IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
AUSTIN DIVISION

CROSSROADS SYSTEMS, INC.,	§	
	§	
Plaintiff,	§	
	§	CIVIL ACTION NO. 1:14-cv-00149
v.	§	
	§	JURY DEMANDED
NETAPP, INC.,	§	
	§	
Defendant.	§	

PLAINTIFF CROSSROADS SYSTEMS, INC.'S
FIRST AMENDED COMPLAINT FOR PATENT INFRINGEMENT

THE PARTIES

1. Pursuant to Federal Rule of Civil Procedure 15(a)(1)(B), Plaintiff Crossroads Systems, Inc. ("Crossroads") hereby submits its First Amended Complaint for Patent Infringement as a matter of course within 21 days after service of NetApp, Inc.'s Answer and Affirmative Defenses (Dkt. No. 21).

2. Crossroads is a corporation incorporated under the laws of the State of Delaware and has its principal place of business at 11000 North MoPac Expressway, Austin, Texas 78759.

3. Upon information and belief, Defendant NetApp, Inc. ("Defendant" or "NetApp") is a California corporation with a principal place of business of 495 East Java Drive, Sunnyvale, California 94089.

JURISDICTION AND VENUE

3. This action arises under the laws of the United States, more specifically under 35 U.S.C. § 100, *et seq*. Subject matter jurisdiction is proper in this Court pursuant to 28 U.S.C. §§ 1331 and 1338.

4. Personal jurisdiction and venue are proper in this district under 28 U.S.C. §§ 1391 and 1400(b). Upon information and belief, Defendant NetApp has established minimum contacts with this forum such that the exercise of jurisdiction over Defendant would not offend traditional notions of fair play and substantial justice.

5. This Court has personal jurisdiction over NetApp. Upon information and belief, NetApp regularly conducts business in the State of Texas and in this judicial district and is subject to the jurisdiction of this Court. Upon information and belief, NetApp has been doing business in Texas and this judicial district by distributing, marketing, selling and/or offering for sale its products, including, but not limited to, products that practice the subject matter claimed in United States Patent Nos. 6,425,035 ("the '035 Patent"), 7,934,041 ("the '041 Patent"), 7,051,147 ("the '147 Patent"), and 7,987,311 ("the '311 Patent) (collectively "the Patents-In-Suit"), and/or regularly doing or soliciting business and/or engaging in other persistent courses of conduct in and/or directed to Texas and this judicial district.

COUNT 1: INFRINGEMENT OF U.S. PATENT NO. 6,425,035

6. Crossroads incorporates by reference the allegations set forth in the preceding paragraphs.

7. On July 23, 2002, the '035 Patent was duly and legally issued. A true and correct copy of the '035 Patent is attached hereto as Exhibit A. Crossroads is the assignee and the owner of all right, title, and interest in and to the '035 Patent. The '035 Patent is entitled to a presumption of validity.

8. On information and belief, Defendant has directly infringed the '035 Patent. On information and belief, Defendant continues to directly infringe the '035 Patent.

9. Specifically, on information and belief, Defendant has directly infringed the '035 Patent by making, using, offering for sale, selling and/or importing into the United States certain of its products including at least the following: NetApp E5400 Series Storage Arrays (including but not limited to the E5460, E5424, and E5412), E5500 Series Storage Arrays with FC, iSCSI and InfiniBand interfaces (including but not limited to the E5560, E5524, and E5512), E2700 Storage Systems with FC and iSCSI interfaces (including but not limited to the E2760, E2724, E2712), E2600 Storage Systems with FC and iSCSI interfaces (including but not limited to the E2600-60, E2600-24, E2600-12), EF550 Flash Arrays with FC, iSCSI and InfiniBand Host interfaces, EF540 Flash Arrays, FAS2200 Series (including but not limited to FAS2220 and FAS2240), FAS3200 Series (including but not limited to FAS3270, FAS3250, FAS3240, FAS3220, FAS3210), FAS6200 Series (including but not limited to FAS6210, FAS6220, FAS6240, FAS6250, FAS6280, FAS6290), FAS8000 Series (including but not limited to FAS8060, FAS8040, FAS8020), V3200 Series Storage Controllers (including but not limited to V3220, V3240, V3250, V3270), V6200 Series Storage Controllers (including but not limited to V6210, V6220, V6240, V6250, V6280, V6290) and the Data ONTAP Operating System (including but not limited to Data ONTAP 8.2), hereinafter "the Accused Products".

10. Further, on information and belief, Defendant has been and now is indirectly infringing by way of inducing infringement of the '035 Patent with knowledge of the '035 Patent by making, offering for sale, selling, importing into the United States, marketing, supporting, providing product instruction and/or advertising certain of its products, including the Accused Products, and Defendant knew that its actions were inducing end users to infringe the '035 Patent.

11. Further, on information and belief, Defendant has been and now is indirectly infringing by way of contributing to the infringement by end users of the ’035 Patent by selling, offering to sell and/or importing into the United States components, including the Accused Products, knowing the components to be especially made or especially adapted for use in the infringement of the ’035 Patent. Such components are not a staple article or commodity of commerce suitable for substantial non-infringing uses.

12. Defendant has been on constructive and/or actual notice of the ’035 Patent since at least as early as October 2002, and Defendant has not ceased its infringing activities. The infringement of the ’035 Patent by Defendant has been and continues to be willful and deliberate.

13. Crossroads has been irreparably harmed by Defendant’s acts of infringement of the ’035 Patent, and will continue to be harmed unless and until Defendant’s acts of infringement are enjoined and restrained by order of this Court.

14. As a result of the acts of infringement of the ’035 Patent by Defendant, Crossroads has suffered and will continue to suffer damages in an amount to be proven at trial.

COUNT 2: INFRINGEMENT OF U.S. PATENT NO. 7,934,041

15. Crossroads incorporates by reference the allegations set forth in the preceding paragraphs.

16. On April 26, 2011, the ’041 Patent was duly and legally issued. A true and correct copy of the ’041 Patent is attached hereto as Exhibit B. Crossroads is the assignee and the owner of all right, title, and interest in and to the ’041 Patent. The ’041 Patent is entitled to a presumption of validity.

17. On information and belief, Defendant has directly infringed the ’041 Patent. On information and belief, Defendant continues to directly infringe the ’041 Patent.

18. Specifically, on information and belief, Defendant has directly infringed the '041 Patent by making, using, offering for sale, selling and/or importing into the United States certain of its products including at least the Accused Products.

19. Further, upon information and belief, Defendant has been and now is indirectly infringing by way of inducing infringement of the '041 Patent with knowledge of the '041 Patent by making, offering for sale, selling, importing into the United States, marketing, supporting, providing product instruction and/or advertising certain of its products, including the Accused Products, and Defendant knew that its actions were inducing end users to infringe the '041 Patent.

20. Further, upon information and belief, Defendant has been and now is indirectly infringing by way of contributing to the infringement by end users of the '041 Patent by selling, offering to sell and/or importing into the United States components, including the Accused Products, knowing the components to be especially made or especially adapted for use in the infringement of the '041 Patent. Such components are not a staple article or commodity of commerce suitable for substantial non-infringing uses.

21. Defendant has been on constructive and/or actual notice of the '041 Patent since at least as early as May 2011, and Defendant has not ceased its infringing activities. The infringement of the '041 Patent by Defendant has been and continues to be willful and deliberate.

22. Crossroads has been irreparably harmed by Defendant's acts of infringement of the '041 Patent, and will continue to be harmed unless and until Defendant's acts of infringement are enjoined and restrained by order of this Court.

23. As a result of the acts of infringement of the '041 Patent by Defendant, Crossroads has suffered and will continue to suffer damages in an amount to be proven at trial.

COUNT 3: INFRINGEMENT OF U.S. PATENT NO. 7,051,147

24. Crossroads incorporates by reference the allegations set forth in the preceding paragraphs.

25. On May 23, 2006, the ’147 Patent was duly and legally issued. A true and correct copy of the ’147 Patent is attached hereto as Exhibit C. Crossroads is the assignee and the owner of all right, title, and interest in and to the ’147 Patent. The ’147 Patent is entitled to a presumption of validity.

26. On information and belief, Defendant has directly infringed the ’147 Patent. On information and belief, Defendant continues to directly infringe the ’147 Patent.

27. Specifically, on information and belief, Defendant has directly infringed the ’147 Patent by making, using, offering for sale, selling and/or importing into the United States certain of its products including at least the V3200 Series Storage Controllers (including but not limited to V3220, V3240, V3250, V3270) and V6200 Series Storage Controllers (including but not limited to V6210, V6220, V6240, V6250, V6280 and V6290) and the Data ONTAP operating system, hereinafter “the Accused Fibre-to-Fibre Products”.

28. Further, upon information and belief, Defendant has been and now is indirectly infringing by way of inducing infringement of the ’147 Patent with knowledge of the ’147 Patent by making, offering for sale, selling, importing into the United States, marketing, supporting, providing product instruction and/or advertising certain of its products, including the Accused Fibre-to-Fibre Products, and Defendant knew that its actions were inducing end users to infringe the ’147 Patent.

29. Further, upon information and belief, Defendant has been and now is indirectly infringing by way of contributing to the infringement by end users of the ’147 Patent by selling,

offering to sell and/or importing into the United States components, including the Accused Fibre-to-Fibre Products, knowing the components to be especially made or especially adapted for use in the infringement of the '147 Patent. Such components are not a staple article or commodity of commerce suitable for substantial non-infringing uses.

30. Defendant has been on constructive and/or actual notice of the '147 Patent since at least as early as August 2006, and Defendant has not ceased its infringing activities. The infringement of the '147 Patent by Defendant has been and continues to be willful and deliberate.

31. Crossroads has been irreparably harmed by Defendant's acts of infringement of the '147 Patent, and will continue to be harmed unless and until Defendant's acts of infringement are enjoined and restrained by order of this Court.

32. As a result of the acts of infringement of the '147 Patent by Defendant, Crossroads has suffered and will continue to suffer damages in an amount to be proven at trial.

COUNT 4: INFRINGEMENT OF U.S. PATENT NO. 7,987,311

33. Crossroads incorporates by reference the allegations set forth in the preceding paragraphs.

34. On July 26, 2011, the '311 Patent was duly and legally issued. A true and correct copy of the '311 Patent is attached hereto as Exhibit D. Crossroads is the assignee and the owner of all right, title, and interest in and to the '311 Patent. The '311 Patent is entitled to a presumption of validity.

35. On information and belief, Defendant has directly infringed the '311 Patent. On information and belief, Defendant continues to directly infringe the '311 Patent.

36. Specifically, on information and belief, Defendant has directly infringed the ’311 Patent by making, using, offering for sale, selling and/or importing into the United States certain of its products including at least the Accused Products.

37. Further, on information and belief, Defendant has been and now is indirectly infringing by way of inducing infringement of the ’311 Patent with knowledge of the ’311 Patent by making, offering for sale, selling, importing into the United States, marketing, supporting, providing product instruction and/or advertising certain of its products, including the Accused Products, and Defendant knew that its actions were inducing end users to infringe the ’311 Patent.

38. Further, on information and belief, Defendant has been and now is indirectly infringing by way of contributing to the infringement by end users of the ’311 Patent by selling, offering to sell and/or importing into the United States components, including the Accused Products, knowing the components to be especially made or especially adapted for use in the infringement of the ’311 Patent. Such components are not a staple article or commodity of commerce suitable for substantial non-infringing uses.

39. On information and belief, Defendant has been on constructive and/or actual notice of the ’311 Patent. Thus, the infringement of the ’311 Patent by Defendant has been and continues to be willful and deliberate.

40. Crossroads has been irreparably harmed by Defendant’s acts of infringement of the ’311 Patent, and will continue to be harmed unless and until Defendant’s acts of infringement are enjoined and restrained by order of this Court.

41. As a result of the acts of infringement of the ’311 Patent by Defendant, Crossroads has suffered and will continue to suffer damages in an amount to be proven at trial.

DEMAND FOR JURY TRIAL

Crossroads hereby demands a trial by jury on all issues.

PRAYER FOR RELIEF

WHEREFORE, Crossroads requests this Court enter judgment as follows:

A. That Defendant has infringed the ’035 Patent;

B. That such infringement of the ’035 Patent by Defendant has been willful;

C. That Defendant accounts for and pays to Crossroads all damages caused by the infringement of the ’035 Patent;

D. That Crossroads receive enhanced damages from Defendant in the form of treble damages, pursuant to 35 U.S.C. § 284 based on Defendant’s willful infringement of the ’035 Patent;

E. That Crossroads be granted pre-judgment and post-judgment interest on the damages caused to it by reason of Defendant’s infringement of the ’035 Patent, including pre-judgment and post-judgment interest on any enhanced damages or attorneys’ fees award;

F. That Defendant has infringed the ’041 Patent;

G. That such infringement of the ’041 Patent by Defendant has been willful;

H. That Defendant accounts for and pays to Crossroads all damages caused by the infringement of the ’041 Patent;

I. That Crossroads receive enhanced damages from Defendant in the form of treble damages, pursuant to 35 U.S.C. § 284 based on Defendant’s willful infringement of the ’041 Patent;

J. That Crossroads be granted pre-judgment and post-judgment interest on the damages caused to it by reason of Defendant's infringement of the '041 Patent, including pre-judgment and post-judgment interest on any enhanced damages or attorneys' fees award;

K. That Defendant has infringed the '147 Patent;

L. That such infringement of the '147 Patent by Defendant has been willful;

M. That Defendant accounts for and pays to Crossroads all damages caused by the infringement of the '147 Patent;

N. That Crossroads receive enhanced damages from Defendant in the form of treble damages, pursuant to 35 U.S.C. § 284 based on Defendant's willful infringement of the '147 Patent;

O. That Crossroads be granted pre-judgment and post-judgment interest on the damages caused to it by reason of Defendant's infringement of the '147 Patent, including pre-judgment and post-judgment interest on any enhanced damages or attorneys' fees award;

P. That Defendant has infringed the '311 Patent;

Q. That such infringement of the '311 Patent by Defendant has been willful;

R. That Defendant accounts for and pays to Crossroads all damages caused by the infringement of the '311 Patent;

S. That Crossroads receive enhanced damages from Defendant in the form of treble damages, pursuant to 35 U.S.C. § 284 based on Defendant's willful infringement of the '311 Patent;

T. That Crossroads be granted pre-judgment and post-judgment interest on the damages caused to it by reason of Defendant's infringement of the '311 Patent, including pre-judgment and post-judgment interest on any enhanced damages or attorneys' fees award;

U. That Defendant pay Crossroads all of Crossroads' reasonable attorneys' fees and expenses;

V. That costs be awarded to Crossroads;

W. That Defendant, its agents, employees, representatives, successors and assigns, and those acting in privity or in concert with it, be preliminarily and permanently enjoined from further infringement of the '035 Patent;

X. That Defendant, its agents, employees, representatives, successors and assigns, and those acting in privity or in concert with it, be preliminarily and permanently enjoined from further infringement of the '041 Patent;

Y. That Defendant, its agents, employees, representatives, successors and assigns, and those acting in privity or in concert with it, be preliminarily and permanently enjoined from further infringement of the '147 Patent;

Z. That Defendant, its agents, employees, representatives, successors and assigns, and those acting in privity or in concert with it, be preliminarily and permanently enjoined from further infringement of the '311 Patent;

AA. That this is an exceptional case under 35 U.S.C. § 285; and

BB. That Crossroads be granted such other and further relief as the Court may deem just and proper under the circumstances.

Dated: April 15, 2014

Respectfully submitted,

By: */s/ Susan K. Knoll*

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ATTORNEYS FOR PLAINTIFF
CROSSROADS SYSTEMS, INC.

CERTIFICATE OF SERVICE

I certify that on April 15, 2014, I electronically filed the foregoing with the Clerk of Court using the CM/ECF system, which will send notification of such filing to all CM/ECF participants.

/s/ *Lynn Marlin*
Lynn Marlin

EXHIBIT A

US006425035B2

(12) **United States Patent**
Hoese et al.

(10) **Patent No.: US 6,425,035 B2**
(45) **Date of Patent: *Jul. 23, 2002**

(54) **STORAGE ROUTER AND METHOD FOR PROVIDING VIRTUAL LOCAL STORAGE**

(75) Inventors: **Geoffrey B. Hoese**, Austin; **Jeffry T. Russell**, Cibolo, both of TX (US)

(73) Assignee: **Crossroads Systems, Inc.**, Austin, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/965,335**

(22) Filed: **Sep. 27, 2001**

Related U.S. Application Data

(63) Continuation of application No. 09/354,682, filed on Jul. 15, 1999, which is a continuation of application No. 09/001,799, filed on Dec. 31, 1997, now Pat. No. 5,941,972.

(51) **Int. Cl.**[7] **G06F 13/00**

(52) **U.S. Cl.** **710/129**; 710/128; 710/8; 710/36; 710/105

(58) **Field of Search** 710/1–5, 8–13, 710/36–38, 105, 100–101, 126–131; 711/100, 112, 113; 714/42

(56) **References Cited**

U.S. PATENT DOCUMENTS

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6,343,324	B1	*	1/2002	Hubis et al.	709/229

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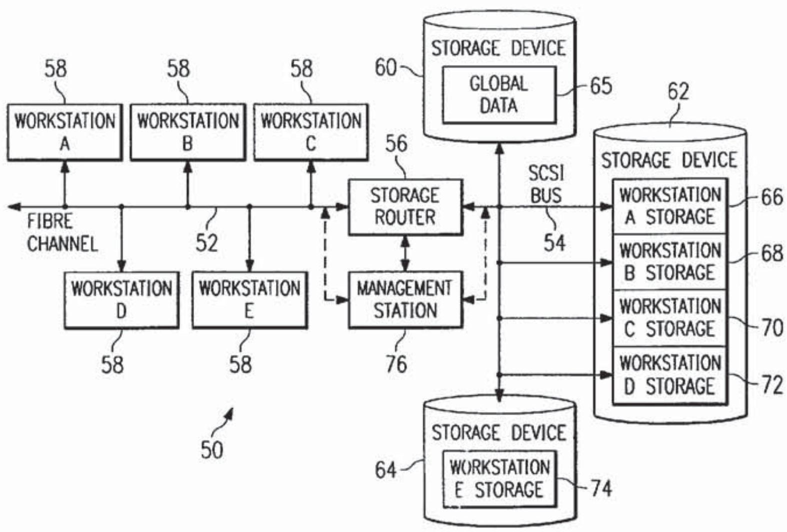
Primary Examiner—Christopher B. Shin
(74) *Attorney, Agent, or Firm*—Gray Cary Ware & Friedrich LLP

(57) **ABSTRACT**

A storage router (**56**) and storage network (**50**) provide virtual local storage on remote SCSI storage devices (**60, 62, 64**) to Fiber Channel devices. A plurality of Fiber Channel devices, such as workstations (**58**), are connected to a Fiber Channel transport medium (**52**), and a plurality of SCSI storage devices (**60, 62, 64**) are connected to a SCSI bus transport medium (**54**). The storage router (**56**) interfaces between the Fibre Channel transport medium (**52**) and the SCSI bus transport medium (**54**). The storage router (**56**) maps between the workstations (**58**) and the SCSI storage devices (**60, 62, 64**) and implements access controls for storage space on the SCSI storage devices (**60, 62, 64**). The storage router (**56**) then allows access from the workstations (**58**) to the SCSI storage devices (**60, 62, 64**) using native low level, block protocol in accordance with the mapping and the access controls.

