, the I/O channel switch **401** checks the destination of the data input/output request and output data and transfers the data input/output request and output data to the destination storage system **200**.

[**0330**] The I/O adaptors **106** and **107** receive data stored in the storage system **200** via the I/O channel switches **401**.

[**0331**] In the sixth embodiment, too, two I/O adaptors are provided, but more I/O adaptors may be provided. The two I/O adaptors **106** and **107** operate independently. The processing system is thus duplicated so that access from the server system (**0**) **100** to the storage system **200** is not stopped even when one I/O adaptor fails.

[**0332**] The storage system **200** stores data required for operations of the server systems **100** and **150**. The configuration and functions of parts of the storage system **200** are the same as those described in the first embodiment.

[**0333**] The channel adaptors (**0**) **231** to (**3**) **234** are connected with the I/O channel switches **401** through the I/O channels **400**. The I/O channel switches **401** are connected also with the server system (**0**) **100** and the server system (**1**) **150**.

[**0334**] The channel adaptor (**0**) **231** and the channel adaptor (**1**) **232** are connected with the server system (**0**) **100** through the I/O channels **400** and the I/O channel switches **401**. The channel adaptors **231** and **232** receive data input/output requests and output data from the server system (**0**) **100** and send data stored in the storage system **200**.

[**0335**] Similarly, the channel adaptor (**2**) **233** and the channel adaptor (**3**) **234** are connected with the server system (**1**) **150** through the I/O channels **400** and the I/O channel switches **401**. The channel adaptors **233** and **234** receive data input/output requests and output data from the server system (**1**) **150** and send data stored in the storage system **200**.

[**0336**] The storage system **200** thus has a plurality of channel adaptors. The plurality of channel adaptors **231** to **234** operate independently. The processing system is thus duplicated so that access to the storage system **200** from the server systems **100** and **150** does not stop even when one channel adaptor fails.

[**0337**] The control terminal **300** is a computer apparatus that manage in an integrated fashion. The control terminal **300** has a virtual path control table **317** shown in **FIG. 27** of a type different from that described in the first embodiment. This is because the paths pass via the I/O channel switches **401** in the sixth embodiment.

[**0338**] The configuration and functions of the other parts of the control terminal **300** are the same as those described in the first embodiment.

[**0339**] The I/O channels **400** are formed of a communication medium that can make communication according to a protocol suitable for data transfer, e.g., the Fibre Channel protocol.

[**0340**] In the sixth embodiment, the I/O channels **400** connect between the I/O adaptors of the server systems **100** and **150** and the I/O channel switches **401**, and between the channel adaptors of the storage system **200** and the I/O channel switches **401**.

[**0341**] The I/O channel switches **401** are packet transfer devices having a plurality of ports. For example, when the Fibre Channel protocol is used for the I/O channels **400**, SAN switches are used as the I/O channel switches **401**.

[**0342**] The I/O channel switches **401** each have ports respectively connected to the I/O channels **400** that connect with the I/O adaptors or the channel adaptors. The I/O channel switches **401** hold routing information. The routing information is a routing table (not shown) used to judge destinations of transferred packets. The I/O channel switches **401** refer to the routing table to judge the destination of a packet inputted to a port and sends the packet from a port connected to the destination I/O adaptor or channel adaptor.

[**0343**] The I/O channel switches **401** have a zone configuration table shown in **FIG. 30**. The zone configuration table defines whether communication is possible or not between ports of the I/O channel switches **401**. The I/O channel switches **401** transfer packets only between ports

defined as being capable of making communication. Therefore, packet transfer is implemented only between particular apparatuses. The zone configuration table and the routing table may be formed as a single table.

[0344] The I/O channel switches **401** are connected also to the network **410**. The I/O channel switches **401** are connected also to each other through an interconnecting line **402**. The I/O channel switches **401** exchange the routing information for packet transfer through the interconnecting line **402**. The I/O channel switches **401** thus share the routing information.

[0345] In the sixth embodiment, two I/O channel switches **401** are provided. The two I/O channel switches **401**, too, operate independently. The processing system is thus duplicated so that access from the server system (**0**) **100** to the storage system **200** is not stopped even when one I/O channel switch fails.