14 Claims, 2 Drawing Sheets



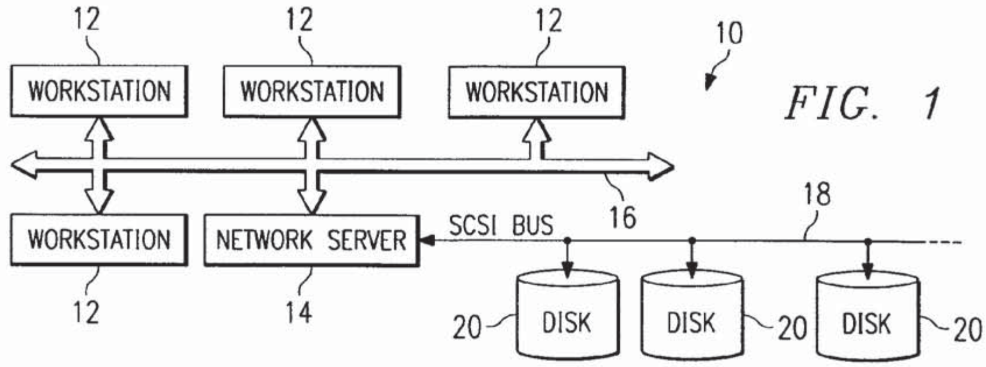


FIG. 1

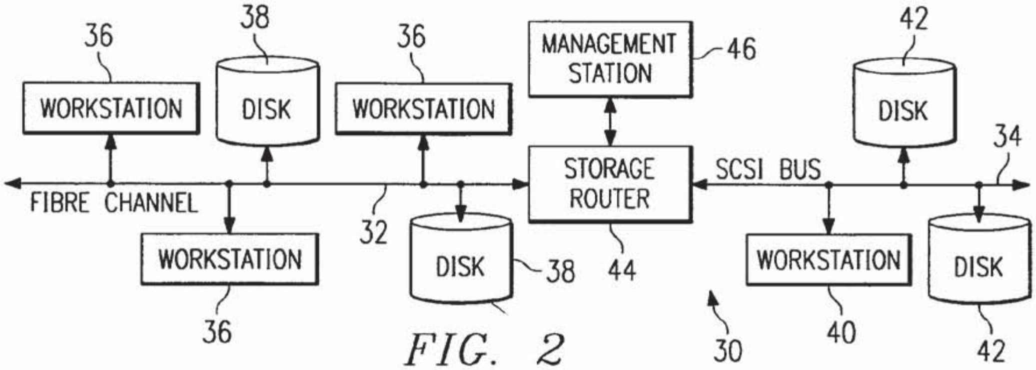


FIG. 2

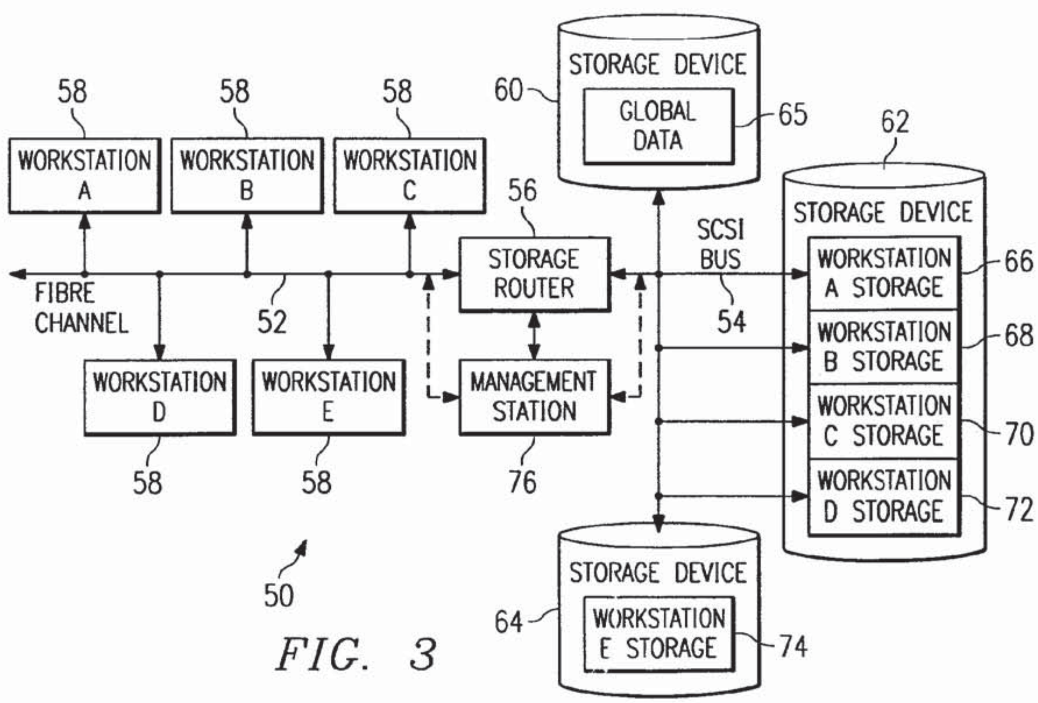
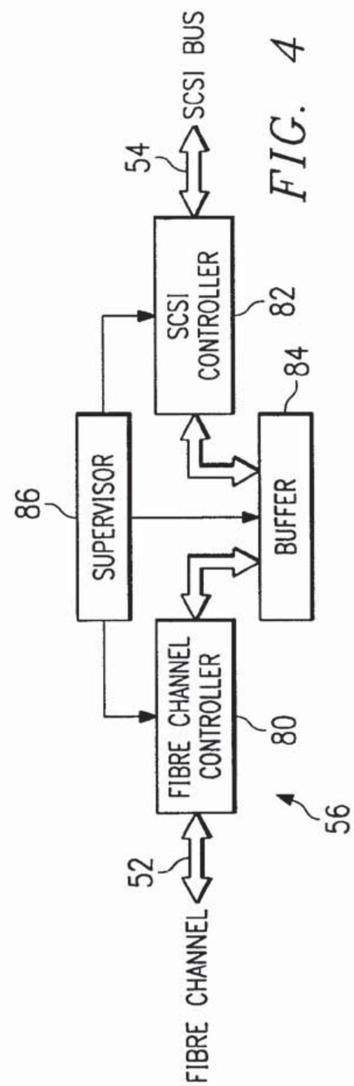
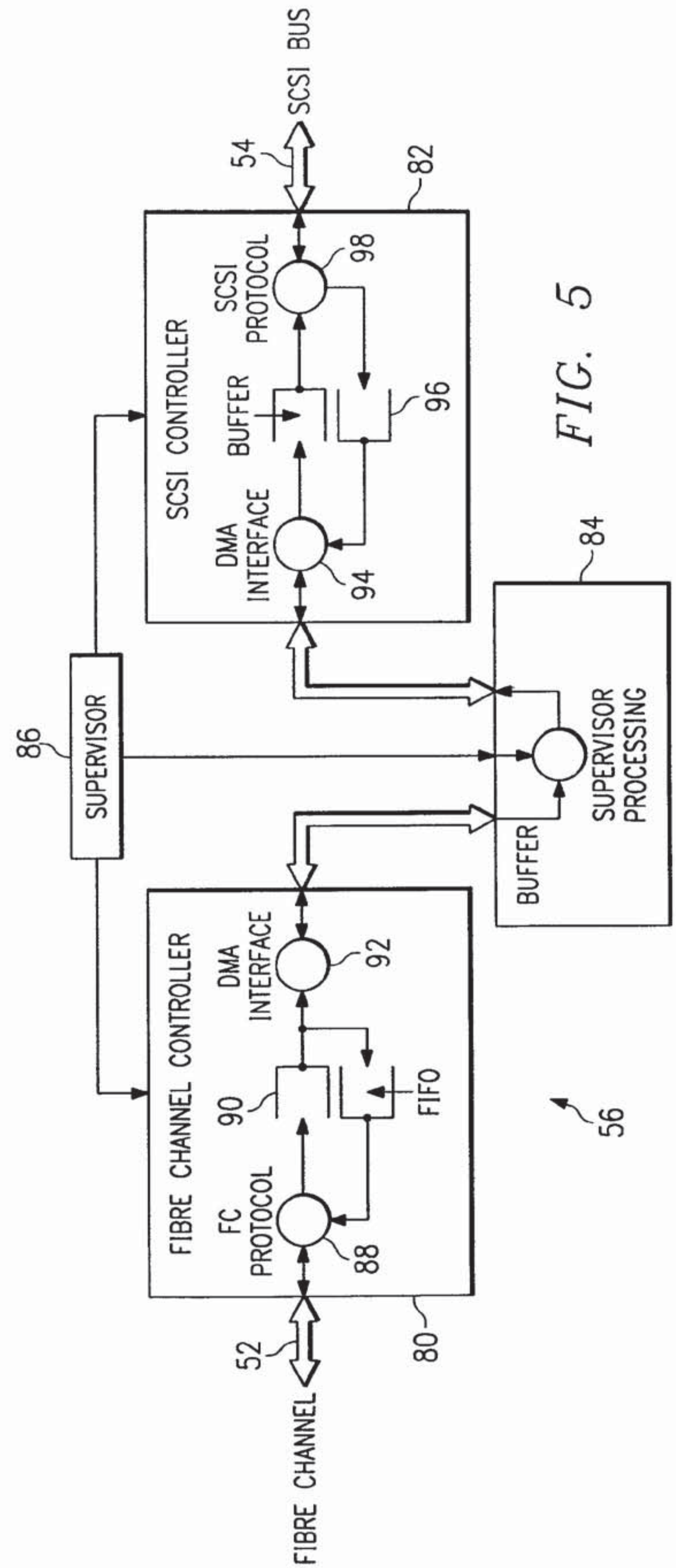


FIG. 3



SCSI BUS
54
SCSI CONTROLLER
82
86
SUPERVISOR
BUFFER
84
FIBRE CHANNEL CONTROLLER
80
52
FIBRE CHANNEL
56

FIG. 4



SCSI BUS
54
82
SCSI CONTROLLER
SCSI PROTOCOL
98
BUFFER
96
DMA INTERFACE
94
84
86
SUPERVISOR
SUPERVISOR PROCESSING
BUFFER
FIBRE CHANNEL CONTROLLER
DMA INTERFACE
92
90
FIFO
FC PROTOCOL
88
52
80
FIBRE CHANNEL
56

FIG. 5

STORAGE ROUTER AND METHOD FOR PROVIDING VIRTUAL LOCAL STORAGE

RELATED APPLICATIONS

This application claims the benefit of the filing date of U.S. patent application Ser. No. 09/354,682 by inventors Geoffrey B. Hoese and Jeffry T. Russell, entitled "Storage Router and Method for Providing Virtual Local Storage" filed on Jul. 15, 1999, which is a continuation of U.S. patent application Ser. No. 091001,799, filed on Dec. 31, 1997, now U.S. Pat. No. 5.941,972, and hereby incorporates these applications by reference in their entireties as if they had been fully set forth herein.

TECHNICAL FIELD OF THE INVENTION

This invention relates in general to network storage devices, and more particularly to a storage router and method for providing virtual local storage on remote SCSI storage devices to Fiber Channel devices.

BACKGROUND OF THE INVENTION

Typical storage transport mediums provide for a relatively small number of devices to be attached over relatively short distances. One such transport medium is a Small Computer System Interface (SCSI) protocol, the structure and operation of which is generally well known as is described, for example, in the SCSI-**1**, SCSI-**2** and SCSI-**3** specifications. High speed serial interconnects provide enhanced capability to attach a large number of high speed devices to a common storage transport medium over large distances. One such serial interconnect is Fibre Channel, the structure and operation of which is described, for example, in Fiber Channel Physical and Signaling Interface (FC-PH), ANSI X3.230 Fiber Channel Arbitrated Loop (FC-AL), and ANSI X3.272 Fiber Channel Private Loop Direct Attach (FC-PLDA).

Conventional computing devices, such as computer workstations, generally access storage locally or through network interconnects. Local storage typically consists of a disk drive, tape drive, CD-ROM drive or other storage device contained within, or locally connected to the workstation. The workstation provides a file system structure, that includes security controls, with access to the local storage device through native low level, block protocols. These protocols map directly to the mechanisms used by the storage device and consist of data requests without security controls. Network interconnects typically provide access for a large number of computing devices to data storage on a remote network server. The remote network server provides file system structure, access control, and other miscellaneous capabilities that include the network interface. Access to data through the network server is through network protocols that the server must translate into low level requests to the storage device. A workstation with access to the server storage must translate its file system protocols into network protocols that are used to communicate with the server. Consequently, from the perspective of a workstation, or other computing device, seeking to access such server data, the access is much slower than access to data on a local storage device.

SUMMARY OF THE INVENTION

In accordance with the present invention, a storage router and method for providing virtual local storage on remote SCSI storage devices to Fiber Channel devices are disclosed that provide advantages over conventional network storage devices and methods.

According to one aspect of the present invention, a storage router and storage network provide virtual local storage on remote SCSI storage devices to Fiber Channel devices. A plurality of Fiber Channel devices, such as workstations, are connected to a Fiber Channel transport medium, and a plurality of SCSI storage devices are connected to a SCSI bus transport medium. The storage router interfaces between the Fiber Channel transport medium and the SCSI bus transport medium. The storage router maps between the workstations and the SCSI storage devices and implements access controls for storage space on the SCSI storage devices. The storage router then allows access from the workstations to the SCSI storage devices using native low level, block protocol in accordance with the mapping and the access controls.

According to another aspect of the present invention, virtual local storage on remote SCSI storage devices is provided to Fiber Channel devices. A Fibre Channel transport medium and a SCSI bus transport medium are interfaced with. A configuration is maintained for SCSI storage devices connected to the SCSI bus transport medium. The configuration maps between Fiber Channel devices and the SCSI storage devices and implements access controls for storage space on the SCSI storage devices. Access is then allowed from Fiber Channel initiator devices to SCSI storage devices using native low level, block protocol in accordance with the configuration.

A technical advantage of the present invention is the ability to centralize local storage for networked workstations without any cost of speed or overhead. Each workstation access its virtual local storage as if it work locally connected. Further, the centralized storage devices can be located in a significantly remote position even in excess of ten kilometers as defined by Fibre Channel standards.

Another technical advantage of the present invention is the ability to centrally control and administer storage space for connected users without limiting the speed with which the users can access local data. In addition, global access to data, backups, virus scanning and redundancy can be more easily accomplished by centrally located storage devices.

A further technical advantage of the present invention is providing support for SCSI storage devices as local storage for Fiber Channel hosts. In addition, the present invention helps to provide extended capabilities for Fiber Channel and for management of storage subsystems.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present invention and the advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings, in which like reference numbers indicate like features, and wherein:

FIG. **1** is a block diagram of a conventional network that provides storage through a network server;

FIG. **2** is a block diagram of one embodiment of a storage network with a storage router that provides global access and routing;

FIG. **3** is a block diagram of one embodiment of a storage network with a storage router that provides virtual local storage;

FIG. **4** is a block diagram of one embodiment of the storage router of FIG. **3**; and

FIG. **5** is a block diagram of one embodiment of data flow within the storage router of FIG. **4**.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a block diagram of a conventional network, indicated generally at **10**, that provides access to storage through a network server. As shown, network **10** includes a plurality of workstations **12** interconnected with a network server **14** via a network transport medium **16**. Each workstation **12** can generally comprise a processor, memory, input/output devices, storage devices and a network adapter as well as other common computer components. Network server **14** uses a SCSI bus **18** as a storage transport medium to interconnect with a plurality of storage devices **20** (tape drives, disk drives, etc.). In the embodiment of FIG. **1**, network transport medium **16** is an network connection and storage devices **20** comprise hard disk drives, although there are numerous alternate transport mediums and storage devices.

In network **10**, each workstation **12** has access to its local storage device as well as network access to data on storage devices **20**. The access to a local storage device is typically through native low level, block protocols. On the other hand, access by a workstation **12** to storage devices **20** requires the participation of network server **14** which implements a file system and transfers data to workstations **12** only through high level file system protocols. Only network server **14** communicates with storage devices **20** via native low level, block protocols. Consequently, the network access by workstations **12** through network server **14** is slow with respect to their access to local storage. In network **10**, it can Also be a logistical problem to centrally manage and administer local data distributed across an organization, including accomplishing tasks such as backups, virus scanning and redundancy.

FIG. **2** is a block diagram of one embodiment of a storage network, indicated generally at **30**, with a storage router that provides global access and routing. This environment is significantly different from that of FIG. **1** in that there is no network server involved. In FIG. **2**, a Fiber Channel high speed serial transport **32** interconnects a plurality of workstations **36** and storage devices **38**. A SCSI bus storage transport medium interconnects workstations **40** and storage devices **42**. A storage router **44** then serves to interconnect these mediums and provide devices on either medium global, transparent access to devices on the other medium. Storage router **44** routes requests from initiator devices on one medium to target devices on the other medium and routes data between the target and the initiator. Storage router **44** can allow initiators and targets to be on either side. In this manner, storage router **44** enhances the functionality of Fiber Channel **32** by providing access, for example, to legacy SCSI storage devices on SCSI bus **34**. In the embodiment of FIG. **2**, the operation of storage router **44** can be managed by a management station **46** connected to the storage router via a direct serial connection.

In storage network **30**, any workstation **36** or workstation **40** can access any storage device **38** or storage device **42** through native low level, block protocols, and vice versa. This functionality is enabled by storage router **44** which routes requests and data as a generic transport between Fiber Channel **32** and SCSI bus **34**. Storage router **44** uses tables to map devices from one medium to the other and distributes requests and data across Fiber Channel **32** and SCSI bus **34** without any security access controls. Although this extension of the high speed serial interconnect provided by Fiber Channel **32** is beneficial, it is desirable to provide security controls in addition to extended access to storage devices through a native low level, block protocol.

FIG. **3** is a block diagram of one embodiment of a storage network, indicated generally at **50**, with a storage router that provides virtual local storage. Similar to that of FIG. **2**, storage network **50** includes a Fiber Channel high speed serial interconnect **52** and a SCSI bus **54** bridged by a storage router **56**. Storage router **56** of FIG. **3** provides for a large number of workstations **58** to be interconnected on a common storage transport and to access common storage devices **60**, **62** and **64** through native low level, block protocols.

According to the present invention, storage router **56** has enhanced functionality to implement security controls and routing such that each workstation **58** can have access to a specific subset of the overall data stored in storage devices **60**, **62** and **64**. This specific subset of data has the appearance and characteristics of local storage and is referred to herein as virtual local storage. Storage router **56** allows the configuration and modification of the storage allocated to each attached workstation **58** through the use of mapping tables or other mapping techniques.

As shown in FIG. **3**, for example, storage device **60** can be configured to provide global data **65** which can be accessed by all workstations **58**. Storage device **62** can be configured to provide partitioned subsets **66**, **68**, **70** and **72**, where each partition is allocated to one of the workstations **58** (workstations A, B, C and D). These subsets **66**, **68**, **70** and **72** can only be accessed by the associated workstation **58** and appear to the associated workstation **58** as local storage accessed using native low level, block protocols. Similarly, storage device **64** can be allocated as storage for the remaining workstation **58** (workstation E).

Storage router **56** combines access control with routing such that each workstation **58** has controlled access to only the specified partition of storage device **62** which forms virtual local storage for the workstation **58**. This access control allows security control for the specified data partitions. Storage router **56** allows this allocation of storage devices **60**, **62** and **64** to be managed by a management station **76**. Management station **76** can connect directly to storage router **56** via a direct connection or, alternately, can interface with storage router **56** through either Fiber Channel **52** or SCSI bus **54**. In the latter case, management station **76** can be a workstation or other computing device with special rights such that storage router **56** allows access to mapping tables and shows storage devices **60**, **62** and **64** as they exist physically rather than as they have been allocated.

The environment of FIG. **3** extends the concept of a single workstation having locally connected storage devices to a storage network **50** in which workstations **58** are provided virtual local storage in a manner transparent to workstations **58**. Storage router **56** provides centralized control of what each workstation **58** sees as its local drive, as well as what data it sees as global data accessible by other workstations **58**. Consequently, the storage space considered by the workstation **58** to be its local storage is actually a partition (i.e., logical storage definition) of a physically remote storage device **60**, **62** or **64** connected through storage router **56**. This means that similar requests from workstations **58** for access to their local storage devices produce different accesses to the storage space on storage devices **60**, **62** and **64**. Further, no access from a workstation **58** is allowed to the virtual local storage of another workstation **58**.

The collective storage provided by storage devices **60**, **62** and **64** can have blocks allocated by programming means within storage router **56**. To accomplish this function, storage router **56** can include routing tables and security controls that define storage allocation for each workstation **58**. The advantages provided by implementing virtual local storage in centralized storage devices include the ability to do collective backups and other collective administrative functions more easily. This is accomplished without limiting the performance of workstations **58** because storage access involves native low level, block protocols and does not involve the overhead of high level protocols and file systems required by network servers.

FIG. **4** is a block diagram of one embodiment of storage router **56** of FIG. **3**. Storage router **56** can comprise a Fiber Channel controller **80** that interfaces with Fiber Channel **52** and a SCSI controller **82** that interfaces with SCSI bus **54**. A buffer **84** provides memory work space and is connected to both Fiber Channel controller **80** and to SCSI controller **82**. A supervisor unit **86** is connected to Fiber Channel controller **80**, SCSI controller **82** and buffer **84**. Supervisor unit **86** comprises a microprocessor for controlling operation of storage router **56** and to handle mapping and security access for requests between Fiber Channel **52** and SCSI bus **54**.

FIG. **5** is a block diagram of one embodiment of data flow within storage router **56** of FIG. **4**. As shown, data from Fiber Channel **52** is processed by a Fibre Channel (FC) protocol unit **88** and placed in a FIFO queue **90**. A direct memory access (DMA) interface **92** then takes data out of FIFO queue **90** and places it in buffer **84**.

Supervisor unit **86** processes the data in buffer **84** as represented by supervisor processing **93**. This processing involves mapping between Fiber Channel **52** and SCSI bus **54** and applying access controls and routing functions. A DMA interface **94** then pulls data from buffer **84** and places it into a buffer **96**. A SCSI protocol unit **98** pulls data from buffer **96** and communicates the data on SCSI bus **54**. Data flow in the reverse direction, from SCSI bus **54** to Fiber Channel **52**, is accomplished in a reverse manner.

The storage router of the present invention is a bridge device that connects a Fiber Channel link directly to a SCSI bus and enables the exchange of SCSI command set information between application clients on SCSI bus devices and the Fiber Channel links. Further, the storage router applies access controls such that virtual local storage can be established in remote SCSI storage devices for workstations on the Fiber Channel link. In one embodiment, the storage router provides a connection for Fiber Channel links running the SCSI Fiber Channel Protocol (FCP) to legacy SCSI devices attached to a SCSI bus. The Fiber Channel topology is typically an Arbitrated Loop (FC_AL).

In part, the storage router enables a migration path to Fiber Channel based, serial SCSI networks by providing connectivity for legacy SCSI bus devices. The storage router can be attached to a Fiber Channel Arbitrated Loop and a SCSI bus to support a number of SCSI devices. Using configuration settings, the storage router can make the SCSI bus devices available on the Fiber Channel network as FCP logical units. Once the configuration is defined, operation of the storage router is transparent to application clients. In this manner, the storage router can form an integral part of the migration to new Fibre Channel based networks while providing a means to continue using legacy SCSI devices.

In one implementation (not shown), the storage router can be a rack mount or free standing device with an internal power supply. The storage router can have a Fibre Channel and SCSI port, and a standard, detachable power cord can be used, the FC connector can be a copper DB9 connector, and the SCSI connector can be a 68-pin type. Additional modular jacks can be provided for a serial port and a 802.3 10BaseT port, i.e. twisted pair Ethernet, for management access. The SCSI port of the storage router an support SCSI direct and sequential access target devices and can support SCSI initiators, as well. The Fiber Channel port can interface to SCSI-**3** FCP enabled devices and initiators.

To accomplish its functionality, one implementation of the storage router uses: a Fiber Channel interface based on the HEWLETT-PACKARD TACHYON HPFC-5000 controller and a GLM media interface; an Intel 80960RP processor, incorporating independent data and program memory spaces, and associated logic required to implement a stand alone processing system; and a serial port for debug and system configuration. Further, this implementation includes a SCSI interface supporting Fast-20 based on the SYMBIOS 53C8xx series SCSI controllers, and an operating system based upon the WIND RIVERS SYSTEMS VXWORKS or IXWORKS kernel, as determined. by design. In addition, the storage router includes software as required to control basic functions of the various elements, and to provide appropriate translations between the FC and SCSI protocols.

The storage router has various modes of operation that are possible between FC and SCSI target and initiator combinations. These modes are: FC Initiator to SCSI Target; SCSI Initiator to FC Target; SCSI Initiator to SCSI Target; and FC Initiator to FC Target. The first two modes can be supported concurrently in a single storage router device are discussed briefly below. The third mode can involve two storage router devices back to back and can serve primarily as a device to extend the physical distance beyond that possible via a direct SCSI connection. The last mode can be used to carry FC protocols encapsulated on other transmission technologies (e.g. ATM, SONET), or to act as a bridge between two FC loops (e.g. as a two port fabric).

The FC Initiator to SCSI Target mode provides for the basic configuration of a server using Fiber Channel to communicate with SCSI targets. This mode requires that a host system have an FC attached device and associated device drivers and software to generate SCSI-**3** FCP requests. This system acts as an initiator using the storage router to communicate with SCSI target devices. The SCSI devices supported can include SCSI-**2** compliant direct or sequential access (disk or tape) devices. The storage router serves to translate command and status information and transfer data between SCSI-**3** FCP and SCSI-**2**, allowing the use of standard SCSI-**2** devices in a Fibre Channel environment.

The SCSI Initiator to FC Target mode provides for the configuration of a server using SCSI-**2** to communicate with Fiber Channel targets. This mode requires that a host system has a SCSI-**2** interface and driver software to control SCSI-**2** target devices. The storage router will connect to the SCSI-**2** bus and respond as a target to multiple target IDs. Configuration information is required to identify the target IDs to which the bridge will respond on the SCSI-**2** bus. The storage router then translates the SCSI-**2** requests to SCSI-**3** FCP requests, allowing the use of FC devices with a SCSI host system. This will also allow features such as a tape device acting as an initiator on the SCSI bus to provide full support for this type of SCSI device.

In general, user configuration of the storage router will be needed to support various functional modes of operation. Configuration can be modified, for example, through a serial port or through an Ethernet port via SNMP (simple network management protocol) or a Telnet session. Specifically, SNMP manageability can be provided via an 802.3 Ethernet interface. This can provide for configuration changes as well as providing statistics and error information. Configuration can also be performed via TELNET or RS-232 interfaces with menu driven command interfaces. Configuration information can be stored in a segment of flash memory and can be retained across resets and power off cycles. Password protection can also be provided.

In the first two modes of operation, addressing information is needed to map from FC addressing to SCSI addressing and vice versa. This can be 'hard' configuration data, due to the need for address information to be maintained across initialization and partial reconfigurations of the Fiber Channel address space. In an arbitrated loop configuration, user configured addresses will be needed for AL_PAs in order to insure that known addresses are provided between loop reconfigurations.

With respect to addressing, FCP and SCSI **2** systems employ different methods of addressing target devices. Additionally, the inclusion of a storage router means that a method of translating device IDs needs to be implemented. In addition, the storage router can respond to commands without passing the commands through to the opposite interface. This can be implemented to allow all generic FCP and SCSI commands to pass through the storage router to address attached devices, but allow for configuration and diagnostics to be performed directly on the storage router through the FC and SCSI interfaces.

Management commands are those intended to be processed by the storage router controller directly. This may include diagnostic, mode, and log commands as well as other vendor-specific commands. These commands can be received and processed by both the FCP and SCSI interfaces, but are not typically bridged to the opposite interface. These commands may also have side effects on the operation of the storage router, and cause other storage router operations to change or terminate.

A primary method of addressing management commands though the FCP and SCSI interfaces can be through peripheral device type addressing. For example, the storage router can respond to all operations addressed to logical unit (LUN) zero as a controller device. Commands that the storage router will support can include INQUIRY as well as vendor-specific management commands. These are to be generally consistent with SCC standard commands.

The SCSI bus is capable of establishing bus connections between targets. These targets may internally address logical units. Thus, the prioritized addressing scheme used by SCSI subsystems can be represented as follows: BUS:TARGET:LOGICAL UNIT. The BUS identification is intrinsic in the configuration, as a SCSI initiator is attached to only one-bus. Target addressing is handled by bus arbitration from information provided to the arbitrating device. Target addresses are assigned to SCSI devices directly, though some means of configuration, such as a hardware jumper, switch setting, or device specific software configuration. As such, the SCSI protocol provides only logical unit addressing within the Identify message. Bus and target information is implied by the established connection.

Fiber Channel devices within a fabric are addressed by a unique port identifier. This identifier is assigned to a port during certain well-defined states of the FC protocol. Individual ports are allowed to arbitrate for a known, user defined address. If such an address is not provided, or if arbitration for a particular user address fails, the port is assigned a unique address by the FC protocol. This address is generally not guaranteed to be unique between instances. Various scenarios exist where the AL-PA of a device will change, either after power cycle or loop reconfiguration.

The FC protocol also provides a logical unit address field within command structures to provide addressing to devices

internal to a port. The FCP_CMD payload specifies an eight byte LUN field. Subsequent identification of the exchange between devices is provided by the FQXID (Fully Qualified Exchange ID).

FC ports can be required to have specific addresses assigned. Although basic functionality is not dependent on this, changes in the loop configuration could result in disk targets changing identifiers with the potential risk of data corruption or loss. This configuration can be straightforward, and can consist of providing the device a loop-unique ID (AL_PA) in the range of "01h" to "EFh." Storage routers could be shipped with a default value with the assumption that most configurations will be using single storage routers and no other devices requesting the present ID. This would provide a minimum amount of initial configuration to the system administrator. Alternately, storage routers could be defaulted to assume any address so that configurations requiring multiple storage routers on a loop would not require that the administrator assign a unique ID to the additional storage routers.

Address translation is needed where commands are issued in the cases FC Initiator to SCSI Target and SCSI Initiator to FC Target. Target responses are qualified by the FQXID and will retain the translation acquired at the beginning of the exchange. This prevents configuration changes occurring during the course of execution of a command from causing data or state information to be inadvertently misdirected. Configuration can be required in cases of SCSI Initiator to FC Target, as discovery may not effectively allow for FCP targets to consistently be found. This is due to an FC arbitrated loop supporting addressing of a larger number of devices than a SCSI bus and the possibility of FC devices changing their AL-PA due to device insertion or other loop initialization.

In the direct method, the translation to BUS:TARGET:LUN of the SCSI address information will be direct. That is, the values represented in the FCP LUN field will directly map to the values in effect on the SCSI bus. This provides a clean translation and does not require SCSI bus discovery. It also allows devices to be dynamically added to the SCSI bus without modifying the address map. It may not allow for complete discovery by FCP initiator devices, as gaps between device addresses may halt the discovery process. Legacy SCSI device drivers typically halt discovery on a target device at the first unoccupied LUN, and proceed to the next target. This would lead to some devices not being discovered. However, this allows for hot plugged devices and other changes to the loop addressing.

In the ordered method, ordered translation requires that the storage router perform discovery on reset, and collapses the addresses on the SCSI bus to sequential FCP LUN values. Thus, the FCP LUN values 0-N can represent N+1 SCSI devices, regardless of SCSI address values, in the order in which they are isolated during the SCSI discovery process. This would allow the FCP initiator discovery process to identify all mapped SCSI devices without further configuration. This has the limitation that hot-plugged devices will not be identified until the next reset cycle. In this case, the address may also be altered as well.

In addition to addressing, according to the present invention, the storage router provides configuration and access controls that cause certain requests from FC Initiators to be directed to assigned virtual local storage partitioned on SCSI storage devices. For example, the same request for LUN **0** (local storage) by two different FC Initiators can be directed to two separate subsets of storage. The storage router can use tables to map, for each initiator, what storage access is available and what partition is being addressed by a particular request. In this manner, the storage space provided by SCSI storage devices can be allocated to FC initiators to provide virtual local storage as well as to create any other desired configuration for secured access.

Although the present invention has been described in detail, it should be understood that various changes, substitutions, and alterations can be made hereto without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A storage router for providing virtual local storage on remote storage devices to devices, comprising:

a buffer providing memory work space for the storage router;

a first controller operable to connect to and interface with a first transport medium;

a second controller operable to connect to and interface with a second transport medium; and

a supervisor unit coupled to the first controller, the second controller and the buffer, the supervisor unit operable to map between devices connected to the first transport medium and the storage devices, to implement access controls for storage space on the storage devices and to process data in the buffer to interface between the first controller and the second controller to allow access from devices connected to the first transport medium to the storage devices using native low level, block protocols.

2. The storage router of claim 1, wherein the supervisor unit maintains an allocation of subsets of storage space to associated devices connected to the first transport medium, wherein each subset is only accessible by the associated device connected to the first transport medium.

3. The storage router of claim 2, wherein the devices connected to the first transport medium comprise workstations.

4. The storage router of claim 2, wherein the storage devices comprise hard disk drives.

5. The storage router of claim 1, wherein the first controller comprises:

a first protocol unit operable to connect to the first transport medium;

a first-in-first-out queue coupled to the first protocol unit; and

a direct memory access (DMA) interface coupled to the first-in-first-out queue and to the buffer.

6. The storage router of claim 1, wherein the second controller comprises:

a second protocol unit operable to connect to the second transport medium;

an internal buffer coupled to the second protocol unit; and

a direct memory access (DMA) interface coupled to the internal buffer and to the buffer of the storage router.

7. A storage network, comprising:

a first transport medium;

a second transport medium;

a plurality of workstations connected to the first transport medium;

a plurality of storage devices connected to the second transport medium; and

a storage router interfacing between the first transport medium and the second transport medium, the storage router providing virtual local storage on the storage devices to the workstations and operable:

to map between the workstations and the storage devices;

to implement access controls for storage space on the storage devices; and

to allow access from the workstations to the storage devices using native low level, block protocol in accordance with the mapping and access controls.

8. The storage network of claim 7, wherein the access controls include an allocation of subsets of storage space to associated workstations, wherein each subset is only accessible by the associated workstation.

9. The storage network of claim 7, wherein the storage devices comprise hard disk drives.

10. The storage network of claim 7, wherein the storage router comprises:

a buffer providing memory work space for the storage router;

a first controller operable to connect to and interface with the first transport medium, the first controller further operable to pull outgoing data from the buffer and to place incoming data into the buffer;

a second controller operable to connect to and interface with the second transport medium, the second controller further operable to pull outgoing data from the buffer and to place incoming data into the buffer; and

a supervisor unit coupled to the first controller, the second controller and the buffer, the supervisor unit operable:

to map between devices connected to the first transport medium and the storage devices, to implement the access controls for storage space on the storage devices and to process data in the buffer to interface between the first controller and the second controller to allow access from workstations to storage devices.

11. A method for providing virtual local storage on remote storage devices connected to one transport medium to devices connected to another transport medium, comprising:

interfacing with a first transport medium;

interfacing with a second transport medium;

mapping between devices connected to the first transport medium and the storage devices and that implements access controls for storage space on the storage devices; and

allowing access from devices connected to the first transport medium to the storage devices using native low level, block protocols.

12. The method of claim 11, wherein mapping between devices connected to the first transport medium and the storage devices includes allocating subsets of storage space to associated devices connected to the first transport medium, wherein each subset is only accessible by the associated device connected to the first transport medium.

13. The method of claim 12, wherein the devices connected to the first transport medium comprise workstations.

14. The method of claim 12, wherein the storage devices comprise hard disk drives.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,425,035 B2
DATED : July 23, 2002
INVENTOR(S) : Geoffry B. Hoese et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 10,
Line 47, delete "that implements" and insert -- implementing --

Signed and Sealed this

Twenty-sixth Day of August, 2003

JAMES E. ROGAN
Director of the United States Patent and Trademark Office

US006425035C1

(12) **EX PARTE REEXAMINATION CERTIFICATE** (5472nd)

United States Patent

Hoese et al.

(10) **Number: US 6,425,035 C1**
(45) **Certificate Issued: *Aug. 8, 2006**

(54) **STORAGE ROUTER AND METHOD FOR PROVIDING VIRTUAL LOCAL STORAGE**

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(73) Assignee: **Crossworlds Software**, Burlingame, CA (US)

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Related U.S. Application Data

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(51) **Int. Cl.**
G06F 13/00 (2006.01)

(52) **U.S. Cl.** **710/315**; 710/2; 710/8; 710/36; 710/105; 710/305; 710/308; 711/112

(58) **Field of Classification Search** 710/1–5, 710/8–13, 36–38, 105, 100, 101, 305–316; 711/100, 112, 113; 714/42
See application file for complete search history.

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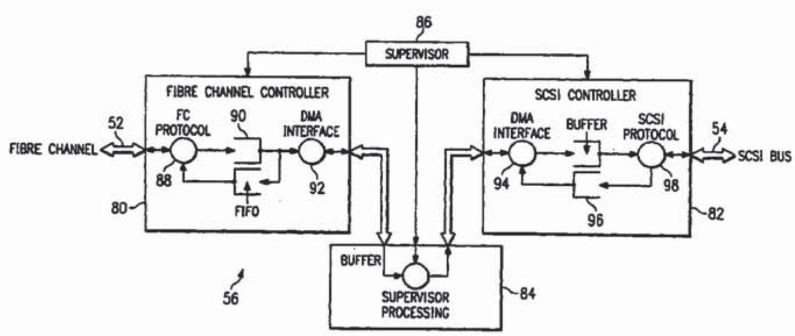
Primary Examiner—Dov Popovici

(57) **ABSTRACT**

A storage router (**56**) and storage network (**50**) provide virtual local storage on remote SCSI storage devices (**60**, **62**, **64**) to Fiber Channel devices. A plurality of Fiber Channel devices, such as workstations (**58**), are connected to a Fiber Channel transport medium (**52**), and a plurality of SCSI storage devices (**60**, **62**, **64**) are connected to a SCSI bus transport medium (**54**). The storage router (**56**) interfaces between the Fibre Channel transport medium (**52**) and the SCSI bus transport medium (**54**). The storage router (**56**) maps between the workstations (**58**) and the SCSI storage devices (**60**, **62**, **64**) and implements access, controls for storage space on the SCSI storage devices (**60**, **62**, **64**). The storage router (**56**) then allows access from the workstations (**58**) to the SCSI storage devices (**60**, **62**, **64**) using native low level, block protocol in accordance with the mapping and the access controls.



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EX PARTE REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

NO AMENDMENTS HAVE BEEN MADE TO THE PATENT

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

The patentability of claims **1**–**14** is confirmed.

* * * * *

EXHIBIT B

US007934041B2

(12) United States Patent
Hoese et al.

(10) Patent No.: **US 7,934,041 B2**
(45) Date of Patent: **Apr. 26, 2011**

(54) **STORAGE ROUTER AND METHOD FOR PROVIDING VIRTUAL LOCAL STORAGE**

(75) Inventors: **Geoffrey B. Hoese**, Austin, TX (US); **Jeffry T. Russell**, Cibolo, TX (US)

(73) Assignee: **Crossroads Systems, Inc.**, Austin, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **12/690,592**

(22) Filed: **Jan. 20, 2010**

(65) **Prior Publication Data**

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Related U.S. Application Data

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G06F 13/00 (2006.01)
G06F 3/00 (2006.01)

(52) **U.S. Cl.** **710/305**; 710/11; 709/258

(58) **Field of Classification Search** 710/1–5, 710/8–13, 36–38, 126–131, 250, 305; 709/258; 714/42; 711/110–113
See application file for complete search history.

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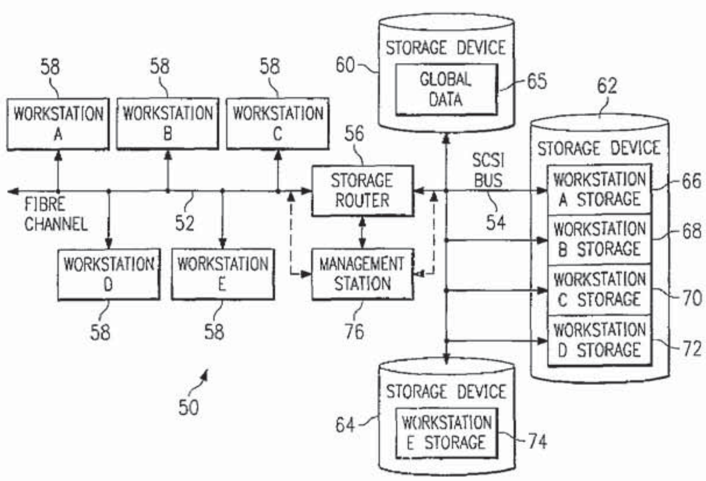
(57) **ABSTRACT**

A storage router and storage network provide virtual local storage on remote storage devices. A plurality of devices are connected to a first transport medium. In one embodiment, a storage router maintains a map to allocate storage space on the remote storage devices to devices connected to the first transport medium by associating representations of the devices connected to the first transport medium with representations of storage space on the remote storage devices. The storage router controls access from the devices connected to the first transport medium to the storage space on the remote storage devices in accordance with the map and allows access from devices connected to the first transport medium to the remote storage devices using native low level block protocol.

53 Claims, 2 Drawing Sheets



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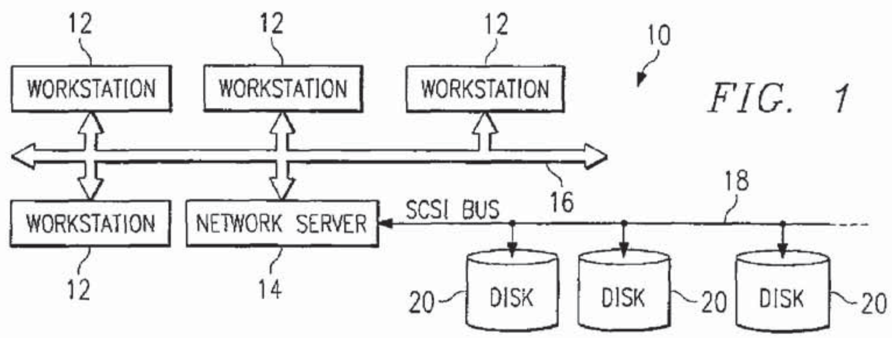

FIG. 1

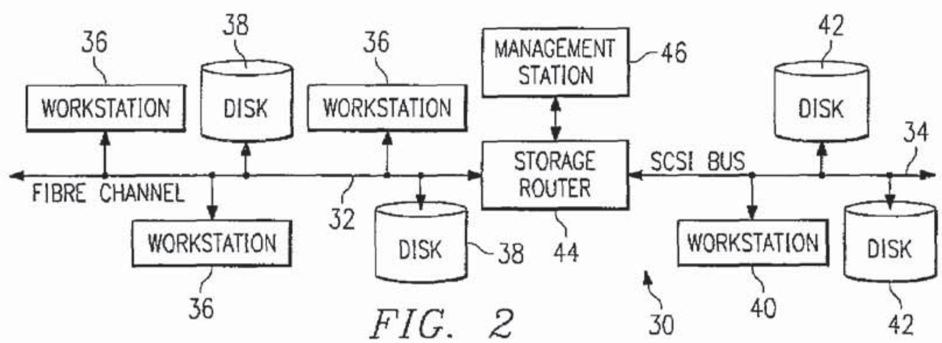

FIG. 2

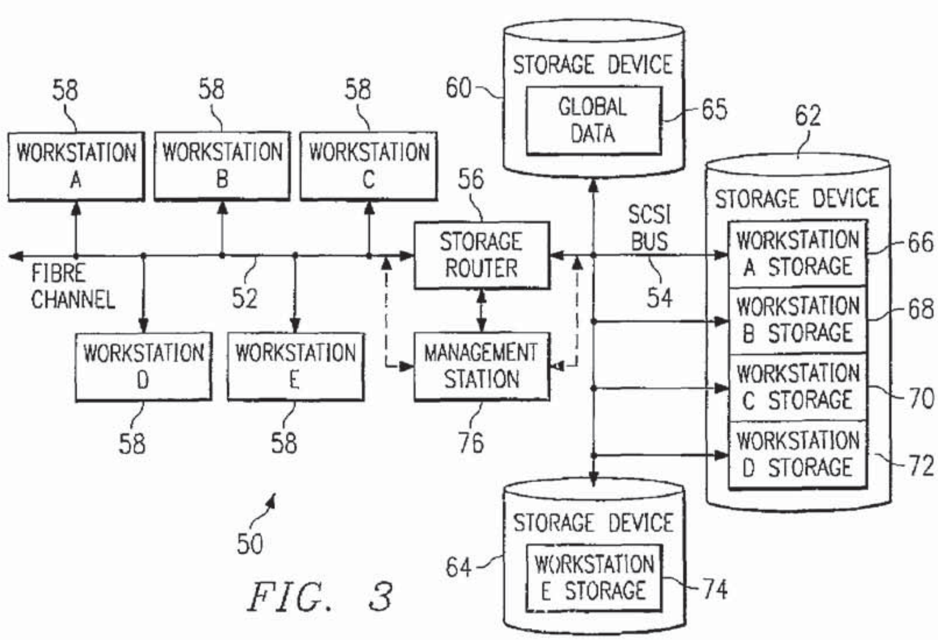

FIG. 3

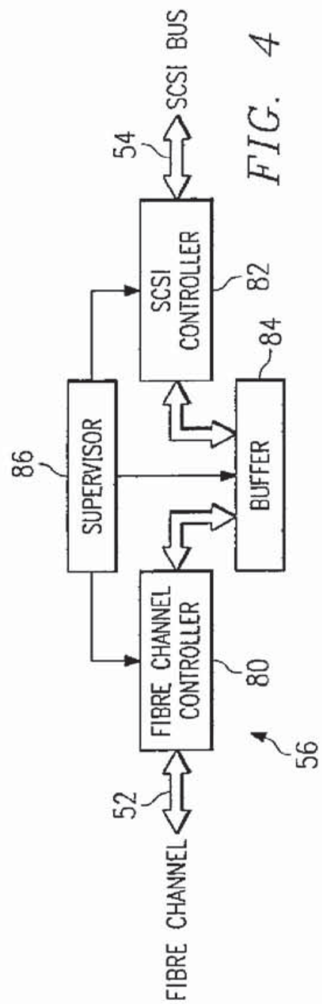
FIBRE CHANNEL
52
FIBRE CHANNEL CONTROLLER
80
56
SUPERVISOR
86
BUFFER
84
SCSI CONTROLLER
82
54
SCSI BUS

FIG. 4

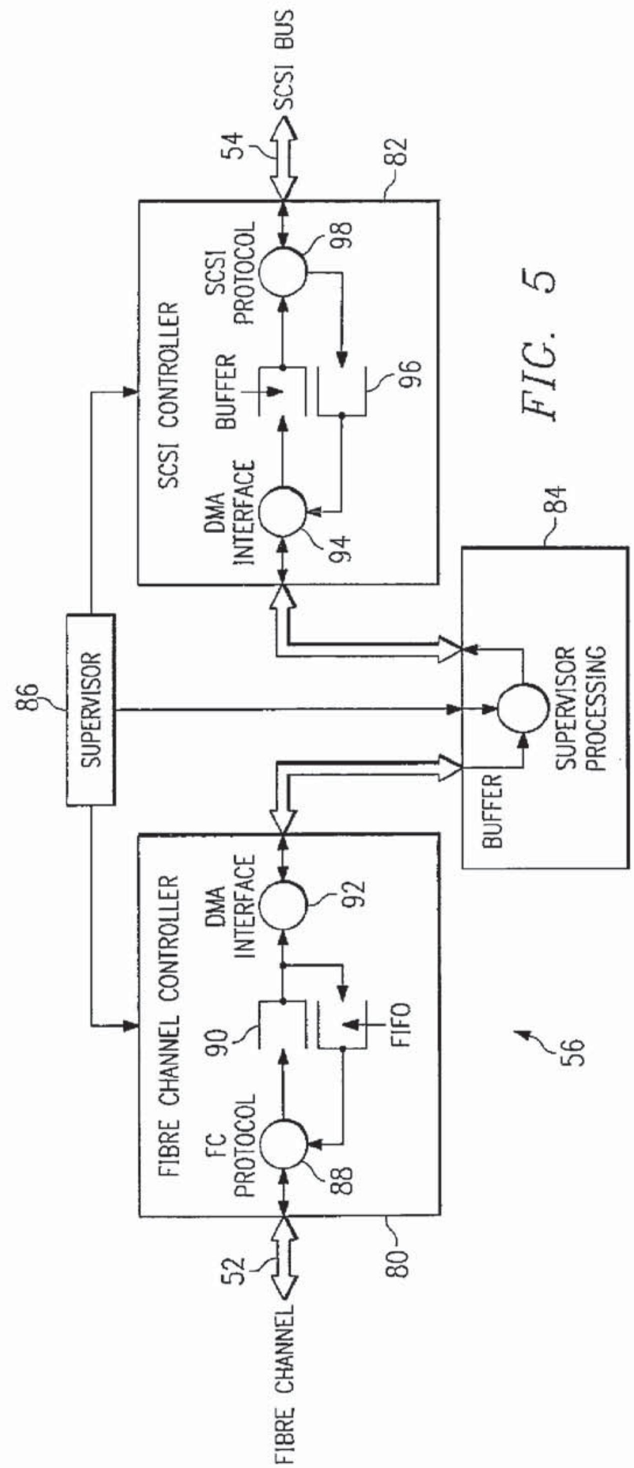
FIBRE CHANNEL
52
80
FIBRE CHANNEL CONTROLLER
FC PROTOCOL
88
90
FIFO
DMA INTERFACE
92
56
SUPERVISOR
86
BUFFER
SUPERVISOR PROCESSING
84
SCSI CONTROLLER
DMA INTERFACE
94
BUFFER
96
SCSI PROTOCOL
98
82
54
SCSI BUS

FIG. 5

STORAGE ROUTER AND METHOD FOR PROVIDING VIRTUAL LOCAL STORAGE

This application is a continuation of, and claims a benefit of priority under 35 U.S.C. 120 of the filing date of U.S. patent application Ser. No. 12/552,885 entitled "Storage Router and Method for Providing Virtual Local Storage" filed Sep. 2, 2009, which is a continuation of and claims the benefit of priority of U.S. application Ser. No. 11/851,724 entitled "Storage Router and Method for Providing Virtual Local Storage" filed Sep. 7, 2007, now U.S. Pat. No. 7,689,754 issued Mar. 30, 2010, which is a continuation of and claims the benefit of priority of U.S. patent application Ser. No. 11/442,878 entitled "Storage Router and Method for Providing Virtual Local Storage" filed May 30, 2006, now abandoned, which is a continuation of and claims the benefit of priority of U.S. patent application Ser. No. 11/353,826 entitled "Storage Router and Method for Providing Virtual Local Storage" filed on Feb. 14, 2006, now U.S. Pat. No. 7,340,549 issued Mar. 4, 2008, which is a continuation of and claims the benefit of priority of U.S. patent application Ser. No. 10/658,163 entitled "Storage Router and Method for Providing Virtual Local Storage" filed on Sep. 9, 2003 now U.S. Pat. No. 7,051,147 issued May 23, 2006, which is a continuation of and claims the benefit of benefit of priority of U.S. patent application Ser. No. 10/081,110 by inventors Geoffrey B. Hoese and Jeffery T. Russell, entitled "Storage Router and Method for Providing Virtual Local Storage" filed on Feb. 22, 2002, now U.S. Pat. No. 6,789,152 issued on Sep. 7, 2004, which in turn is a continuation of and claims benefit of priority of U.S. application Ser. No. 09/354,682 by inventors Geoffrey B. Hoese and Jeffrey T. Russell, entitled "Storage Router and Method for Providing Virtual Local Storage" filed on Jul. 15, 1999, now U.S. Pat. No. 6,421,753 issued on Jul. 16, 2002, which in turn is a continuation of and claims benefit of priority of U.S. patent application Ser. No. 09/001, 799, filed on Dec. 31, 1997, now U.S. Pat. No. 5,941,972 issued on Aug. 24, 1999, and hereby incorporates these applications and patents by reference in their entireties as if they had been fully set forth herein.