[0346] The I/O channel switches **401** are also capable of monitoring mutual operating status using the interconnecting line **402**. A method similar to the cluster control programs described in the third embodiment can be adopted for the monitoring of operating conditions and the handling of faults.

[0347] The network **410** connects the server system (**0**) **100**, the server system (**1**) **150**, the storage system **200**, the control terminal **300**, and the I/O channel switches **401**. The network **410** is configured so that control signals and control information can be communicated among computers according to, e.g., the TCP/IP protocol, where Ethernet is used, for example.

[0348] While **FIG. 26** shows an example connecting two server systems **100** and **150** and one storage system **200**, three or more server systems may be provided and two or more storage systems may be provided.

[0349] **FIG. 27** is a diagram illustrating the virtual path control table **317** according to the sixth embodiment.

[0350] The virtual path control table **317** contains I/O channel switch port numbers **318** and **319** in addition to the items contained in the virtual path control table **310** described in the first embodiment.

[0351] The I/O channel port numbers (storage side) **318** are port numbers of the I/O channel switches **401** that are connected to the channel adaptors **231** to **234**.

[0352] The I/O channel port numbers (server side) **319** are port numbers of the I/O channel switches **401** that are connected to the I/O adaptors **106** to **157**.

[0353] In the sixth embodiment, managing the virtual paths requires additionally managing the port numbers of the I/O channel switches **401** because the I/O adaptors **106** to **157** and the channel adaptors **231** to **234** are connected only with the I/O channel switches **401**.

[0354] **FIG. 28** is a flowchart of a cable connection process in the computer system according to the sixth embodiment. This cable connection process is performed in the server system (**0**) **100**. The same process is performed also in the server system (**1**) **150** and the storage system **200**.

[0355] First, an I/O adaptor of the server system (**0**) **100** (a channel adaptor of the storage system **200**) detects that a connection has been made with an I/O channel switch **401** (S**191**).

[0356] Next, the server system (**0**) **100** exchanges physical addresses with the I/O channel switch **401** (S**192**). The addresses exchanged in the step S**192** are configured so that the ports of the I/O channel switches **401** can be identified.

[0357] The physical addresses exchanged in the step S**192** can be any addresses that uniquely identify the ports of the connected I/O channel switch **401**. For example, World Wide Names (WWNs) according to the Fibre Channel protocol or MAC addresses according to the iSCSI protocol are exchanged.

[0358] Next, the hypervisor **103** notifies the control terminal **300** of the obtained cable connection status (the physical address of the I/O adaptor and the physical address of the I/O channel switch) through the network **410** (S**193**).

[0359] Then, the control terminal **300** registers the correspondence between the I/O adaptor and the I/O channel switch **401** in the virtual path control table **317**. Specifically, from the obtained physical addresses, the control terminal **300** registers identifiers of the ports and adaptors in the channel adaptor number **313**, the I/O adaptor number **314**, the I/O channel port number (storage side) **318**, and the I/O channel port number (server side) **319**.

[0360] **FIG. 29** is a flowchart of a process of creating a virtual machine in the computer system according to the sixth embodiment.

[0361] In the virtual machine creation process of the sixth embodiment, the process steps from the virtual machine creation instruction (S**111**) to the path creation between the I/O adaptor and the virtual I/O adaptor (S**121**) are the same as the corresponding process steps of the virtual machine creation process of the first embodiment shown in **FIG. 10**.

[0362] After the control terminal **300** has registered the virtual I/O adaptor number **315** and the virtual machine number **316** in the virtual path control table **317** (S**121**), a procedure of connecting the I/O adaptor and the channel adaptor is performed (S**201**).

[0363] Specifically, the channel adaptor and the I/O adaptor that are capable of communication are identified by referring to the channel adaptor number **313** and the I/O adaptor number **314** in the virtual path control table **317**. Then, a port corresponding to the channel adaptor and a port corresponding to the I/O adaptor are specified, and whether communication between the ports is possible is checked. The result of the judgement is set in the zone configuration table shown in **FIG. 30** of the I/O channel switch **401**. With this zoning process, the I/O channel switch **401** transfers packets only between particular ports (between particular apparatuses).

[0364] Then, whether a redundant path should be created is checked (S**122**). Then, whether a redundant configuration should be created is checked (S**123**). These process steps S**122** and S**123** are the same as those of the virtual machine creation process of the first embodiment shown in **FIG. 10**.