TECHNICAL FIELD OF THE INVENTION

This invention relates in general to network storage devices, and more particularly to a storage router and method for providing virtual local storage on remote SCSI storage devices to Fibre Channel devices.

BACKGROUND OF THE INVENTION

Typical storage transport mediums provide for a relatively small number of devices to be attached over relatively short distances. One such transport medium is a Small Computer System Interface (SCSI) protocol, the structure and operation of which is generally well known as is described, for example, in the SCSI-1, SCSI-2 and SCSI-3 specifications. High speed serial interconnects provide enhanced capability to attach a large number of high speed devices to a common storage transport medium over large distances. One such, serial interconnect is Fibre Channel, the structure and operation of which is described, for example, in Fibre Channel Physical and Signaling Interface (FC-PH), ANSI X3.230 Fibre Channel Arbitrated Loop (FC-AL), and ANSI X3.272 Fibre Channel Private Loop Direct Attach (FC-PLDA).

Conventional computing devices, such as computer workstations, generally access storage locally or through network interconnects. Local storage typically consists of a disk drive,

tape drive, CD-ROM drive or other storage device contained within, or locally connected to the workstation. The workstation provides a file system structure that includes security controls, with access to the local storage device through native low level block protocols. These protocols map directly to the mechanisms used by the storage device and consist of data requests without security controls. Network interconnects typically provide access for a large number of computing devices to data storage on a remote network server. The remote network server provides file system structure, access control, and other miscellaneous capabilities that include the network interface. Access to data through the network server is through network protocols that the server must translate into low level requests to the storage device. A workstation with access to the server storage must translate its file system protocols into network protocols that are used to communicate with the server. Consequently, from the perspective of a workstation, or other computing device, seeking to access such server data, the access is much slower than access to data on a local storage device.

SUMMARY OF THE INVENTION

In accordance with the present invention, a storage router and method for providing virtual local storage on remote SCSI storage devices to Fibre Channel devices are disclosed that provide advantages over conventional network storage devices and methods.

According to one aspect of the present invention, a storage router and storage network provide virtual local storage on remote SCSI storage devices to Fibre Channel devices. A plurality of Fibre Channel devices, such as workstations, are connected to a Fibre Channel transport medium, and a plurality of SCSI storage devices are connected to a SCSI bus transport medium. The storage router interfaces between the Fibre Channel transport medium and the SCSI bus transport medium. The storage router maps between the workstations and the SCSI storage devices and implements access controls for storage space on the SCSI storage devices. The storage router then allows access from the workstations to the SCSI storage devices using native low level, block protocol in accordance with the mapping and the access controls.

According to another aspect of the present invention, virtual local storage on remote SCSI storage devices is provided to Fibre Channel devices. A Fibre Channel transport medium and a SCSI bus transport medium are interfaced with. A configuration is maintained for SCSI storage devices connected to the SCSI bus transport medium. The configuration maps between Fibre Channel devices and the SCSI storage devices and implements access controls for storage space on the SCSI storage devices. Access is then allowed from Fibre Channel initiator devices to SCSI storage devices using native low level, block protocol in accordance with the configuration.

A technical advantage of the present invention is the ability to centralize local storage for networked workstations without any cost of speed or overhead. Each workstation accesses its virtual local storage as if it were locally connected. Further, the centralized storage devices can be located in a significantly remote position even in excess of ten kilometers as defined by Fibre Channel standards.

Another technical advantage of the present invention is the ability to centrally control and administer storage space for connected users without limiting the speed with which the users can access local data. In addition, global access to data, backups, virus scanning and redundancy can be more easily accomplished by centrally located storage devices.

A further technical advantage of the present invention is providing support for SCSI storage devices as local storage for Fibre Channel hosts. In addition, the present invention helps to provide extended capabilities for Fibre Channel and for management of storage subsystems.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present invention and the advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings, in which like reference numbers indicate like features, and wherein:

FIG. **1** is a block diagram of a conventional network that provides storage through a network server;

FIG. **2** is a block diagram of one embodiment of a storage network with a storage router that provides global access and routing;

FIG. **3** is a block diagram of one embodiment of a storage network with a storage router that provides virtual local storage;

FIG. **4** is a block diagram of one embodiment of the storage router of FIG. **3**; and

FIG. **5** is a block diagram of one embodiment of data flow within the storage router of FIG. **4**.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a block diagram of a conventional network, indicated generally at **10**, that provides access to storage through a network server. As shown, network **10** includes a plurality of workstations **12** interconnected with a network server **14** via a network transport medium **16**. Each workstation **12** can generally comprise a processor, memory, input/output devices, storage devices and a network adapter as well as other common computer components. Network server **14** uses a SCSI bus **18** as a storage transport medium to interconnect with a plurality of storage devices **20** (tape drives, disk drives, etc.). In the embodiment of FIG. **1**, network transport medium **16** is a network connection and storage devices **20** comprise hard disk drives, although there are numerous alternate transport mediums and storage devices.

In network **10**, each workstation **12** has access to its local storage device as well as network access to data on storage devices **20**. The access to a local storage device is typically through native low level, block protocols. On the other hand, access by a workstation **12** to storage devices **20** requires the participation of network server **14** which implements a file system and transfers data to workstations **12** only through high level file system protocols. Only network server **14** communicates with storage devices **20** via native low level, block protocols. Consequently, the network access by workstations **12** through network server **14** is slow with respect to their access to local storage. In network **10**, it can also be a logistical problem to centrally manage and administer local data distributed across an organization, including accomplishing tasks such as backups, virus scanning and redundancy.

FIG. **2** is a block diagram of one embodiment of a storage network, indicated generally at **30**, with a storage router that provides global access and routing. This environment is significantly different from that of FIG. **1** in that there is no network server involved. In FIG. **2**, a Fibre Channel high speed serial transport **32** interconnects a plurality of workstations **36** and storage devices **38**. A SCSI bus storage transport medium interconnects workstations **40** and storage devices **42**. A storage router **44** then serves to interconnect these mediums and provide devices on either medium global, transparent access to devices on the other medium. Storage router **44** routes requests from initiator devices on one medium to target devices on the other medium and routes data between the target and the initiator. Storage router **44** can allow initiators and targets to be on either side. In this manner, storage router **44** enhances the functionality of Fibre Channel **32**, by providing access, for example, to legacy SCSI storage devices on SCSI bus **34**. In the embodiment of FIG. **2**, the operation of storage router **44** can be managed by a management station **46** connected to the storage router via a direct serial connection.

In storage network **30**, any workstation **36** or workstation **40** can access any storage device **38** or storage device **42** through native low level, block protocols, and vice versa. This functionality is enabled by storage router **44** which routes requests and data as a generic transport between Fibre Channel **32** and SCSI bus **34**. Storage router **44** uses tables to map devices from one medium to the other and distributes requests and data across Fibre Channel **32** and SCSI bus **34** without any security access controls. Although this extension of the high speed serial interconnect provided by Fibre Channel is beneficial, it is desirable to provide security controls in addition to extended access to storage devices through a native low level, block protocol.

FIG. **3** is a block diagram of one embodiment of a storage network, indicated generally at **50**, with a storage router that provides virtual local storage. Similar to that of FIG. **2**, storage network **50** includes a Fibre Channel high speed serial interconnect **52** and a SCSI bus **54** bridged by a storage router **56**. Storage router **56** of FIG. **3** provides for a large number of workstations **58** to be interconnected on a common storage transport and to access common storage devices **60**, **62** and **64** through native low level, block protocols.

According to the present invention, storage router **56** has enhanced functionality to implement security controls and routing such that each workstation **58** can have access to a specific subset of the overall data stored in storage devices **60**, **62** and **64**. This specific subset of data has the appearance and characteristics of local storage and is referred to herein as virtual local storage. Storage router **56** allows the configuration and modification of the storage allocated to each attached workstation **58** through the use of mapping tables or other mapping techniques.

As shown in FIG. **3**, for example, storage device **60** can be configured to provide global data **65** which can be accessed by all workstations **58**. Storage device **62** can be configured to provide partitioned subsets **66**, **68**, **70** and **72**, where each partition is allocated to one of the workstations **58** (workstations A, B, C and D). These subsets **66**, **68**, **70** and **72** can only be accessed by the associated workstation **58** and appear to the associated workstation **58** as local storage accessed using native low level, block protocols. Similarly, storage device **64** can be allocated as storage for the remaining workstation **58** (workstation E).

Storage router **56** combines access control with routing such that each workstation **58** has controlled access to only the specified partition of storage device **62** which forms virtual local storage for the workstation **58**. This access control allows security control for the specified data partitions. Storage router **56** allows this allocation of storage devices **60**, **62** and **64** to be managed by a management station **76**. Management station **76** can connect directly to storage router **56** via a direct connection or, alternately, can interface with storage router **56** through either Fibre Channel **52** or SCSI bus **54**. In the latter case, management station **76** can be a workstation or other computing device with special rights such that storage router **56** allows access to mapping tables and shows storage devices **60**, **62** and **64** as they exist physically rather than as they have been allocated.

The environment of FIG. **3** extends the concept of single workstation having locally connected storage devices to a storage network **50** in which workstations **58** are provided virtual local storage in a manner transparent to workstations **58**. Storage router **56** provides centralized control of what each workstation **58** sees as its local drive, as well as what data it sees as global data accessible by other workstations **58**. Consequently, the storage space considered by the workstation **58** to be its local storage is actually a partition (i.e., logical storage definition) of a physically remote storage device **60**, **62** or **64** connected through storage router **56**. This means that similar requests from workstations **58** for access to their local storage devices produce different accesses to the storage space on storage devices **60**, **62** and **64**. Further, no access from a workstation **58** is allowed to the virtual local storage of another workstation **58**.

The collective storage provided by storage devices **60**, **62** and **64** can have blocks allocated by programming means within storage router **56**. To accomplish this function, storage router **56** can include routing tables and security controls that define storage allocation for each workstation **58**. The advantages provided by implementing virtual local storage in centralized storage devices include the ability to do collective backups and other collective administrative functions more easily. This is accomplished without limiting the performance of workstations **58** because storage access involves native low level, block protocols and does not involve the overhead of high level protocols and file systems required by network servers.

FIG. **4** is a block diagram of one embodiment of storage router **56** of FIG. **3**. Storage router **56** can comprise a Fibre Channel controller **80** that interfaces with Fibre Channel **52** and a SCSI controller **82** that interfaces with SCSI bus **54**. A buffer **84** provides memory work space and is connected to both Fibre Channel controller **80** and to SCSI controller **82**. A supervisor unit **86** is connected to Fibre Channel controller **80**, SCSI controller **82** and buffer **84**. Supervisor unit **86** comprises a microprocessor for controlling operation of storage router **56** and to handle mapping and-security access for requests between Fibre Channel **52** and SCSI bus **54**.

FIG. **5** is a block diagram of one embodiment of data flow within storage router **56** of FIG. **4**. As shown, data from Fibre Channel **52** is processed by a Fibre Channel (FC) protocol unit **88** and placed in a FIFO queue **90**. A direct memory access (DMA) interface **92** then takes data out of FIFO queue **90** and places it in buffer **84**. Supervisor unit **86** processes the data in buffer **84** as represented by supervisor processing **93**. This processing involves mapping between Fibre Channel **52** and SCSI bus **54** and applying access controls and routing functions. A DMA interface **94** then pulls data from buffer **84** and places it into a buffer **96**. A SCSI protocol unit **98** pulls data from buffer **96** and communicates the data on SCSI bus **54**. Data flow in the reverse direction, from SCSI bus **54** to Fibre Channel **52**, is accomplished in a reverse manner.

The storage router of the present invention is a bridge device that connects a Fibre Channel link directly to a SCSI bus and enables the exchange of SCSI command set information between application clients on SCSI bus devices and the Fibre Channel links. Further, the storage router applies access controls such that virtual local storage can be established in remote SCSI storage devices for workstations on the Fibre Channel link. In one embodiment, the storage router provides a connection for Fibre Channel links running the SCSI Fibre Channel Protocol (FCP) to legacy SCSI devices attached to a SCSI bus. The Fibre Channel topology is typically an Arbitrated Loop (FC_AL).

In part, the storage router enables a migration path Fibre Channel based, serial SCSI networks by providing connectivity for legacy SCSI bus devices. The storage router can be attached to a Fibre Channel Arbitrated Loop and a SCSI bus to support a number of SCSI devices. Using configuration settings, the storage router can make the SCSI bus devices available on the Fibre Channel network as FCP logical units. Once the configuration is defined, operation of the storage router is transparent to application clients. In this manner, the storage router can form an integral part of the migration to new Fibre Channel based networks while providing a means to continue using legacy SCSI devices.

In one implementation (not shown), the storage router can be a rack mount or free standing device with an internal power supply. The storage router can have a Fibre Channel and SCSI port, and a standard, detachable power cord can be used, the FC connector can be a copper DB9 connector, and the SCSI connector can be a 68-pin type. Additional modular jacks can be provided for a serial port and an 802.3 10 BaseT port, i.e. twisted pair Ethernet, for management access. The SCSI port of the storage router an support SCSI direct and sequential access target devices and can support SCSI initiators, as well. The Fibre Channel port can interface to SCSI-3 FCP enabled devices and initiators.

To accomplish its functionality, one implementation of the storage router uses: a Fibre Channel interface based on the HEWLETT-PACKARD TACHYON HPFC-5000 controller and a GLM media interface; an Intel 80960RP processor, incorporating independent data and program memory spaces, and associated logic required to implement a stand alone processing system; and a serial port for debug and system configuration. Further, this implementation includes a SCSI interface supporting Fast-20 based on the SYMBIOS 53C8xx series SCSI controllers, and an operating system based upon the WIND RIVERS SYSTEMS VXWORKS or IXWORKS kernel, as determined by design. In addition, the storage router includes software as required to control basic functions of the various elements, and to provide appropriate translations between the FC and SCSI protocols.

The storage router has various modes of operation that are possible between FC and SCSI target and initiator combinations. These modes are: FC Initiator to SCSI Target; SCSI Initiator to FC Target; SCSI Initiator to SCSI Target; and FC Initiator to FC Target. The first two modes can be supported concurrently in a single storage router device and are discussed briefly below. The third mode can involve two storage router devices back to back and can serve primarily as a device to extend the physical distance beyond that possible via a direct SCSI connection. The last mode can be used to carry FC protocols encapsulated on other transmission technologies (e.g. ATM, SONET), or to act as a bridge between two FC loops (e.g. as a two port fabric).

The FC Initiator to SCSI Target mode provides for the basic configuration of a server using Fibre Channel to communicate with SCSI targets. This mode requires that a host system have an FC attached device and associated device drivers and software to generate SCSI-3 FCP requests. This system acts as an initiator using the storage router to communicate with SCSI target devices. The SCSI devices supported can include SCSI-2 compliant direct or sequential access (disk or tape) devices. The storage router serves to translate command and status information and transfer data between SCSI-3 FCP and SCSI-2, allowing the use of standard SCSI-2 devices in a Fibre Channel environment.

The SCSI Initiator to FC Target mode provides for the configuration of a server using SCSI-2 to communicate with Fibre Channel targets. This mode requires that a host system has a SCSI-2 interface and driver software to control SCSI-2 target devices. The storage router will connect to the SCSI-2 bus and respond as a target to multiple target IDs. Configuration information is required to identify the target IDs to which the bridge will respond on the SCSI-2 bus. The storage router then translates the SCSI-2 requests to SCSI-3 FCP requests, allowing the use of FC devices with a SCSI host system. This will also allow features such as a tape device acting as an initiator on the SCSI bus to provide full support for this type of SCSI device.

In general, user configuration of the storage router will be needed to support various functional modes of operation. Configuration can be modified, for example, through a serial port or through an Ethernet port via SNMP (simple network management protocol) or the Telnet session. Specifically, SNMP manageability can be provided via a B02.3 Ethernet interface. This can provide for configuration changes as well as providing statistics and error information. Configuration can also be performed via TELNET or RS-232 interfaces with menu driven command interfaces. Configuration information can be stored in a segment of flash memory and can be retained across resets and power off cycles. Password protection can also be provided.

In the first two modes of operation, addressing information is needed to map from FC addressing to SCSI addressing and vice versa. This can be 'hard' configuration data, due to the need for address information to be maintained across initialization and partial reconfigurations of the Fibre Channel address space. In an arbitrated loop configuration, user configured addresses will be needed for AL_PAs in order to insure that known addresses are provided between loop reconfigurations.

With respect to addressing, FCP and SCSI 2 systems employ different methods of addressing target devices. Additionally, the inclusion of a storage router means that a method of translating device IDs needs to be implemented. In addition, the storage router can respond to commands without passing the commands through to the opposite interface. This can be implemented to allow all generic FCP and SCSI commands to pass through the storage router to address attached devices, but allow for configuration and diagnostics to be performed directly on the storage router through the FC and SCSI interfaces.

Management commands are those intended to be processed by the storage router controller directly. This may include diagnostic, mode, and log commands as well as other vendor-specific commands. These commands can be received and processed by both the FOP and SCSI interfaces, but are not typically bridged to the opposite interface. These commands may also have side effects on the operation of the storage router, and cause other storage router operations to change or terminate.

A primary method of addressing management commands though the FCP and SCSI interfaces can be through peripheral device type addressing. For example, the storage router can respond to all operations addressed to logical unit (LUN) zero as a controller device. Commands that the storage router will support can include INQUIRY as well as vendor-specific management commands. These are to be generally consistent with SCC standard commands.

The SCSI bus is capable of establishing bus connections between targets. These targets may internally address logical units. Thus, the prioritized addressing scheme used by SCSI subsystems can be represented as follows: BUS:TARGET: LOGICAL UNIT. The BUS identification is intrinsic in the configuration, as a SCSI initiator is attached to only one bus. Target addressing is handled by bus arbitration from information provided to the arbitrating device. Target addresses are assigned to SCSI devices directly through some means of configuration, such as a hardware jumper, switch setting, or device specific software configuration. As such, the SCSI protocol provides only logical unit addressing within the Identify message. Bus and target information is implied by the established connection.

Fibre Channel devices within a fabric are addressed by a unique port identifier. This identifier is assigned to a port during certain well-defined states of the FC protocol. Individual ports are allowed to arbitrate for a known, user defined address. If such an address is not provided, or if arbitration for a particular-user address fails, the port is assigned a unique address by the FC protocol. This address is generally not guaranteed to be unique between instances. Various scenarios exist where the AL-PA of a device will change, either after power cycle or loop reconfiguration.

The FC protocol also provides a logical unit address field within command structures to provide addressing to devices internal to a port. The FCP_CMD payload specifies an eight byte LUN field. Subsequent identification of the exchange between devices is provided by the FQXID (Fully Qualified Exchange ID).

FC ports can be required to have specific addresses assigned. Although basic functionality is not dependent on this, changes in the loop configuration could result in disk targets changing identifiers with the potential risk of data corruption or loss. This configuration can be straightforward, and can consist of providing the device a loop-unique ID (AL_PA) in the range of "01h" to "EFh." Storage routers could be shipped with a default value with the assumption that most configurations will be using single storage routers and no other devices requesting the present ID. This would provide a minimum amount of initial configuration to the system administrator. Alternately, storage routers could be defaulted to assume any address so that configurations requiring multiple storage routers on a loop would not require that the administrator assign a unique ID to the additional storage routers.

Address translation is needed where commands are issued in the cases FC Initiator to SCSI Target and SCSI Initiator to FC Target. Target responses are qualified by the FQXID and will retain the translation acquired at the beginning of the exchange. This prevents configuration changes occurring during the course of execution of a command from causing data or state information to be inadvertently misdirected. Configuration can be required in cases of SCSI Initiator to FC Target, as discovery may not effectively allow for FCP targets to consistently be found. This is due to an FC arbitrated loop supporting addressing of a larger number of devices than a SCSI bus and the possibility of FC devices changing their AL-PA due to device insertion or other loop initialization.

In the direct method, the translation to BUS:TARGET: LUN of the SCSI address information will be direct. That is, the values represented in the FCP LUN field will directly map to the values in effect on the SCSI bus. This provides a clean translation and does not require SCSI bus discovery. It also allows devices to be dynamically added to the SCSI bus without modifying the address map. It may not allow for complete discovery by FCP initiator devices, as gaps between device addresses may halt the discovery process. Legacy SCSI device drivers typically halt discovery on a target device at the first unoccupied LUN, and proceed to the next target.

This would lead to some devices not being discovered. However, this allows for hot plugged devices and other changes to the loop addressing.

In the ordered method, ordered translation requires that the storage router perform discovery on reset, and collapses the addresses on the SCSI bus to sequential FSP LUN values. Thus, the FCP LUN values 0-N can represent N+1 SCSI devices, regardless of SCSI address values, in the order in which they are isolated during the SCSI discovery process. This would allow the FCP initiator discovery process to identify all mapped SCSI devices without further configuration. This has the limitation that hot-plugged devices will not be identified until the next reset cycle. In this case, the address may also be altered as well.

In addition to addressing, according to the present invention, the storage router provides configuration and access controls that cause certain requests from FC Initiators to be directed to assigned virtual local storage partitioned on SCSI storage devices. For example, the same request for LUN 0 (local storage) by two different FC Initiators can be directed to two separate subsets of storage. The storage router can use tables to map, for each initiator, what storage access is available and what partition is being addressed by a particular request. In this manner, the storage space provided by SCSI storage devices can be allocated to FC initiators to provide virtual local storage as well as to create any other desired configuration for secured access.

Although the present invention has been described in detail, it should be understood that various changes, substitutions, and alterations can be made hereto without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A storage router for providing virtual local storage on remote storage devices, comprising:

- a first controller operable to interface with a first transport medium, wherein the first medium is a serial transport media; and
- a processing device coupled to the first controller, wherein the processing device is configured to:
  - maintain a map to allocate storage space on the remote storage devices to devices connected to the first transport medium by associating representations of the devices connected to the first transport medium with representations of storage space on the remote storage devices, wherein each representation of a device connected to the first transport medium is associated with one or more representations of storage space on the remote storage devices;
  - control access from the devices connected to the first transport medium to the storage space on the remote storage devices in accordance with the map; and
  - allow access from devices connected to the first transport medium to the remote storage devices using native low level block protocol.

2. The storage router of claim **1**, wherein the map associates a representation of storage space on the remote storage devices with multiple devices connected to the first transport medium.

3. The storage router of claim **1**, wherein the storage space on the remote storage devices comprises storage space on multiple remote storage devices.

4. The storage router of claim **1**, wherein the map associates a representation of a device connected to the first transport medium with a representation of an entire storage space of at least one remote storage device.

5. The storage router of claim **1**, wherein the map resides at the storage router and is maintained at the storage router.

6. The storage router of claim **1**, wherein the native low level block protocol is received at the storage router via the first transport medium and the processing device uses the received native low level block protocol to allow the devices connected to the first transport medium access to storage space specifically allocated to them in the map.

7. The storage router of claim **1**, wherein the storage router is configured to receive commands according to a first low level block protocol from the device connected to the first transport medium and forward commands according to a second low level block protocol to the remote storage devices.

8. The storage router of claim **7**, wherein the first low level block protocol is an FCP protocol and the second low level block protocol is a protocol other than FCP.

9. The storage router of claim **1**, wherein the map comprises one or more tables.

10. The storage router of claim **1**, wherein the virtual local storage is provided to the devices connected to the first transport medium in a manner that is transparent to the devices and wherein the storage space allocated to the devices connected to the first transport medium appears to the devices as local storage.

11. The storage router of claim **1**, wherein the storage router provides centralized control of what the devices connected to the first transport medium see as local storage.

12. The storage router of claim **1**, wherein the representations of storage space comprise logical unit numbers that represent a subset of storage on the remote storage devices.

13. The storage router of claim **12**, wherein the storage router is operable to route requests to the same logical unit number from different devices connected to the first transport medium to different subsets of storage space on the remote storage devices.

14. The storage router of claim **1**, wherein the representations of devices connected to the first transport medium are unique identifiers.

15. The storage router of claim **14**, wherein the unique identifiers are world wide names.

16. The storage router of claim **1**, wherein the storage router is configured to allow modification of the map in a manner transparent to and without involvement of the devices connected to the first transport medium.

17. The storage router of claim **1**, wherein the processing device is a microprocessor.

18. The storage router of claim **1**, wherein the processing device is a microprocessor and associated logic to implement a stand-alone processing system.

19. The storage router of claim **1**, wherein the first transport medium is a fibre channel transport medium and further comprising a second transport medium connected to the remote storage devices that is a fibre channel transport medium.

20. A storage network comprising:

- a set of devices connected a first transport medium, wherein the first transport medium;
- a set of remote storage devices connected to a second transport medium;
- a storage router connected to the serial transport medium;
- a storage router connected to the first transport medium and second transport medium to provide virtual local storage on the remote storage devices, the storage router configured to:
  - maintain a map to allocate storage space on the remote storage devices to devices connected to the first transport medium by associating representations of the devices connected to the first transport medium with

representations of storage space on the remote storage devices, wherein each representation of a device connected to the first transport medium is associated with one or more representations of storage space on the remote storage devices;

control access from the devices connected to the first transport medium to the storage space on the remote storage devices in accordance with the map; and

allow access from devices connected to the first transport medium to the remote storage devices using native low level block protocol.

21. The storage network of claim **20**, wherein the map associates a representation of storage space on the remote storage devices with multiple devices connected to the first transport medium.

22. The storage network of claim **20**, wherein the storage space on the remote storage devices comprises storage space on multiple remote storage devices.

23. The storage network of claim **20**, wherein the map associates a representation of a device connected to the first transport medium with a representation of an entire storage space of at least one remote storage device.

24. The storage network of claim **20**, wherein the map resides at the storage router and is maintained at the storage router.

25. The storage network of claim **20**, wherein the native low level block protocol is received at the storage router via the first transport medium and the storage router uses the received native low level block protocol to allow the devices connected to the first transport medium access to storage space specifically allocated to them in the map.

26. The storage router of claim **20**, wherein the storage router is configured to receive commands according to a first low level block protocol from the device connected to the first transport medium and forward commands according to a second low level block protocol to the remote storage devices.

27. The storage network of claim **20**, wherein the first low level block protocol is an FCP protocol and the second low level block protocol is a protocol other than FCP.

28. The storage network of claim **20**, wherein the map comprises one or more tables.

29. The storage network of claim **20**, wherein the virtual local storage is provided to the devices connected to the first transport medium in a manner that is transparent to the devices and wherein the storage space allocated to the devices connected to the first transport medium appears to the devices as local storage.

30. The storage network of claim **20**, wherein the storage router provides centralized control of what the devices connected to the first transport medium see as local storage.

31. The storage network of claim **20**, wherein the representations of storage space comprise logical unit numbers that represent a subset of storage on the remote storage devices.

32. The storage network of claim **31**, wherein the storage router is operable to route requests to the same logical unit number from different devices connected to the first transport medium to different subsets of storage space on the remote storage devices.

33. The storage network of claim **20**, wherein the representations of devices connected to the first transport medium are unique identifiers.

34. The storage network of claim **33**, wherein the unique identifiers are world wide names.

35. The storage network of claim **20**, wherein the storage router is configured to allow modification of the map in a manner transparent to and without involvement of the devices connected to the first transport medium.

36. The storage network of claim **20**, wherein the first transport medium is a fibre channel transport medium and the second transport medium is a fibre channel transport medium.

37. A method for providing virtual local storage on remote storage devices comprising:

connecting a storage router between a set of devices connected to a first transport medium and a set of remote storage devices, wherein the first transport medium is a serial transport medium;

maintaining a map at the storage router to allocate storage space on the remote storage devices to devices connected to the first transport medium by associating representations of the devices connected to the first transport medium with representations of storage space on the remote storage devices, wherein each representation of a device connected to the first transport medium is associated with one or more representations of storage space on the remote storage devices;

controlling access from the devices connected to the first transport medium to the storage space on the remote storage devices in accordance with the map; and

allowing access from devices connected to the first transport medium to the remote storage devices using native low level block protocol.

38. The method of claim **37**, wherein the map associates a representation of storage space on the remote storage devices with multiple devices connected to the first transport medium.

39. The method of claim **37**, wherein the storage space on the remote storage devices comprises storage space on multiple remote storage devices.

40. The method of claim **37**, wherein the map associates a representation of a device connected to the first transport medium with a representation of an entire storage space of at least one remote storage device.

41. The method of claim **37**, wherein the map resides at the storage router and is maintained at the storage router.

42. The method of claim **37**, further comprising:

receiving the native low level block protocol at the storage router via the first transport medium;

using the received native low level block protocol at the storage router to allow the devices connected to the first transport medium access to storage space specifically allocated to them in the map.

43. The method of claim **37**, further comprising receiving commands at the storage router according to a first low level block protocol from the device connected to the first transport medium and forwarding commands according to a second low level block protocol to the remote storage devices.

44. The method of claim **43**, wherein the first low level block protocol is an FCP protocol and the second low level block protocol is a protocol other than FCP.

45. The method of claim **37**, wherein the map comprises one or more tables.

46. The method of claim **37**, wherein the virtual local storage is provided to the devices connected to the first transport medium in a manner that is transparent to the devices and wherein the storage space allocated to the devices connected to the first transport medium appears to the devices as local storage.

47. The method of claim **37**, wherein the storage router provides centralized control of what the devices connected to the first transport medium see as local storage.

48. The method of claim **37**, wherein the representations of storage space comprise logical unit numbers that represent a subset of storage on the remote storage devices.

49. The method of claim **48**, wherein the storage router is operable to route requests to the same logical unit number from different devices connected to the first transport medium to different subsets of storage space on the remote storage devices.

50. The method of claim **37**, wherein the representations of devices connected to the first transport medium are unique identifiers.

51. The method of claim **50**, wherein the unique identifiers are world wide names.

52. The method of claim **51**, wherein the storage router is configured to allow modification of the map in a manner transparent to and without involvement of the devices connected to the first transport medium.

53. The method of claim **1** wherein connecting the storage router between a set of devices connected to a first transport medium and a set of remote storage devices further comprises connecting the storage router between a first fibre channel transport medium and a second fibre channel transport medium.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,934,041 B2
APPLICATION NO. : 12/690592
DATED : April 26, 2011
INVENTOR(S) : Geoffrey B. Hoese et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Claim 20: Col. 10 line 56 should read -

A set of devices connected --to-- a first transport medium, wherein the first transport medium --is a serial transport medium--;

Signed and Sealed this
Thirteenth Day of September, 2011

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office

EXHIBIT C

US007051147B2

(12) United States Patent
Hoese et al.

(10) Patent No.: US 7,051,147 B2
(45) Date of Patent: *May 23, 2006

(54) STORAGE ROUTER AND METHOD FOR PROVIDING VIRTUAL LOCAL STORAGE

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This patent is subject to a terminal disclaimer.

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(51) **Int. Cl.**
G06F 13/00 (2006.01)

(52) **U.S. Cl.** **710/305**; 710/11; 709/258

(58) **Field of Classification Search** 710/1–5, 710/8–13, 22–28, 104–105, 305–306, 325, 710/250, 126–131, 36–38; 709/250, 258; 714/42; 711/112, 113, 110

See application file for complete search history.

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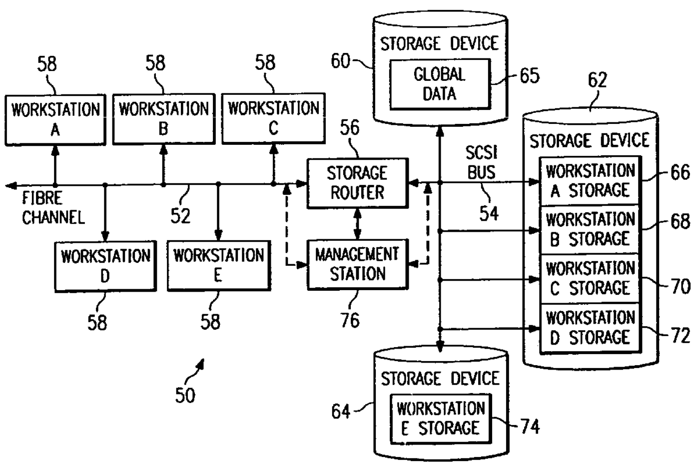
(74) *Attorney, Agent, or Firm*—Sprinkle IP Law Group

(57) **ABSTRACT**

A storage router and storage network provide virtual local storage on remote storage devices to Fiber Channel devices. A plurality of Fiber Channel devices, such as workstations, are connected to a Fiber Channel transport medium, and a plurality of storage devices are connected to a second Fiber Channel transport medium. The storage router interfaces between the Fiber Channel transport media. The storage router maps between the workstations and the storage devices and implements access controls for storage space on the storage devices. The storage router then allows access from the workstations to the storage devices using native low level, block protocol in accordance with the mapping and the access controls.

39 Claims, 2 Drawing Sheets



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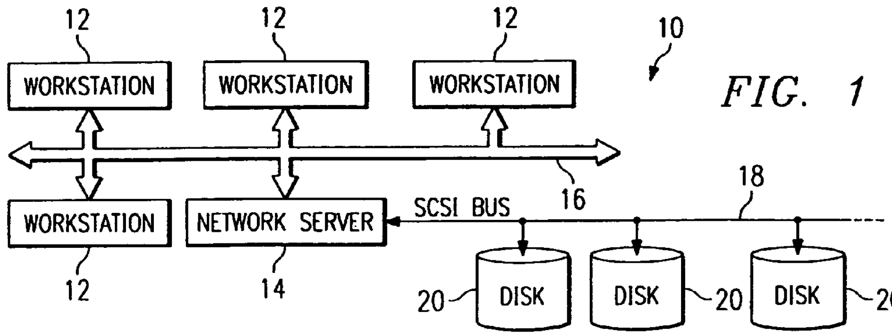

FIG. 1

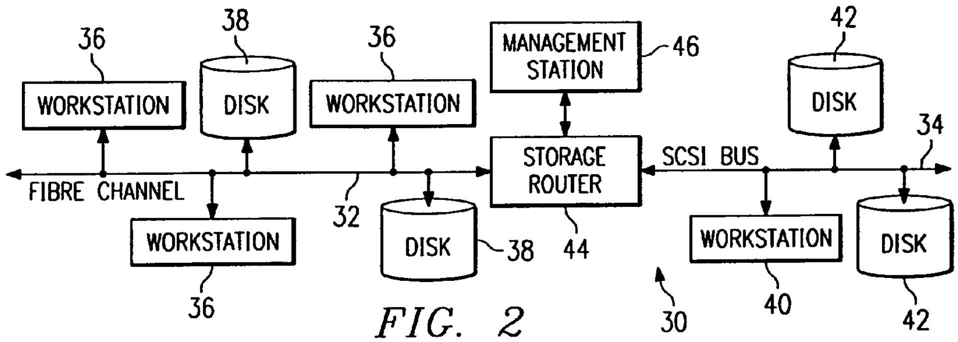

FIG. 2

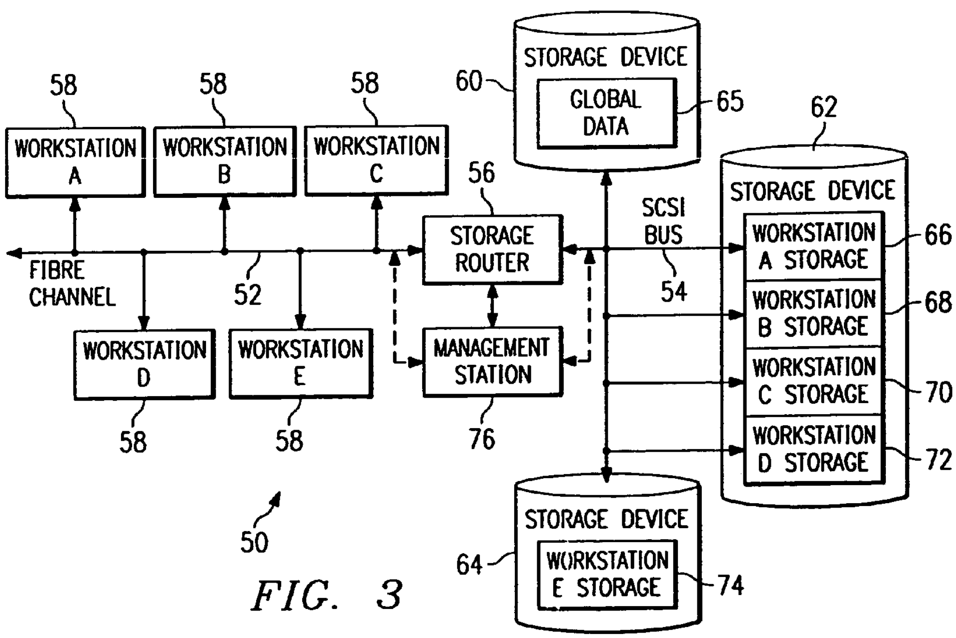

FIG. 3

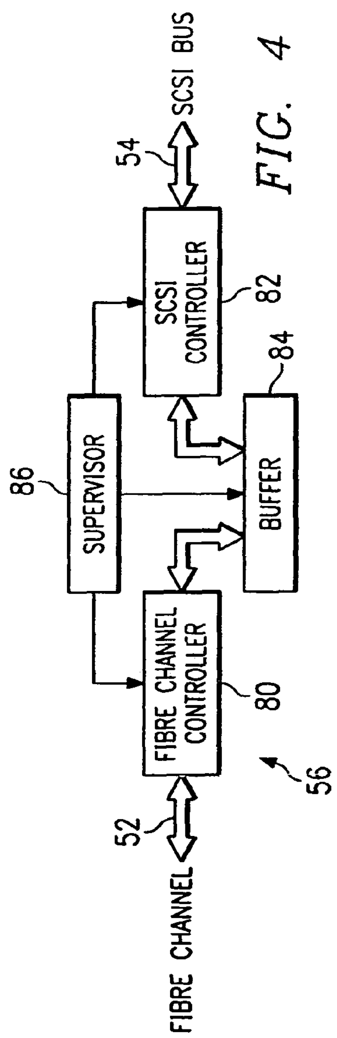
SCSI BUS
54
SCSI CONTROLLER
82
84
BUFFER
SUPERVISOR
86
FIBRE CHANNEL CONTROLLER
80
52
FIBRE CHANNEL
56

FIG. 4

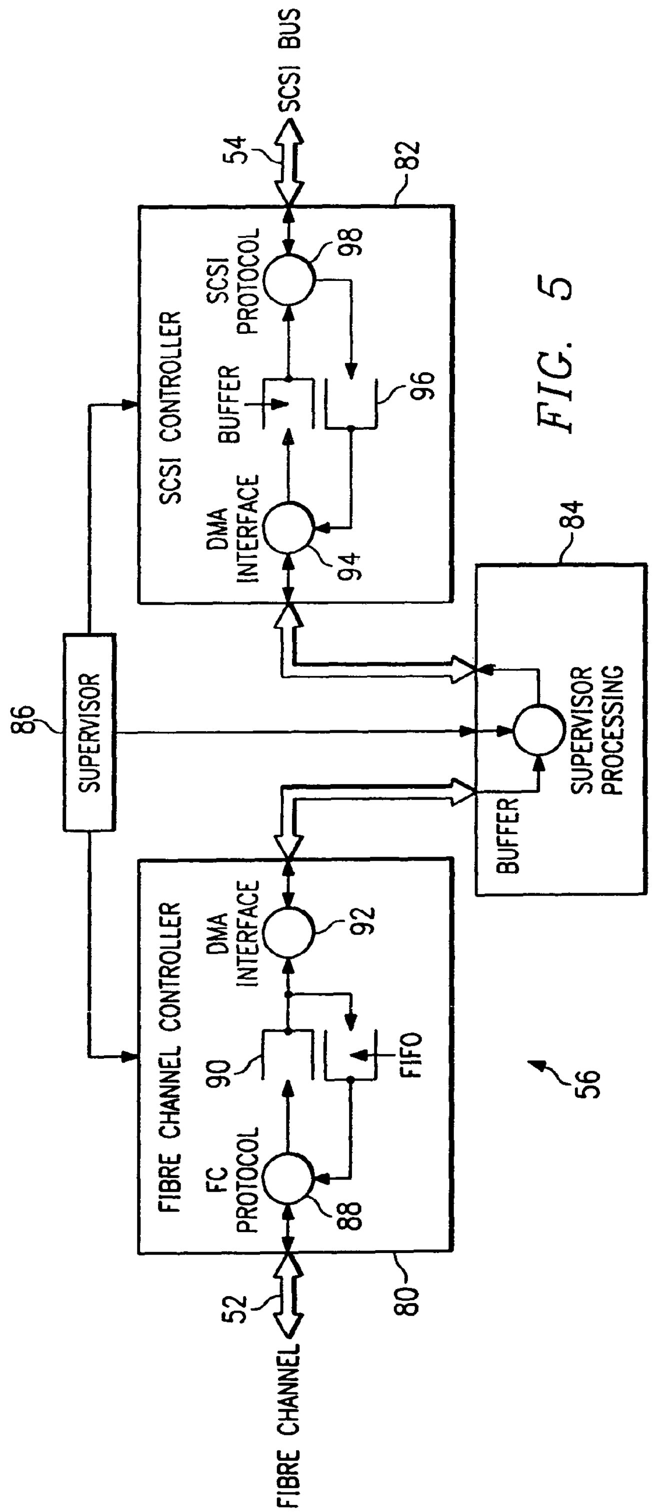
SCSI BUS
54
82
SCSI CONTROLLER
SCSI PROTOCOL
98
BUFFER
96
DMA INTERFACE
94
84
SUPERVISOR
86
SUPERVISOR PROCESSING
BUFFER
FIBRE CHANNEL CONTROLLER
DMA INTERFACE
92
90
FIFO
FC PROTOCOL
88
80
52
FIBRE CHANNEL
56

FIG. 5

STORAGE ROUTER AND METHOD FOR PROVIDING VIRTUAL LOCAL STORAGE

RELATED APPLICATIONS

This application is a continuation of and claims the benefit of the filing dates of U.S. patent application Ser. No. 10/081,110 by inventors Geoffrey B. Hoese and Jeffry T. Russell, entitled "Storage Router and Method for Providing Virtual Local Storage" filed on Feb. 22, 2002, now U.S. Pat. No. 6,789,152 which in turn is a continuation of U.S. application Ser. No. 09/354,682 by inventors Geoffrey B. Hoese and Jeffry T. Russell, entitled "Storage Router and Method for Providing Virtual Local Storage" filed on Jul. 15, 1999, now U.S. Pat. No. 6,421,753, which in turn is a continuation of U.S. patent application Ser. No. 09/001,799, filed on Dec. 31, 1997, now U.S. Pat. No. 5,941,972, and hereby incorporates these applications by reference in their entireties as if they had been fully set forth herein.

TECHNICAL FIELD OF THE INVENTION

This invention relates in general to network storage devices, and more particularly to a storage router and method for providing virtual local storage on remote SCSI storage devices to Fibre Channel devices.

BACKGROUND OF THE INVENTION

Typical storage transport mediums provide for a relatively small number of devices to be attached over relatively short distances. One such transport medium is a Small Computer System Interface (SCSI) protocol, the structure and operation of which is generally well known as is described, for example, in the SCSI-1, SCSI-2 and SCSI-3 specifications. High speed serial interconnects provide enhanced capability to attach a large number of high speed devices to a common storage transport medium over large distances. One such serial interconnect is Fibre Channel, the structure and operation of which is described, for example, in *Fibre Channel Physical and signaling Interface* (*FC-PH*), ANSI X3.230 *Fibre Channel Arbitrated Loop* (*FC-AL*), and ANSI X3.272 *Fibre Channel Private Loop Direct Attach* (*FC-PLDA*).