[0365] **FIG. 30** is a diagram showing a configuration of the zone configuration table **1300** according to the sixth embodiment.

[0366] The zone configuration table **1300** contains input port numbers **1301**, output port numbers **1302**, and information as to whether communication is possible between the ports.

[0367] For example, a packet inputted to the input port (**0**) can be outputted from the output port (**1**) but cannot be outputted from the output port (n). Therefore, a packet can be transferred from a system connected to the input port (**0**) to a system connected to the output port (**1**), but a packet cannot be transferred from a system connected to the input port (**0**) to a system connected to the output port (n).

[0368] In other words, when the destination of a packet inputted to the input port (**0**) is a system connected to the output port (n), the packet cannot be transferred to that system.

[0369] Also in the sixth embodiment, the virtual path control table **317** may be possessed by the server systems **100** and **150**, or by the storage system **200**. Also, the I/O channel switches **401** may possess the virtual path control table **317**. When the I/O channel switches **401**, connected to all of the server systems **100** and **150** and the storage system **200**, possess the virtual path control table **317** to control the computer system, then it is not necessary to provide the control terminal **300** in the computer system.

[0370] Thus, the hypervisor **103**, the hypervisor **153**, the storage hypervisor **214**, the storage hypervisor **224**, and the I/O channel switches **401** cooperate with one another to implement an I/O channel redundant configuration. Also, with the zoning, the security between the virtual machines and between the virtual storage systems is ensured also in the I/O channels.

[0371] The description so far has mentioned that a plurality of server systems and a plurality of storage systems may be provided. The embodiments of this invention have shown examples in which one server system is logically partitioned into a plurality of virtual machines, but, needless to say, this invention does not depend on how virtual machines are implemented.

[0372] For example, this invention is applicable also to implementation of virtual machines as shown in **FIG. 31**. A server system (**0**) **100** has server resources **3100** and **3101**. Similarly, a server system (**1**) **150** has server resources **3102** and **3103**. Each of the server resources **3100**, **3101**, **3102**, and **3103** includes a CPU, a memory, etc.

[0373] Then, the resource **3100** of the server system (**0**) and the resource **3102** of the server system (**1**) may be extracted to create a virtual machine (**4**) **3104**. Similarly, the resource **3101** of the server system (**0**) and the resource **3103** of the server system (**1**) may be extracted to create a virtual machine (**5**) **3105**.

[0374] In a similar way, one virtual storage system can be configured by extracting resources of a plurality of storage systems.

[0375] This invention is applicable also to such virtual machine and virtual storage system configurations.

[0376] While the present invention has been described in detail and pictorially in the accompanying drawings, the present invention is not limited to such detail but covers various obvious modifications and equivalent arrangements, which fall within the purview of the appended claims.

What is claimed is:

1. A computer system comprising a server system on which an application program runs, a storage system that stores data used by the server system, an I/O channel that connects the server system and the storage system, and a control terminal that manages control information about the computer system,

the server system comprising: server resources including a CPU, a memory, and an I/O adaptor; a first hypervisor that logically partitions the server resources to create and run an independently operating virtual machine; and a virtual I/O adaptor control table that stores control information about a virtual I/O adaptor generated by the first hypervisor,

the storage system comprising: storage resources including a CPU, a disk cache, a channel adaptor, and a physical disk; a second hypervisor that logically partitions the storage resources to create and run an independently operating virtual storage system; and a virtual channel adaptor control table that stores control information about a virtual channel adaptor generated by the second hypervisor,

the I/O channel connecting the I/O adaptor and the channel adaptor,

the control terminal having a virtual path control table that defines a connection between the virtual machine and the virtual storage system, generating the virtual path control table based on the information stored in the virtual I/O adaptor control table and the information stored in the virtual channel adaptor control table.

2. A computer system comprising a computer and a storage system that stores data,

the computer comprising: a first control unit that logically partitions a first resource provided in the computer to create and run an independently operating virtual machine; and first information that is used to manage the first resource,

the storage system comprising: a second control unit that logically partitions a second resource provided in the storage system to create and run an independently operating virtual storage system; and second information that is used to manage the second resource provided in the storage system,

wherein a relation between the virtual machine and the virtual storage system is defined based on the first information and the second information.