Conventional computing devices, such as computer workstations, generally access storage locally or through network interconnects. Local storage typically consists of a disk drive, tape drive, CD-ROM drive or other storage device contained within, or locally connected to the workstation. The workstation provides a file system structure, that includes security controls, with access to the local storage device through native low level, block protocols. These protocols map directly to the mechanisms used by the storage device and consist of data requests without security controls. Network interconnects typically provide access for a large number of computing devices to data storage on a remote network server. The remote network server provides file system structure, access control, and other miscellaneous capabilities that include the network interface. Access to data through the network server is through network protocols that the server must translate into low level requests to the storage device. A workstation with access to the server storage must translate its file system protocols into network protocols that are used to communicate with the server. Consequently, from the perspective of a workstation, or other computing device, seeking to access such server data, the access is much slower than access to data on a local storage device.

SUMMARY OF THE INVENTION

In accordance with the present invention, a storage router and method for providing virtual local storage on remote SCSI storage devices to Fibre Channel devices are disclosed that provide advantages over conventional network storage devices and methods.

According to one aspect of the present invention, a storage router and storage network provide virtual local storage on remote SCSI storage devices to Fibre Channel devices. A plurality of Fibre Channel devices, such as workstations, are connected to a Fibre Channel transport medium, and a plurality of SCSI storage devices are connected to a SCSI bus transport medium. The storage router interfaces between the Fibre Channel transport medium and the SCSI bus transport medium. The storage router maps between the workstations and the SCSI storage devices and implements access controls for storage space on the SCSI storage devices. The storage router then allows access from the workstations to the SCSI storage devices using native low level, block protocol in accordance with the mapping and the access controls.

According to another aspect of the present invention, virtual local storage on remote SCSI storage devices is provided to Fibre Channel devices. A Fibre Channel transport medium and a SCSI bus transport medium are interfaced with. A configuration is maintained for SCSI storage devices connected to the SCSI bus transport medium. The configuration maps between Fibre Channel devices and the SCSI storage devices and implements access controls for storage space on the SCSI storage devices. Access is then allowed from Fibre Channel initiator devices to SCSI storage devices using native low level, block protocol in accordance with the configuration.

A technical advantage of the present invention is the ability to centralize local storage for networked workstations without any cost of speed or overhead. Each workstation access its virtual local storage as if it work locally connected. Further, the centralized storage devices can be located in a significantly remote position even in excess of ten kilometers as defined by Fibre Channel standards.

Another technical advantage of the present invention is the ability to centrally control and administer storage space for connected users without limiting the speed with which the users can access local data. In addition, global access to data, backups, virus scanning and redundancy can be more easily accomplished by centrally located storage devices.

A further technical advantage of the present invention is providing support for SCSI storage devices as local storage for Fibre Channel hosts. In addition, the present invention helps to provide extended capabilities for Fibre Channel and for management of storage subsystems.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present invention and the advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings, in which like reference numbers indicate like features, and wherein:

FIG. **1** is a block diagram of a conventional network that provides storage through a network server;

FIG. **2** is a block diagram of one embodiment of a storage network with a storage router that provides global access and routing;

FIG. **3** is a block diagram of one embodiment of a storage network with a storage router that provides virtual local storage;

FIG. **4** is a block diagram of one embodiment of the storage router of FIG. **3**; and

FIG. **5** is a block diagram of one embodiment of data flow within the storage router of FIG. **4**.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a block diagram of a conventional network, indicated generally at **10**, that provides access to storage through a network server. As shown, network **10** includes a plurality of workstations **12** interconnected with a network server **14** via a network transport medium **16**. Each workstation **12** can generally comprise a processor, memory, input/output devices, storage devices and a network adapter as well as other common computer components. Network server **14** uses a SCSI bus **18** as a storage transport medium to interconnect with a plurality of storage devices **20** (tape drives, disk drives, etc.). In the embodiment of FIG. **1**, network transport medium **16** is an network connection and storage devices **20** comprise hard disk drives, although there are numerous alternate transport mediums and storage devices.

In network **10**, each workstation **12** has access to its local storage device as well as network access to data on storage devices **20**. The access to a local storage device is typically through native low level, block protocols. On the other hand, access by a workstation **12** to storage devices **20** requires the participation of network server **14** which implements a file system and transfers data to workstations **12** only through high level file system protocols. Only network server **14** communicates with storage devices **20** via native low level, block protocols. Consequently, the network access by workstations **12** through network server **14** is slow with respect to their access to local storage. In network **10**, it can Also be a logistical problem to centrally manage and administer local data distributed across an organization, including accomplishing tasks such as backups, virus scanning and redundancy.

FIG. **2** is a block diagram of one embodiment of a storage network, indicated generally at **30**, with a storage router that provides global access and routing. This environment is significantly different from that of FIG. **1** in that there is no network server involved. In FIG. **2**, a Fibre Channel high speed serial transport **32** interconnects a plurality of workstations **36** and storage devices **38**. A SCSI bus storage transport medium interconnects workstations **40** and storage devices **42**. A storage router **44** then serves to interconnect these mediums and provide devices on either medium global, transparent access to devices on the other medium. Storage router **44** routes requests from initiator devices on one medium to target devices on the other medium and routes data between the target and the initiator. Storage router **44** can allow initiators and targets to be on either side. In this manner, storage router **44** enhances the functionality of Fibre Channel **32** by providing access, for example, to legacy SCSI storage devices on SCSI bus **34**. In the embodiment of FIG. **2**, the operation of storage router **44** can be managed by a management station **46** connected to the storage router via a direct serial connection.

In storage network **30**, any workstation **36** or workstation **40** can access any storage device **38** or storage device **42** through native low level, block protocols, and vice versa. This functionality is enabled by storage router **44** which routes requests and data as a generic transport between Fibre Channel **32** and SCSI bus **34**. Storage router **44** uses tables to map devices from one medium to the other and distributes requests and data across Fibre Channel **32** and SCSI bus **34** without any security access controls. Although this extension of the high speed serial interconnect provided by Fibre Channel **32** is beneficial, it is desirable to provide security controls in addition to extended access to storage devices through a native low level, block protocol.

FIG. **3** is a block diagram of one embodiment of a storage network, indicated generally at **50**, with a storage router that provides virtual local storage. Similar to that of FIG. **2**, storage network **50** includes a Fibre Channel high speed serial interconnect **52** and a SCSI bus **54** bridged by a storage router **56**. Storage router **56** of FIG. **3** provides for a large number of workstations **58** to be interconnected on a common storage transport and to access common storage devices **60**, **62** and **64** through native low level, block protocols.

According to the present invention, storage router **56** has enhanced functionality to implement security controls and routing such that each workstation **58** can have access to a specific subset of the overall data stored in storage devices **60**, **62** and **64**. This specific subset of data has the appearance and characteristics of local storage and is referred to herein as virtual local storage. Storage router **56** allows the configuration and modification of the storage allocated to each attached workstation **58** through the use of mapping tables or other mapping techniques.

As shown in FIG. **3**, for example, storage device **60** can be configured to provide global data **65** which can be accessed by all workstations **58**. Storage device **62** can be configured to provide partitioned subsets **66**, **68**, **70** and **72**, where each partition is allocated to one of the workstations **58** (workstations A, B, C and D). These subsets **66**, **68**, **70** and **72** can only be accessed by the associated workstation **58** and appear to the associated workstation **58** as local storage accessed using native low level, block protocols. Similarly, storage device **64** can be allocated as storage for the remaining workstation **58** (workstation E).

Storage router **56** combines access control with routing such that each workstation **58** has controlled access to only the specified partition of storage device **62** which forms virtual local storage for the workstation **58**. This access control allows security control for the specified data partitions. Storage router **56** allows this allocation of storage devices **60**, **62** and **64** to be managed by a management station **76**. Management station **76** can connect directly to storage router **56** via a direct connection or, alternately, can interface with storage router **56** through either Fibre Channel **52** or SCSI bus **54**. In the latter case, management station **76** can be a workstation or other computing device with special rights such that storage router **56** allows access to mapping tables and shows storage devices **60**, **62** and **64** as they exist physically rather than as they have been allocated.

The environment of FIG. **3** extends the concept of a single workstation having locally connected storage devices to a storage network **50** in which workstations **58** are provided virtual local storage in a manner transparent to workstations **58**. Storage router **56** provides centralized control of what each workstation **58** sees as its local drive, as well as what data it sees as global data accessible by other workstations **58**. Consequently, the storage space considered by the workstation **58** to be its local storage is actually a partition (i.e., logical storage definition) of a physically remote storage device **60**, **62** or **64** connected through storage router **56**. This means that similar requests from workstations **58** for access to their local storage devices produce different accesses to the storage space on storage devices **60**, **62** and **64**. Further, no access from a workstation **58** is allowed to the virtual local storage of another workstation **58**.

The collective storage provided by storage devices **60**, **62** and **64** can have blocks allocated by programming means within storage router **56**. To accomplish this function, storage router **56** can include routing tables and security controls that define storage allocation for each workstation **58**. The advantages provided by implementing virtual local storage in centralized storage devices include the ability to do collective backups and other collective administrative functions more easily. This is accomplished without limiting the performance of workstations **58** because storage access involves native low level, block protocols and does not involve the overhead of high level protocols and file systems required by network servers.

FIG. **4** is a block diagram of one embodiment of storage router **56** of FIG. **3**. Storage router **56** can comprise a Fibre Channel controller **80** that interfaces with Fibre Channel **52** and a SCSI controller **82** that interfaces with SCSI bus **54**. A buffer **84** provides memory work space and is connected to both Fibre Channel controller **80** and to SCSI controller **82**. A supervisor unit **86** is connected to Fibre Channel controller **80**, SCSI controller **82** and buffer **84**. Supervisor unit **86** comprises a microprocessor for controlling operation of storage router **56** and to handle mapping and security access for requests between Fibre Channel **52** and SCSI bus **54**.

FIG. **5** is a block diagram of one embodiment of data flow within storage router **56** of FIG. **4**. As shown, data from Fibre Channel **52** is processed by a Fibre Channel (FC) protocol unit **88** and placed in a FIFO queue **90**. A direct memory access (DMA) interface **92** then takes data out of FIFO queue **90** and places it in buffer **84**. Supervisor unit **86** processes the data in buffer **84** as represented by supervisor processing **93**. This processing involves mapping between Fibre Channel **52** and SCSI bus **54** and applying access controls and routing functions. A DMA interface **94** then pulls data from buffer **84** and places it into a buffer **96**. A SCSI protocol unit **98** pulls data from buffer **96** and communicates the data on SCSI bus **54**. Data flow in the reverse direction, from SCSI bus **54** to Fibre Channel **52**, is accomplished in a reverse manner.

The storage router of the present invention is a bridge device that connects a Fibre Channel link directly to a SCSI bus and enables the exchange of SCSI command set information between application clients on SCSI bus devices and the Fibre Channel links. Further, the storage router applies access controls such that virtual local storage can be established in remote SCSI storage devices for workstations on the Fibre Channel link. In one embodiment, the storage router provides a connection for Fibre Channel links running the SCSI Fibre Channel Protocol (FCP) to legacy SCSI devices attached to a SCSI bus. The Fibre Channel topology is typically an Arbitrated Loop (FC_AL).

In part, the storage router enables a migration path to Fibre Channel based, serial SCSI networks by providing connectivity for legacy SCSI bus devices. The storage router can be attached to a Fibre Channel Arbitrated Loop and a SCSI bus to support a number of SCSI devices. Using configuration settings, the storage router can make the SCSI bus devices available on the Fibre Channel network as FCP logical units. Once the configuration is defined, operation of the storage router is transparent to application clients. In this manner, the storage router can form an integral part of the migration to new Fibre Channel based networks while providing a means to continue using legacy SCSI devices.

In one implementation (not shown), the storage router can be a rack mount or free standing device with an internal power supply. The storage router can have a Fibre Channel and SCSI port, and a standard, detachable power cord can be used, the FC connector can be a copper DB**9** connector, and the SCSI connector can be a 68-pin type. Additional modular jacks can be provided for a serial port and a 802.3 10BaseT port, i.e. twisted pair Ethernet, for management access. The SCSI port of the storage router an support SCSI direct and sequential access target devices and can support SCSI initiators, as well. The Fibre Channel port can interface to SCSI-3 FCP enabled devices and initiators.

To accomplish its functionality, one implementation of the storage router uses: a Fibre Channel interface based on the HEWLETT-PACKARD TACHYON HPFC-5000 controller and a GLM media interface; an Intel 80960RP processor, incorporating independent data and program memory spaces, and associated logic required to implement a stand alone processing system; and a serial port for debug and system configuration. Further, this implementation includes a SCSI interface supporting Fast-20 based on the SYMBIOS 53C8xx series SCSI controllers, and an operating system based upon the WIND RIVERS SYSTEMS VXWORKS or IXWORKS kernel, as determined by design. In addition, the storage router includes software as required to control basic functions of the various elements, and to provide appropriate translations between the FC and SCSI protocols.

The storage router has various modes of operation that are possible between FC and SCSI target and initiator combinations. These modes are: FC Initiator to SCSI Target; SCSI Initiator to FC Target; SCSI Initiator to SCSI Target; and FC Initiator to FC Target. The first two modes can be supported concurrently in a single storage router device are discussed briefly below. The third mode can involve two storage router devices back to back and can serve primarily as a device to extend the physical distance beyond that possible via a direct SCSI connection. The last mode can be used to carry FC protocols encapsulated on other transmission technologies (e.g. ATM, SONET), or to act as a bridge between two FC loops (e.g. as a two port fabric).

The FC Initiator to SCSI Target mode provides for the basic configuration of a server using Fibre Channel to communicate with SCSI targets. This mode requires that a host system have an FC attached device and associated device drivers and software to generate SCSI-3 FCP requests. This system acts as an initiator using the storage router to communicate with SCSI target devices. The SCSI devices supported can include SCSI-2 compliant direct or sequential access (disk or tape) devices. The storage router serves to translate command and status information and transfer data between SCSI-3 FCP and SCSI-2, allowing the use of standard SCSI-2 devices in a Fibre Channel environment.

The SCSI Initiator to FC Target mode provides for the configuration of a server using SCSI-2 to communicate with Fibre Channel targets. This mode requires that a host system has a SCSI-2 interface and driver software to control SCSI-2 target devices. The storage router will connect to the SCSI-2 bus and respond as a target to multiple target IDs. Configuration information is required to identify the target IDs to which the bridge will respond on the SCSI-2 bus. The storage router then translates the SCSI-2 requests to SCSI-3 FCP requests, allowing the use of FC devices with a SCSI host system. This will also allow features such as a tape device acting as an initiator on the SCSI bus to provide full support for this type of SCSI device.

In general, user configuration of the storage router will be needed to support various functional modes of operation. Configuration can be modified, for example, through a serial port or through an Ethernet port via SNMP (simple network management protocol) or a Telnet session. Specifically, SNMP manageability can be provided via an 802.3 Ethernet interface. This can provide for configuration changes as well as providing statistics and error information. Configuration can also be performed via TELNET or RS-232 interfaces with menu driven command interfaces. Configuration information can be stored in a segment of flash memory and can be retained across resets and power off cycles. Password protection can also be provided.

In the first two modes of operation, addressing information is needed to map from FC addressing to SCSI addressing and vice versa. This can be 'hard' configuration data, due to the need for address information to be maintained across initialization and partial reconfigurations of the Fibre Channel address space. In an arbitrated loop configuration, user configured addresses will be needed for AL_PAs in order to insure that known addresses are provided between loop reconfigurations.

With respect to addressing, FCP and SCSI 2 systems employ different methods of addressing target devices. Additionally, the inclusion of a storage router means that a method of translating device IDs needs to be implemented. In addition, the storage router can respond to commands without passing the commands through to the opposite interface. This can be implemented to allow all generic FCP and SCSI commands to pass through the storage router to address attached devices, but allow for configuration and diagnostics to be performed directly on the storage router through the FC and SCSI interfaces.

Management commands are those intended to be processed by the storage router controller directly. This may include diagnostic, mode, and log commands as well as other vendor-specific commands. These commands can be received and processed by both the FCP and SCSI interfaces, but are not typically bridged to the opposite interface. These commands may also have side effects on the operation of the storage router, and cause other storage router operations to change or terminate.

A primary method of addressing management commands though the FCP and SCSI interfaces can be through peripheral device type addressing. For example, the storage router can respond to all operations addressed to logical unit (LUN) zero as a controller device. Commands that the storage router will support can include INQUIRY as well as vendor-specific management commands. These are to be generally consistent with SCC standard commands.

The SCSI bus is capable of establishing bus connections between targets. These targets may internally address logical units. Thus, the prioritized addressing scheme used by SCSI subsystems can be represented as follows: BUS:TARGET: LOGICAL UNIT. The BUS identification is intrinsic in the configuration, as a SCSI initiator is attached to only one bus. Target addressing is handled by bus arbitration from information provided to the arbitrating device. Target addresses are assigned to SCSI devices directly, though some means of configuration, such as a hardware jumper, switch setting, or device specific software configuration. As such, the SCSI protocol provides only logical unit addressing within the Identify message. Bus and target information is implied by the established connection.

Fibre Channel devices within a fabric are addressed by a unique port identifier. This identifier is assigned to a port during certain well-defined states of the FC protocol. Individual ports are allowed to arbitrate for a known, user defined address. If such an address is not provided, or if arbitration for a particular user address fails, the port is assigned a unique address by the FC protocol. This address is generally not guaranteed to be unique between instances. Various scenarios exist where the AL-PA of a device will change, either after power cycle or loop reconfiguration.

The FC protocol also provides a logical unit address field within command structures to provide addressing to devices internal to a port. The FCP_CMD payload specifies an eight byte LUN field. Subsequent identification of the exchange between devices is provided by the FQXID (Fully Qualified Exchange ID).

FC ports can be required to have specific addresses assigned. Although basic functionality is not dependent on this, changes in the loop configuration could result in disk targets changing identifiers with the potential risk of data corruption or loss. This configuration can be straightforward, and can consist of providing the device a loop-unique ID (AL_PA) in the range of "01h" to "EFh." Storage routers could be shipped with a default value with the assumption that most configurations will be using single storage routers and no other devices requesting the present ID. This would provide a minimum amount of initial configuration to the system administrator. Alternately, storage routers could be defaulted to assume any address so that configurations requiring multiple storage routers on a loop would not require that the administrator assign a unique ID to the additional storage routers.

Address translation is needed where commands are issued in the cases FC Initiator to SCSI Target and SCSI Initiator to FC Target. Target responses are qualified by the FQXID and will retain the translation acquired at the beginning of the exchange. This prevents configuration changes occurring during the course of execution of a command from causing data or state information to be inadvertently misdirected. Configuration can be required in cases of SCSI Initiator to FC Target, as discovery may not effectively allow for FCP targets to consistently be found. This is due to an FC arbitrated loop supporting addressing of a larger number of devices than a SCSI bus and the possibility of FC devices changing their AL-PA due to device insertion or other loop initialization.

In the direct method, the translation to BUS:TARGET: LUN of the SCSI address information will be direct. That is, the values represented in the FCP LUN field will directly map to the values in effect on the SCSI bus. This provides a clean translation and does not require SCSI bus discovery. It also allows devices to be dynamically added to the SCSI bus without modifying the address map. It may not allow for complete discovery by FCP initiator devices, as gaps between device addresses may halt the discovery process. Legacy SCSI device drivers typically halt discovery on a target device at the first unoccupied LUN, and proceed to the next target. This would lead to some devices not being discovered. However, this allows for hot plugged devices and other changes to the loop addressing.

In the ordered method, ordered translation requires that the storage router perform discovery on reset, and collapses the addresses on the SCSI bus to sequential FCP LUN values. Thus, the FCP LUN values 0-N can represent N+1 SCSI devices, regardless of SCSI address values, in the order in which they are isolated during the SCSI discovery process. This would allow the FCP initiator discovery process to identify all mapped SCSI devices without further configuration. This has the limitation that hot-plugged devices will not be identified until the next reset cycle. In this case, the address may also be altered as well.

In addition to addressing, according to the present invention, the storage router provides configuration and access controls that cause certain requests from FC Initiators to be directed to assigned virtual local storage partitioned on SCSI storage devices. For example, the same request for LUN 0 (local storage) by two different FC Initiators can be directed to two separate subsets of storage. The storage router can use tables to map, for each initiator, what storage access is available and what partition is being addressed by a particular request. In this manner, the storage space provided by SCSI storage devices can be allocated to FC initiators to provide virtual local storage as well as to create any other desired configuration for secured access.

Although the present invention has been described in detail, it should be understood that various changes, substitutions, and alterations can be made hereto without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A storage router for providing virtual local storage on remote storage devices to a device, comprising:
- a buffer providing memory work space for the storage router;
- a first Fibre Channel controller operable to connect to and interface with a first Fibre Channel transport medium;
- a second Fibre Channel controller operable to connect to and interface with a second Fibre Channel transport medium; and
- a supervisor unit coupled to the first and second Fibre Channel controllers and the buffer, the supervisor unit operable:
  - to maintain a configuration for remote storage devices connected to the second Fibre Channel transport medium that maps between the device and the remote storage devices and that implements access controls for storage space on the remote storage devices; and
  - to process data in the buffer to interface between the first Fibre Channel controller and the second Fibre Channel controller to allow access from Fibre Channel initiator devices to the remote storage devices using native low level, block protocol in accordance with the configuration.

2. The storage router of claim **1**, wherein the configuration maintained by the supervisor unit includes an allocation of subsets of storage space to associated Fibre Channel devices, wherein each subset is only accessible by the associated Fibre Channel device.

3. The storage router of claim **2**, wherein the Fibre Channel devices comprise workstations.

4. The storage router of claim **2**, wherein the remote storage devices comprise hard disk drives.

5. The storage router of claim **1**, wherein each of the first Fibre Channel controller comprises:
- a Fibre Channel (FC) protocol unit operable to connect to the Fibre Channel transport medium;
- a first-in-first-out queue coupled to the Fibre Channel protocol unit; and
- a direct memory access (DMA) interface coupled to the first-in-first-out queue and to the buffer.

6. A storage network, comprising:
- a first Fibre Channel transport medium;
- a second Fibre Channel transport medium;
- a plurality of workstations connected to the first Fibre Channel transport medium;
- a plurality of storage devices connected to the second Fibre Channel transport medium; and
- a storage router interfacing between the first Fibre Channel transport medium and the second Fibre Channel transport medium, the storage router providing virtual local storage on the storage devices to the workstations and operable:
  - to map between the workstations and the storage devices;
  - to implement access controls for storage space on the storage devices; and
  - to allow access from the workstations to the storage devices using native low level, block protocol in accordance with the mapping and access controls.

7. The storage network of claim **6**, wherein the access controls include an allocation of subsets of storage space to associated workstations, wherein each subset is only accessible by the associated workstation.