3. The computer system according to claim 2, wherein:

the first resource comprises an I/O adaptor, and additionally comprises a CPU and a memory when required; and

the second resource comprises a channel adaptor, and additionally comprises a CPU, a disk cache, and a physical disk when required.

4. The computer system according to claim 3, wherein a packet transfer device that transfers a packet sent/received between the I/O adaptor and the channel adaptor is provided between the I/O adaptor and the channel adaptor.

5. The computer system according to claim 2, wherein

at least one of the computer and the storage system holds third information that is used to define a connection between the virtual machine and the virtual storage system, and generates the third information based on the first information and the second information.

6. The computer system according to claim 2, further comprising a control terminal that holds control information about the computer system, wherein

the control terminal holds third information that is used to define a connection between the virtual machine and the virtual storage system, and generates the third information based on the first information and the second information.

7. The computer system according to claim 2, further comprising a control unit holding third information that is used to define a connection between the virtual machine and the virtual storage system,

wherein the control unit generates, based on the first information and the second information, the third information including routing information about a physical path between the virtual computer and the virtual storage system.

8. The computer system according to claim 7, wherein:

the first resource includes an I/O adaptor;

the second resource includes a channel adaptor; and

the routing information about the physical path included in the third information comprises a correspondence between the I/O adaptor and the channel adaptor.

9. The computer system according to claim 8, wherein a connection between the first resource and the second resource is defined by a correspondence between the I/O adaptor and the channel adaptor included in the third information.

10. The computer system according to claim 7, wherein:

the first resource includes an I/O adaptor;

the second resource includes a channel adaptor;

the first control unit generates a virtual I/O adaptor logically partitioned the I/O adaptor as a resource in the virtual machine;

the second control unit generates a virtual channel adaptor logically partitioned the channel adaptor as a resource in the virtual storage system;

the third information includes information about connections between the virtual machine, the virtual I/O adaptor, the I/O adaptor, the channel adaptor, the virtual channel adaptor and the virtual storage system; and

in the third information, the control unit registers a relation between the I/O adaptor and the channel adaptor based on the connection between the computer and the storage system, registers a relation between the virtual machine, the virtual I/O adaptor, and the I/O adaptor based on an allocation of the first resource, and registers a relation between the virtual storage system, the virtual channel adaptor, and the channel adaptor based on an allocation of the second resource.

11. A computer connected to a storage system that stores data, comprising:

a first control unit that logically partitions a first resource provided in the computer to create and run an independently operating virtual machine; and

first information that is used to manage the first resource,

wherein a relation between the virtual machine and a virtual storage system created in the storage system is defined based on the first information and second information that is used to manage a second resource provided in the storage system.

12. The computer according to claim 11, wherein:

the storage system comprises the second information and a second control unit that logically partitions the second resource to create and run an independently operating virtual storage system; and

the computer holds third information that is used to define a connection between the virtual machine and the virtual storage system, and generates the third information based on the first information and the second information.

13. A storage system that stores data and is connected to a computer, comprising:

a second control unit that logically partitions a second resource provided in the storage system to create and run an independently operating virtual storage system; and

second information that is used to manage the second resource,

wherein a relation between the virtual storage system and a virtual machine created in the computer is defined based on the second information and first information that is used to manage a first resource provided in the computer.

14. The storage system according to claim 13 wherein:

the computer comprises the first information and a first control unit that logically partitions the first resource to create and run an independently operating virtual machine; and

the storage system holds third information that is used to define a connection between the virtual machine and the virtual storage system, and generates the third information based on the first information and the second information.

15. A control terminal that manages control information about a computer system comprising a computer and a storage system that stores data,

the computer comprising a first control unit that logically partitions a first resource provided in the computer to create and run an independently operating virtual machine, and first information that is used to manage the first resource,

the storage system comprising a second control unit that logically partitions a second resource provided in the storage system to create and run an independently operating virtual storage system, and second information that is used to manage the second resource,

wherein a relation between the virtual machine and the virtual storage system is defined based on the first information and the second information.

16. The control terminal according to claim 15, wherein the control terminal holds third information that is used to define a connection between the virtual machine and the virtual storage system, and generates the third information based on the first information and the second information.

* * * * *