8. The storage network of claim **6**, wherein the storage devices comprise hard disk drives.

9. The storage network of claim **6**, wherein the storage router comprises:
- a buffer providing memory work space for the storage router;
- a first Fibre Channel controller operable to connect to and interface with the first Fibre Channel transport medium, the first Fibre Channel controller further operable to pull outgoing data from the buffer and to place incoming data into the buffer;
- a second Fibre Channel controller operable to connect to and interface with the second Fibre Channel transport medium, the second Fibre Channel controller further operable to pull outgoing data from the buffer and to place incoming data into the buffer; and
- a supervisor unit coupled to the first and second Fibre Channel controllers and the buffer, the supervisor unit operable:
  - to maintain a configuration for the storage devices that maps between workstations and storage devices and that implements the access controls for storage space on the storage devices; and
  - to process data in the buffer to interface between the first Fibre Channel controller and the second Fibre Channel controller to allow access from workstations to storage devices in accordance with the configuration.

10. A method for providing virtual local storage on remote storage devices to Fibre Channel devices, comprising:
- interfacing with a first Fibre Channel transport medium;
- interfacing with a second Fibre Channel transport medium;
- maintaining a configuration for remote storage devices connected to the second Fibre Channel transport medium that maps between Fibre Channel devices and the remote storage devices and that implements access controls for storage space on the remote storage devices; and
- allowing access from Fibre Channel initiator devices to the remote storage devices using native low level, block protocol in accordance with the configuration.

11. The method of claim **10**, wherein maintaining the configuration includes allocating subsets of storage space to associated Fibre Channel devices, wherein each subset is only accessible by the associated Fibre Channel device.

12. The method of claim **11**, wherein the Fibre Channel devices comprise workstations.

13. The method of claim **11**, wherein the remote storage devices comprise hard disk drives.

14. An apparatus for providing virtual local storage on a remote storage device to a device operating according to a Fibre Channel protocol, comprising:

a first controller operable to connect to and interface with a first transport medium, wherein the first transport medium is operable according to the Fibre Channel protocol;

a second controller operable to connect to and interface with a second transport medium, wherein the second transport medium is operable according to the Fibre Channel protocol; and

a supervisor unit coupled to the first controller and the second controller, the supervisor unit operable to control access from the device connected to the first transport medium to the remote storage device connected to the second transport medium using native low level, block protocols according to a map between the device and the remote storage device.

15. The apparatus of claim **14**, wherein the supervisor unit is further operable to maintain a configuration wherein the configuration includes the map between the device and the remote storage device, and further wherein the map includes virtual LUNs that provide a representation of the storage device.

16. The apparatus of claim **15**, wherein the map only exposes the device to LUNs that the device may access.

17. The apparatus of claim **14**, wherein the supervisor unit is further operable to maintain a configuration including the map, wherein the map provides a mapping from a host device ID to a virtual LUN representation of the remote storage device to a physical LUN of the remote storage device.

18. The apparatus of claim **14**, wherein the remote storage device further comprises storage space partitioned into virtual local storage for the device connected to the first transport medium.

19. The apparatus of claim **18**, wherein the supervisor unit is further operable to prevent the device from accessing any storage on the remote storage device that is not part of a virtual local storage partition assigned to the device.

20. The apparatus of claim **14**, wherein the first controller and the second controller further comprise a single controller.

21. A system for providing virtual local storage on remote storage devices, comprising:

a first controller operable to connect to and interface with a first transport medium operable according to a Fibre Channel protocol;

a second controller operable to connect to and interface with a second transport medium operable according to the Fibre Channel protocol;

at least one device connected to the first transport medium;

at least one storage device connected to the second transport medium; and

an access control device coupled to the first controller and the second controller, the access control device operable to:

map between the at least one device and a storage space on the at least one storage device; and

control access from the at least one device to the at least one storage device using native low level, block protocol in accordance with the map.

22. The system of claim **21**, wherein the access control device is further operable to maintain a configuration wherein the configuration includes the map between the at least one device and the at least one storage device, and further wherein the map includes virtual LUNs that provide a representation of the at least one storage device.

23. The system of claim **22**, wherein the map only exposes the at least one device to LUNs that the at least one device may access.

24. The system of claim **21**, wherein the access control device is further operable to maintain a configuration including the map, wherein the map provides a mapping from a host device ID to a virtual LUN representation of the at least one storage device to a physical LUN of the at least one storage device.

25. The system of claim **21**, wherein the at least one storage device further comprises storage space partitioned into virtual local storage for the at least one device.

26. The system of claim **25**, wherein the access control unit is further operable to prevent at least one device from accessing any storage on the at least one storage device that is not part of a virtual local storage partition assigned to the at least one device.

27. The system of claim **21**, wherein the first controller and the second controller further comprise a single controller.

28. A method for providing virtual local storage on remote storage devices, comprising:

mapping between a device connected to a first transport medium and a storage device connected to a second transport medium, wherein the first transport medium and the second transport medium operate according to a Fibre Channel protocol;

implementing access controls for storage space on the storage device; and

allowing access from the device connected to the first transport medium to the storage device using native low level, block protocols.

29. The method of claim **28**, further comprising maintaining a configuration wherein the configuration includes a map between the device and the one storage device, and further wherein the map includes virtual LUNs that provide a representation of the storage device.

30. The method of claim **29**, wherein the map only exposes the device to LUNs that the device may access.

31. The method of claim **28**, further comprising maintaining a configuration including a map from a host device ID to a virtual LUN representation of the storage device to a physical LUN of the storage device.

32. The method of claim **28**, further comprising partitioning storage space on the storage device into virtual local storage for the device.

33. The method of claim **32**, further comprising preventing the device from accessing any storage on the storage device that is not part of a virtual local storage partition assigned to the device.

34. A system for providing virtual local storage, comprising:

a host device;

a storage device remote from the host device, wherein the storage device has a storage space;

a first controller;

a second controller

a first transport medium operable according to a Fibre Channel protocol, wherein the first transport medium connects the host device to the first controller;

a second transport medium operable according to the Fibre Channel protocol, wherein the second transport medium connects the second controller to the storage device;

a supervisor unit coupled to the first controller and the second controller, the supervisor unit operable to:

maintain a configuration that maps between the host device and at least a portion of the storage space on the storage device; and

implement access controls according to the configuration for the storage space on the storage device using native low level, block protocol.

35. The system of claim **34**, wherein the supervisor unit is further operable to:

maintain a configuration that maps from the host device to a virtual representation of at least a portion of the storage space on the storage device to the storage device; and

allow the host device to access only that portion of the storage space that is contained in the map.

36. The system of claim **35**, wherein the configuration comprises a map from a host device ID to a virtual LUN representation of the storage device to a physical LUN of the storage device.

37. The system of claim **34**, wherein the storage device further comprises storage space partitioned into virtual local storage for the host device.

38. The system of claim **37**, wherein the supervisor unit is further operable to prevent the host device from accessing any storage on the storage device that is not part of a virtual local storage partition assigned to the host device.

39. The apparatus of claim **34**, wherein the first controller and the second controller further comprise a single controller.

* * * * *

EXHIBIT D

US007987311B2

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Hoese et al.

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(45) **Date of Patent: Jul. 26, 2011**

(54) **STORAGE ROUTER AND METHOD FOR PROVIDING VIRTUAL LOCAL STORAGE**

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(58) **Field of Classification Search** 710/1–5, 710/8–13, 36–38, 126–131, 250, 305; 709/258; 714/42; 711/110–113
See application file for complete search history.

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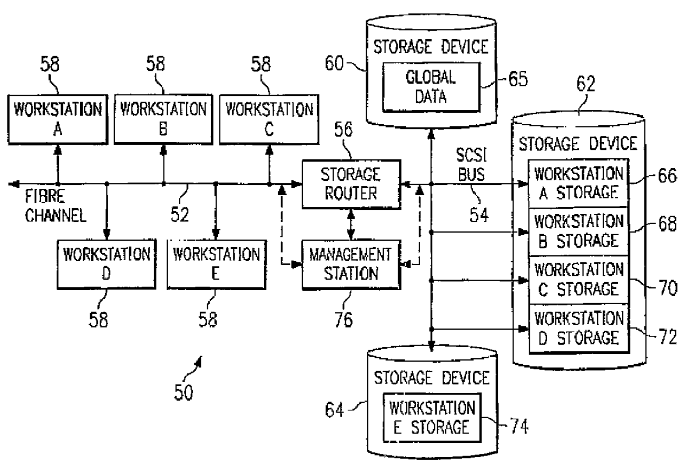
(57) **ABSTRACT**

A storage router and method for providing virtual local storage on remote storage devices to devices are provided. Devices are connected to a first transport medium, and a plurality of storage devices are connected to a second transport medium. In one embodiment, the storage router maintains a map to allocate storage space on the remote storage devices to devices connected to the first transport medium by associating representations of the devices connected to the first transport medium with representations of storage space on the remote storage devices, wherein each representation of a device connected to the first transport medium is associated with one or more representations of storage space on the remote storage devices and controls access from the devices connected to the first transport medium to the storage space on the remote storage devices in accordance with the map and using native low level block protocol.

28 Claims, 2 Drawing Sheets



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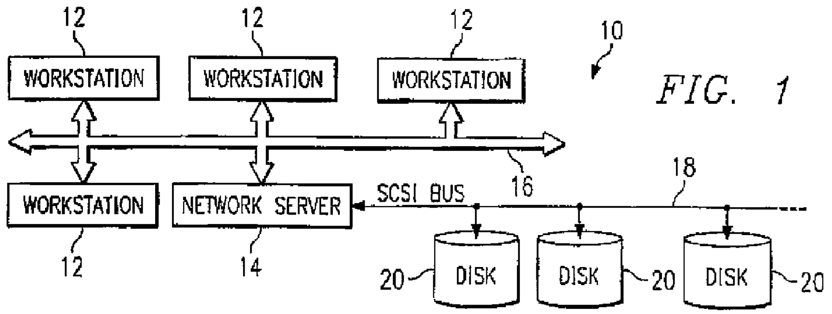

FIG. 1

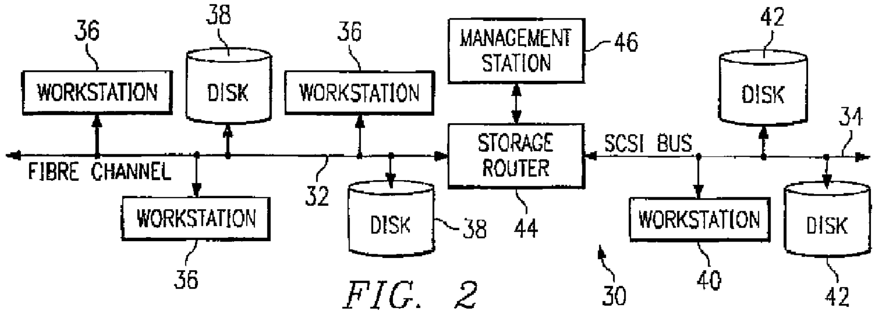

FIG. 2

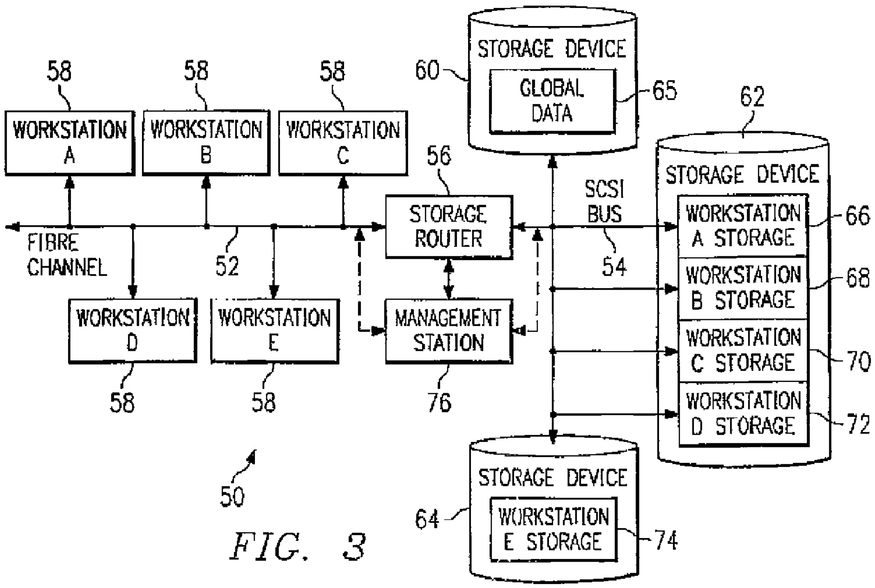

FIG. 3

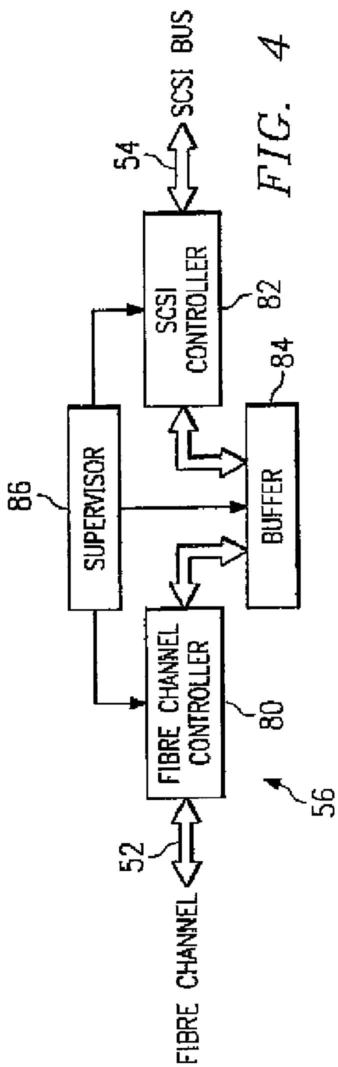
SCSI BUS
54
SCSI CONTROLLER
82
84
BUFFER
SUPERVISOR
86
FIBRE CHANNEL CONTROLLER
80
56
52
FIBRE CHANNEL

FIG. 4

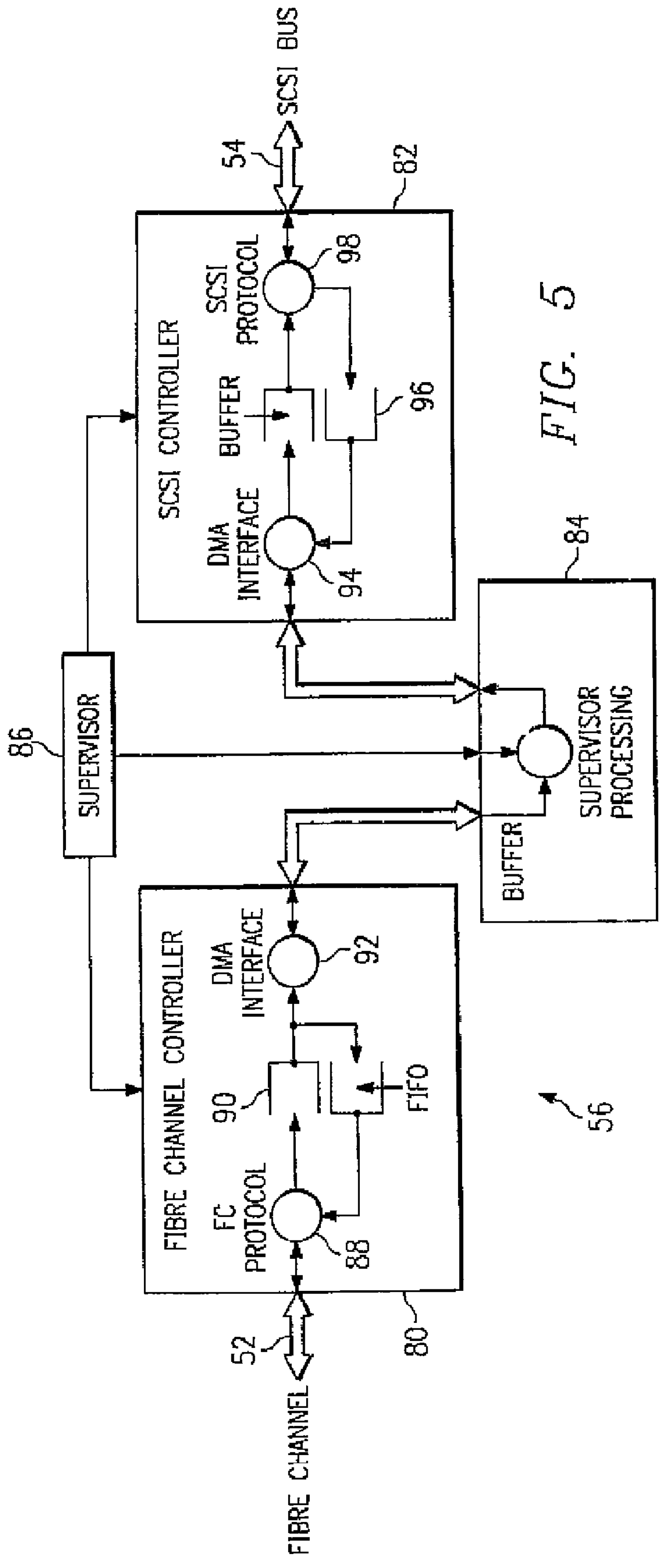
SCSI BUS
54
82
SCSI CONTROLLER
SCSI PROTOCOL
98
BUFFER
96
DMA INTERFACE
94
84
SUPERVISOR
86
SUPERVISOR PROCESSING
BUFFER
FIBRE CHANNEL CONTROLLER
DMA INTERFACE
92
90
FIFO
FC PROTOCOL
88
56
52
80
FIBRE CHANNEL

FIG. 5

STORAGE ROUTER AND METHOD FOR PROVIDING VIRTUAL LOCAL STORAGE

RELATED APPLICATIONS

This application is a continuation of, and claims a benefit of priority under 35 U.S.C. 120 of the filing date of U.S. patent application Ser. No. 12/552,807 entitled "Storage Router and Method for Providing Virtual Local Storage" filed Sep. 2, 2009, which is a continuation of and claims the benefit of priority of U.S. patent application Ser. No. 11/851,724 entitled "Storage Router and Method for Providing Virtual Local Storage" filed Sep. 7, 2007, now U.S. Pat. No. 7,689,754 issued Mar. 30, 2010, which is a continuation of and claims the benefit of priority of U.S. patent application Ser. No. 11/442,878 entitled "Storage Router and Method for Providing Virtual Local Storage" filed, May 30, 2006, now abandoned, which is a continuation of and claims the benefit of priority of U.S. patent application Ser. No. 11/353,826 entitled "Storage Router and Method for Providing Virtual Local Storage" filed on Feb. 14, 2006, now U.S. Pat. No. 7,340,549 issued Mar. 4, 2008, which is a continuation of and claims the benefit of priority of U.S. patent application Ser. No. 10/658,163 entitled "Storage Router and Method for Providing Virtual Local Storage" filed on Sep. 9, 2003 , now U.S. Pat. No. 7,051,147 issued May 23, 2006, which is a continuation of and claims the benefit of benefit of priority of U.S. patent application Ser. No. 10/081,110 by inventors Geoffrey B. Hoese and Jeffery T. Russell, entitled "Storage Router and Method for Providing Virtual Local Storage" filed on Feb. 22, 2002, now U.S. Pat. No. 6,789,152 issued on Sep. 7, 2004, which in turn is a continuation of and claims benefit of priority of U.S. application Ser. No. 09/354,682 by inventors Geoffrey B. Hoese and Jeffrey T. Russell, entitled "Storage Router and Method for Providing Virtual Local Storage" filed on Jul. 15, 1999, now U.S. Pat. No. 6,421,753 issued on Jul. 16, 2002, which in turn is a continuation of and claims benefit of priority of U.S. patent application Ser. No. 09/001,799, filed on Dec. 31, 1997, now U.S. Pat. No. 5,941,972 issued on Aug. 24, 1999, and hereby incorporates these applications and patents by reference in their entireties as if they had been fully set forth herein.

TECHNICAL FIELD OF THE INVENTION

This invention relates in general to network storage devices, and more particularly to a storage router and method for providing virtual local storage on remote SCSI storage devices to Fibre Channel devices.

BACKGROUND OF THE INVENTION

Typical storage transport mediums provide for a relatively small number of devices to be attached over relatively short distances. One such transport medium is a Small Computer System Interface (SCSI) protocol, the structure and operation of which is generally well known as is described, for example, in the SCSI-1, SCSI-2 and SCSI-3 specifications. High speed serial interconnects provide enhanced capability to attach a large number of high speed devices to a common storage transport medium over large distances. One such serial interconnect is Fibre Channel, the structure and operation of which is described, for example, in Fibre Channel Physical and Signaling Interface (FC-PH), ANSI X3.230 Fibre Channel Arbitrated Loop (FC-AL), and ANSI X3.272 Fibre Channel Private Loop Direct Attach (FC-PLDA).

Conventional computing devices, such as computer workstations, generally access storage locally or through network interconnects. Local storage typically consists of a disk drive, tape drive, CD-ROM drive or other storage device contained within, or locally connected to the workstation. The workstation provides a file system structure that includes security controls, with access to the local storage device through native low level block protocols. These protocols map directly to the mechanisms used by the storage device and consist of data requests without security controls. Network interconnects typically provide access for a large number of computing devices to data storage on a remote network server. The remote network server provides file system structure, access control, and other miscellaneous capabilities that include the network interface. Access to data through the network server is through network protocols that the server must translate into low level requests to the storage device. A workstation with access to the server storage must translate its file system protocols into network protocols that are used to communicate with the server. Consequently, from the perspective of a workstation, or other computing device, seeking to access such server data, the access is much slower than access to data on a local storage device.

SUMMARY OF THE INVENTION

In accordance with the present invention, a storage router and method for providing virtual local storage on remote SCSI storage devices to Fibre Channel devices are disclosed that provide advantages over conventional network storage devices and methods.

According to one aspect of the present invention, a storage router and storage network provide virtual local storage on remote SCSI storage devices to Fibre Channel devices. A plurality of Fibre Channel devices, such as workstations, are connected to a Fibre Channel transport medium, and a plurality of SCSI storage devices are connected to a SCSI bus transport medium. The storage router interfaces between the Fibre Channel transport medium and the SCSI bus transport medium. The storage router maps between the workstations and the SCSI storage devices and implements access controls for storage space on the SCSI storage devices. The storage router then allows access from the workstations to the SCSI storage devices using native low level, block protocol in accordance with the mapping and the access controls.

According to another aspect of the present invention, virtual local storage on remote SCSI storage devices is provided to Fibre Channel devices. A Fibre Channel transport medium and a SCSI bus transport medium are interfaced with. A configuration is maintained for SCSI storage devices connected to the SCSI bus transport medium. The configuration maps between Fibre Channel devices and the SCSI storage devices and implements access controls for storage space on the SCSI storage devices. Access is then allowed from Fibre Channel initiator devices to SCSI storage devices using native low level, block protocol in accordance with the configuration.

A technical advantage of the present invention is the ability to centralize local storage for networked workstations without any cost of speed or overhead. Each workstation accesses its virtual local storage as if it were locally connected. Further, the centralized storage devices can be located in a significantly remote position even in excess of ten kilometers as defined by Fibre Channel standards.

Another technical advantage of the present invention is the ability to centrally control and administer storage space for connected users without limiting the speed with which the users can access local data. In addition, global access to data, backups, virus scanning and redundancy can be more easily accomplished by centrally located storage devices.

A further technical advantage of the present invention is providing support for SCSI storage devices as local storage for Fibre Channel hosts. In addition, the present invention helps to provide extended capabilities for Fibre Channel and for management of storage subsystems.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present invention and the advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings, in which like reference numbers indicate like features, and wherein:

FIG. **1** is a block diagram of a conventional network that provides storage through a network server;

FIG. **2** is a block diagram of one embodiment of a storage network with a storage router that provides global access and routing;

FIG. **3** is a block diagram of one embodiment of a storage network with a storage router that provides virtual local storage;

FIG. **4** is a block diagram of one embodiment of the storage router of FIG. **3**; and

FIG. **5** is a block diagram of one embodiment of data flow within the storage router of FIG. **4**.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a block diagram of a conventional network, indicated generally at **10**, that provides access to storage through a network server. As shown, network **10** includes a plurality of workstations **12** interconnected with a network server **14** via a network transport medium **16**. Each workstation **12** can generally comprise a processor, memory, input/output devices, storage devices and a network adapter as well as other common computer components. Network server **14** uses a SCSI bus **18** as a storage transport medium to interconnect with a plurality of storage devices **20** (tape drives, disk drives, etc.). In the embodiment of FIG. **1**, network transport medium **16** is a network connection and storage devices **20** comprise hard disk drives, although there are numerous alternate transport mediums and storage devices.

In network **10**, each workstation **12** has access to its local storage device as well as network access to data on storage devices **20**. The access to a local storage device is typically through native low level, block protocols. On the other hand, access by a workstation **12** to storage devices **20** requires the participation of network server **14** which implements a file system and transfers data to workstations **12** only through high level file system protocols. Only network server **14** communicates with storage devices **20** via native low level, block protocols. Consequently, the network access by workstations **12** through network server **14** is slow with respect to their access to local storage. In network **10**, it can also be a logistical problem to centrally manage and administer local data distributed across an organization, including accomplishing tasks such as backups, virus scanning and redundancy.

FIG. **2** is a block diagram of one embodiment of a storage network, indicated generally at **30**, with a storage router that provides global access and routing. This environment is significantly different from that of FIG. **1** in that there is no network server involved. In FIG. **2**, a Fibre Channel high speed serial transport **32** interconnects a plurality of workstations **36** and storage devices **38**. A SCSI bus storage transport medium interconnects workstations **40** and storage devices **42**. A storage router **44** then serves to interconnect these mediums and provide devices on either medium global, transparent access to devices on the other medium. Storage router **44** routes requests from initiator devices on one medium to target devices on the other medium and routes data between the target and the initiator. Storage router **44** can allow initiators and targets to be on either side. In this manner, storage router **44** enhances the functionality of Fibre Channel **32**, by providing access, for example, to legacy SCSI storage devices on SCSI bus **34**. In the embodiment of FIG. **2**, the operation of storage router **44** can be managed by a management station **46** connected to the storage router via a direct serial connection.

In storage network **30**, any workstation **36** or workstation **40** can access any storage device **38** or storage device **42** through native low level, block protocols, and vice versa. This functionality is enabled by storage router **44** which routes requests and data as a generic transport between Fibre Channel **32** and SCSI bus **34**. Storage router **44** uses tables to map devices from one medium to the other and distributes requests and data across Fibre Channel **32** and SCSI bus **34** without any security access controls. Although this extension of the high speed serial interconnect provided by Fibre Channel is beneficial, it is desirable to provide security controls in addition to extended access to storage devices through a native low level, block protocol.

FIG. **3** is a block diagram of one embodiment of a storage network, indicated generally at **50**, with a storage router that provides virtual local storage. Similar to that of FIG. **2**, storage network **50** includes a Fibre Channel high speed serial interconnect **52** and a SCSI bus **54** bridged by a storage router **56**. Storage router **56** of FIG. **3** provides for a large number of workstations **58** to be interconnected on a common storage transport and to access common storage devices **60**, **62** and **64** through native low level, block protocols.

According to the present invention, storage router **56** has enhanced functionality to implement security controls and routing such that each workstation **58** can have access to a specific subset of the overall data stored in storage devices **60**, **62** and **64**. This specific subset of data has the appearance and characteristics of local storage and is referred to herein as virtual local storage. Storage router **56** allows the configuration and modification of the storage allocated to each attached workstation **58** through the use of mapping tables or other mapping techniques.

As shown in FIG. **3**, for example, storage device **60** can be configured to provide global data **65** which can be accessed by all workstations **58**. Storage device **62** can be configured to provide partitioned subsets **66**, **68**, **70** and **72**, where each partition is allocated to one of the workstations **58** (workstations A, B, C and D). These subsets **66**, **68**, **70** and **72** can only be accessed by the associated workstation **58** and appear to the associated workstation **58** as local storage accessed using native low level, block protocols. Similarly, storage device **64** can be allocated as storage for the remaining workstation **58** (workstation E).

Storage router **56** combines access control with routing such that each workstation **58** has controlled access to only the specified partition of storage device **62** which forms virtual local storage for the workstation **58**. This access control allows security control for the specified data partitions. Storage router **56** allows this allocation of storage devices **60**, **62** and **64** to be managed by a management station **76**. Management station **76** can connect directly to storage router **56** via a direct connection or, alternately, can interface with storage router **56** through either Fibre Channel **52** or SCSI bus **54**. In the latter case, management station **76** can be a workstation or other computing device with special rights such that storage router **56** allows access to mapping tables and shows storage devices **60**, **62** and **64** as they exist physically rather than as they have been allocated.

The environment of FIG. **3** extends the concept of single workstation having locally connected storage devices to a storage network **50** in which workstations **58** are provided virtual local storage in a manner transparent to workstations **58**. Storage router **56** provides centralized control of what each workstation **58** sees as its local drive, as well as what data it sees as global data accessible by other workstations **58**. Consequently, the storage space considered by the workstation **58** to be its local storage is actually a partition (i.e., logical storage definition) of a physically remote storage device **60**, **62** or **64** connected through storage router **56**. This means that similar requests from workstations **58** for access to their local storage devices produce different accesses to the storage space on storage devices **60**, **62** and **64**. Further, no access from a workstation **58** is allowed to the virtual local storage of another workstation **58**.

The collective storage provided by storage devices **60**, **62** and **64** can have blocks allocated by programming means within storage router **56**. To accomplish this function, storage router **56** can include routing tables and security controls that define storage allocation for each workstation **58**. The advantages provided by implementing virtual local storage in centralized storage devices include the ability to do collective backups and other collective administrative functions more easily. This is accomplished without limiting the performance of workstations **58** because storage access involves native low level, block protocols and does not involve the overhead of high level protocols and file systems required by network servers.

FIG. **4** is a block diagram of one embodiment of storage router **56** of FIG. **3**. Storage router **56** can comprise a Fibre Channel controller **80** that interfaces with Fibre Channel **52** and a SCSI controller **82** that interfaces with SCSI bus **54**. A buffer **84** provides memory work space and is connected to both Fibre Channel controller **80** and to SCSI controller **82**. A supervisor unit **86** is connected to Fibre Channel controller **80**, SCSI controller **82** and buffer **84**. Supervisor unit **86** comprises a microprocessor for controlling operation of storage router **56** and to handle mapping and security access for requests between Fibre Channel **52** and SCSI bus **54**.

FIG. **5** is a block diagram of one embodiment of data flow within storage router **56** of FIG. **4**. As shown, data from Fibre Channel **52** is processed by a Fibre Channel (FC) protocol unit **88** and placed in a FIFO queue **90**. A direct memory access (DMA) interface **92** then takes data out of FIFO queue **90** and places it in buffer **84**. Supervisor unit **86** processes the data in buffer **84** as represented by supervisor processing **93**. This processing involves mapping between Fibre Channel **52** and SCSI bus **54** and applying access controls and routing functions. A DMA interface **94** then pulls data from buffer **84** and places it into a buffer **96**. A SCSI protocol unit **98** pulls data from buffer **96** and communicates the data on SCSI bus **54**. Data flow in the reverse direction, from SCSI bus **54** to Fibre Channel **52**, is accomplished in a reverse manner.

The storage router of the present invention is a bridge device that connects a Fibre Channel link directly to a SCSI bus and enables the exchange of SCSI command set information between application clients on SCSI bus devices and the Fibre Channel links. Further, the storage router applies access controls such that virtual local storage can be established in remote SCSI storage devices for workstations on the Fibre Channel link. In one embodiment, the storage router provides a connection for Fibre Channel links running the SCSI Fibre Channel Protocol (FCP) to legacy SCSI devices attached to a SCSI bus. The Fibre Channel topology is typically an Arbitrated Loop (FC_AL).

In part, the storage router enables a migration path Fibre Channel based, serial SCSI networks by providing connectivity for legacy SCSI bus devices. The storage router can be attached to a Fibre Channel Arbitrated Loop and a SCSI bus to support a number of SCSI devices. Using configuration settings, the storage router can make the SCSI bus devices available on the Fibre Channel network as FCP logical units. Once the configuration is defined, operation of the storage router is transparent to application clients. In this manner, the storage router can form an integral part of the migration to new Fibre Channel based networks while providing a means to continue using legacy SCSI devices.

In one implementation (not shown), the storage router can be a rack mount or free standing device with an internal power supply. The storage router can have a Fibre Channel and SCSI port, and a standard, detachable power cord can be used, the FC connector can be a copper DB9 connector, and the SCSI connector can be a 68-pin type. Additional modular jacks can be provided for a serial port and an 802.3 10BaseT port, i.e. twisted pair Ethernet, for management access. The SCSI port of the storage router an support SCSI direct and sequential access target devices and can support SCSI initiators, as well. The Fibre Channel port can interface to SCSI-3 FCP enabled devices and initiators.

To accomplish its functionality, one implementation of the storage router uses: a Fibre Channel interface based on the HEWLETT-PACKARD TACHYON HPFC-5000 controller and a GLM media interface; an Intel 80960RP processor, incorporating independent data and program memory spaces, and associated logic required to implement a stand alone processing system; and a serial port for debug and system configuration. Further, this implementation includes a SCSI interface supporting Fast-20 based on the SYMBIOS 53C8xx series SCSI controllers, and an operating system based upon the WIND RIVERS SYSTEMS VXWORKS or IXWORKS kernel, as determined by design. In addition, the storage router includes software as required to control basic functions of the various elements, and to provide appropriate translations between the FC and SCSI protocols.

The storage router has various modes of operation that are possible between FC and SCSI target and initiator combinations. These modes are: FC Initiator to SCSI Target; SCSI Initiator to FC Target; SCSI Initiator to SCSI Target; and FC Initiator to FC Target. The first two modes can be supported concurrently in a single storage router device and are discussed briefly below. The third mode can involve two storage router devices back to back and can serve primarily as a device to extend the physical distance beyond that possible via a direct SCSI connection. The last mode can be used to carry FC protocols encapsulated on other transmission technologies (e.g. ATM, SONET), or to act as a bridge between two FC loops (e.g. as a two port fabric).

The FC Initiator to SCSI Target mode provides for the basic configuration of a server using Fibre Channel to communicate with SCSI targets. This mode requires that a host system have an FC attached device and associated device drivers and software to generate SCSI-3 FCP requests. This system acts as an initiator using the storage router to communicate with SCSI target devices. The SCSI devices supported can include SCSI-2 compliant direct or sequential access (disk or tape) devices. The storage router serves to translate command and status information and transfer data between SCSI-3 FCP and SCSI-2, allowing the use of standard SCSI-2 devices in a Fibre Channel environment.

The SCSI Initiator to FC Target mode provides for the configuration of a server using SCSI-2 to communicate with Fibre Channel targets. This mode requires that a host system has a SCSI-2 interface and driver software to control SCSI-2 target devices. The storage router will connect to the SCSI-2 bus and respond as a target to multiple target IDs. Configuration information is required to identify the target IDs to which the bridge will respond on the SCSI-2 bus. The storage router then translates the SCSI-2 requests to SCSI-3 FCP requests, allowing the use of FC devices with a SCSI host system. This will also allow features such as a tape device acting as an initiator on the SCSI bus to provide full support for this type of SCSI device.

In general, user configuration of the storage router will be needed to support various functional modes of operation. Configuration can be modified, for example, through a serial port or through an Ethernet port via SNMP (simple network management protocol) or the Telnet session. Specifically, SNMP manageability can be provided via a B02.3 Ethernet interface. This can provide for configuration changes as well as providing statistics and error information. Configuration can also be performed via TELNET or RS-232 interfaces with menu driven command interfaces. Configuration information can be stored in a segment of flash memory and can be retained across resets and power off cycles. Password protection can also be provided.

In the first two modes of operation, addressing information is needed to map from FC addressing to SCSI addressing and vice versa. This can be 'hard' configuration data, due to the need for address information to be maintained across initialization and partial reconfigurations of the Fibre Channel address space. In an arbitrated loop configuration, user configured addresses will be needed for AL_PAs in order to insure that known addresses are provided between loop reconfigurations.

With respect to addressing, FCP and SCSI 2 systems employ different methods of addressing target devices. Additionally, the inclusion of a storage router means that a method of translating device IDs needs to be implemented. In addition, the storage router can respond to commands without passing the commands through to the opposite interface. This can be implemented to allow all generic FCP and SCSI commands to pass through the storage router to address attached devices, but allow for configuration and diagnostics to be performed directly on the storage router through the FC and SCSI interfaces.

Management commands are those intended to be processed by the storage router controller directly. This may include diagnostic, mode, and log commands as well as other vendor-specific commands. These commands can be received and processed by both the FOP and SCSI interfaces, but are not typically bridged to the opposite interface. These commands may also have side effects on the operation of the storage router, and cause other storage router operations to change or terminate.

A primary method of addressing management commands though the FCP and SCSI interfaces can be through peripheral device type addressing. For example, the storage router can respond to all operations addressed to logical unit (LUN) zero as a controller device. Commands that the storage router will support can include INQUIRY as well as vendor-specific management commands. These are to be generally consistent with SCC standard commands.

The SCSI bus is capable of establishing bus connections between targets. These targets may internally address logical units. Thus, the prioritized addressing scheme used by SCSI subsystems can be represented as follows: BUS:TARGET: LOGICAL UNIT. The BUS identification is intrinsic in the configuration, as a SCSI initiator is attached to only one bus. Target addressing is handled by bus arbitration from information provided to the arbitrating device. Target addresses are assigned to SCSI devices directly through some means of configuration, such as a hardware jumper, switch setting, or device specific software configuration. As such, the SCSI protocol provides only logical unit addressing within the Identify message. Bus and target information is implied by the established connection.

Fibre Channel devices within a fabric are addressed by a unique port identifier. This identifier is assigned to a port during certain well-defined states of the FC protocol. Individual ports are allowed to arbitrate for a known, user defined address. If such an address is not provided, or if arbitration for a particular-user address fails, the port is assigned a unique address by the FC protocol. This address is generally not guaranteed to be unique between instances. Various scenarios exist where the AL-PA of a device will change, either after power cycle or loop reconfiguration.

The FC protocol also provides a logical unit address field within command structures to provide addressing to devices internal to a port. The FCP_CMD payload specifies an eight byte LUN field. Subsequent identification of the exchange between devices is provided by the FQXID (Fully Qualified Exchange ID).

FC ports can be required to have specific addresses assigned. Although basic functionality is not dependent on this, changes in the loop configuration could result in disk targets changing identifiers with the potential risk of data corruption or loss. This configuration can be straightforward, and can consist of providing the device a loop-unique ID (AL_PA) in the range of "01h" to "EFh." Storage routers could be shipped with a default value with the assumption that most configurations will be using single storage routers and no other devices requesting the present ID. This would provide a minimum amount of initial configuration to the system administrator. Alternately, storage routers could be defaulted to assume any address so that configurations requiring multiple storage routers on a loop would not require that the administrator assign a unique ID to the additional storage routers.

Address translation is needed where commands are issued in the cases FC Initiator to SCSI Target and SCSI Initiator to FC Target. Target responses are qualified by the FQXID and will retain the translation acquired at the beginning of the exchange. This prevents configuration changes occurring during the course of execution of a command from causing data or state information to be inadvertently misdirected. Configuration can be required in cases of SCSI Initiator to FC Target, as discovery may not effectively allow for FCP targets to consistently be found. This is due to an FC arbitrated loop supporting addressing of a larger number of devices than a SCSI bus and the possibility of FC devices changing their AL-PA due to device insertion or other loop initialization.

In the direct method, the translation to BUS:TARGET: LUN of the SCSI address information will be direct. That is, the values represented in the FCP LUN field will directly map to the values in effect on the SCSI bus. This provides a clean translation and does not require SCSI bus discovery. It also allows devices to be dynamically added to the SCSI bus without modifying the address map. It may not allow for complete discovery by FCP initiator devices, as gaps between device addresses may halt the discovery process. Legacy SCSI device drivers typically halt discovery on a target device at the first unoccupied LUN, and proceed to the next target.

This would lead to some devices not being discovered. However, this allows for hot plugged devices and other changes to the loop addressing.

In the ordered method, ordered translation requires that the storage router perform discovery on reset, and collapses the addresses on the SCSI bus to sequential FSP LUN values. Thus, the FCP LUN values 0-N can represent N+1 SCSI devices, regardless of SCSI address values, in the order in which they are isolated during the SCSI discovery process. This would allow the FCP initiator discovery process to identify all mapped SCSI devices without further configuration. This has the limitation that hot-plugged devices will not be identified until the next reset cycle. In this case, the address may also be altered as well.

In addition to addressing, according to the present invention, the storage router provides configuration and access controls that cause certain requests from FC Initiators to be directed to assigned virtual local storage partitioned on SCSI storage devices. For example, the same request for LUN 0 (local storage) by two different FC Initiators can be directed to two separate subsets of storage. The storage router can use tables to map, for each initiator, what storage access is available and what partition is being addressed by a particular request. In this manner, the storage space provided by SCSI storage devices can be allocated to FC initiators to provide virtual local storage as well as to create any other desired configuration for secured access.

Although the present invention has been described in detail, it should be understood that various changes, substitutions, and alterations can be made hereto without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A storage router for providing virtual local storage on remote storage devices, comprising:

a first controller operable to connect to a first transport medium, wherein the first medium is a serial transport medium;

a second controller operable to connect to a second transport medium; and

a processing device coupled to the first controller, wherein the processing device is configured to:

maintain a map to allocate storage space on the remote storage devices to devices connected to the first transport medium by associating representations of the devices connected to the first transport medium with representations of storage space on the remote storage devices, wherein each representation of a device connected to the first transport medium is associated with one or more representations of storage space on the remote storage devices;

control access from the devices connected to the first transport medium to the storage space on the remote storage devices in accordance with the map and using native low level block protocol, further comprising:

for a device connected to the first transport medium, identifying LUNs for storage space allocated to that device in the map;

presenting to that device only the identified LUNs as available storage space; and

processing native low level block requests directed to the identified LUNs from that device to allow access to the storage space associated with the identified LUNs.

2. The storage router of claim **1**, wherein the storage router is further operable to, present the identified LUNs in response to a native low level block protocol discovery request.

3. The storage router of claim **2**, wherein the storage router identifies the LUNs in response to the discovery request.

4. The storage router of claim **1**, wherein the map resides at the storage router and is maintained at the storage router.

5. The storage router of claim **1**, wherein the storage router is configured to receive requests according to a first low level block protocol from the device connected to the first transport medium and forward commands according to a second low level block protocol to the remote storage devices.

6. The storage router of claim **1**, wherein the map comprises one or more tables.

7. The storage router of claim **1**, wherein the virtual local storage is provided to the devices connected to the first transport medium in a manner that is transparent to the devices and wherein the storage space allocated to the devices connected to the first transport medium appears to the devices as local storage.

8. The storage router of claim **1**, wherein the storage router provides centralized control of what the devices connected to the first transport medium see as local storage.

9. The storage router of claim **1**, wherein the storage router is operable to route requests to the same LUN from different devices connected to the first transport medium to different subsets of storage space on the remote storage devices.

10. The storage router of claim **1**, wherein the representations of devices connected to the first transport medium are unique identifiers.

11. The storage router of claim **10**, wherein the unique identifiers are world wide names.

12. The storage router of claim **1**, wherein the storage router is configured to allow modification of the map in a manner transparent to and without involvement of the devices connected to the first transport medium.

13. The storage router of claim **1**, wherein the processing device is a microprocessor.

14. The storage router of claim **1**, wherein the processing device is a microprocessor and associated logic to implement a stand-alone processing system.

15. The storage router of claim **1**, wherein the storage router is operable to communicate with devices connected to the first transport medium via Ethernet.

16. A method for providing virtual local storage on remote storage devices comprising:

connecting a storage router between a set of devices connected to a first transport medium and a set of remote storage devices, wherein the first transport medium is a serial transport medium;

maintaining a map at the storage router to allocate storage space on the remote storage devices to devices connected to the first transport medium by associating representations of the devices connected to the first transport medium with representations of storage space on the remote storage devices, wherein each representation of a device connected to the first transport medium is associated with one or more representations of storage space on the remote storage devices;

controlling access from the devices connected to the first transport medium to the storage space on the remote storage devices in accordance with the map by:

for a device connected to the first transport medium, identifying LUNs for storage space allocated to that device in the map;

presenting to that device only the identified LUNs as available storage space; and

processing native low level block requests directed to the identified LUNs from that device to allow access to the storage space associated with the identified LUNs.

17. The method of claim **16**, further comprising presenting the identified LUNs in response to a native low level block protocol discovery request.

18. The method of claim **16**, further comprising identifying the LUNs in response to the discovery request.

19. The method of claim **16**, wherein the map associates a representation of a device connected to the first transport medium with a representation of an entire storage space of at least one remote storage device.

20. The method of claim **16**, wherein the map resides at the storage router and is maintained at the storage router.

21. The method of claim **16**, further comprising receiving commands at the storage router according to a first low level block protocol from the device connected to the first transport medium and forwarding commands according to a second low level block protocol to the remote storage devices.

22. The method of claim **16**, wherein the map comprises one or more tables.

23. The method of claim **16**, wherein the virtual local storage is provided to the devices connected to the first transport medium in a manner that is transparent to the devices and wherein the storage space allocated to the devices connected to the first transport medium appears to the devices as local storage.

24. The method of claim **16**, wherein the storage router provides centralized control of what the devices connected to the first transport medium see as local storage.

25. The method of claim **16**, wherein the storage router is operable to route requests to the same LUN from different devices connected to the first transport medium to different subsets of storage space on the remote storage devices.

26. The method of claim **16**, wherein the representations of devices connected to the first transport medium are unique identifiers.

27. The method of claim **26**, wherein the unique identifiers are world wide names.

28. The method of claim **16**, wherein the storage router is configured to allow modification of the map in a manner transparent to and without involvement of the devices connected to the first transport medium.

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