

ACTIVE STORAGE DEVICES

FIELD OF THE INVENTION

[0001] The present invention relates to the field of storage devices, such as Hard Disk Drives (HDDs) and Solid State Drives (SSDs). In particular, it relates to intelligent printed circuit board assemblies (PCBAs) for active storage devices.

BACKGROUND

[0002] Storage devices generally refer to hardware capable of holding data information. One example of a storage device is a Hard Disk Drive (HDD), which conventionally comprises disk media, an actuator for reading or writing data to the disk media, and a printed circuit board assembly (PCBA) which controls the read/write operations of the actuator. Another example of a storage device is a Solid State Drive (SSD) which comprises Non Volatile Memory (NVM) in electrical communication with a PCBA in the SSD. Recent developments in the field of storage devices has integrated Non Volatile Memory (NVM) into HDDs, resulting in hybrid drives having both disk media and NVM in electrical communication with the PCBA of the HDD.

[0003] A disk array controller is needed to connect a plurality of HDDs, SSDs, and/or hybrid drives. The controller is typically a Redundant Array of Independent Disks (RAID) controller, which distributes data across the drives in accordance with predetermined RAID configurations. However, when a large number of storage drives are to be networked, multiple RAID controllers are required. This translates to additional costs required for maintaining and expanding a network of storage drives. Moreover, the dependency on RAID controllers severely limits parallel data excess to

individual drives in the network, therefore restricting the data throughput in the network.

[0004] Accordingly, what is needed is a storage device that is able to perform independently from a disk array controller to facilitate data storage and data management in a storage network. Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background of the disclosure.

SUMMARY OF THE INVENTION

[0005] In accordance with a first aspect of the present invention, a printed circuit board assembly (PCBA) for a storage device is disclosed, the PCBA comprising: a non-volatile memory (NVM); and a multi-core processor; wherein a first core of the multi-core processor is devoted to external interface management; and a second core of the multi-core processor is devoted to internal data management.

[0006] In accordance with a second aspect of the present invention, a hard disk drive (HDD) is disclosed, the HDD comprising the PCBA in accordance with the first aspect of the present invention.

[0007] In accordance with a third aspect of the present invention, a multi actuator, multi HDD is disclosed, the multi actuator, multi HDD comprising the PCBA in accordance with the first aspect of the present invention.

[0008] In accordance with a fourth aspect of the present invention, a Solid State Drive (SSD) is disclosed, the SSD comprising the PCBA in accordance with the first aspect of the present invention.

[0009] In accordance with a fifth aspect of the present invention, a HDD for data storage is disclosed, the HDD for data storage comprising: one or more disk platters, each of the one or more disk platters having magnetic disk media on one or both sides; an axial motor for rotating the one or more disk platters; one or more actuators for reading and writing data from the one or more disk platters; one or more interfaces coupled to the one or more actuators; and a PCBA coupled to the axial motor, the one or more actuators, and the one or more interfaces, wherein the PCBA comprises: an NVM; and a multi-core processor, wherein a first core of the multi-core

processor being devoted to external interface management and a second core of the multi-core processor being devoted to internal data management.

[0010] In accordance with a sixth aspect of the present invention, a system for distributed data storage is disclosed, the system comprising: one or more storage devices, the one or more storage devices comprising a PCBA, the PCBA comprising: an NVM; and a multi-core processor, wherein a first core of the multi-core processor is devoted to external interface management and a second core of the multi-core processor is devoted to internal data management of the corresponding one of the one or more storage devices; one or more client terminals, wherein the one or more storage devices and the one or more client terminals are coupled to a network and configured to perform a distributed data storage operation within the one or more storage devices in response to a request by any one of the one or more client terminals, the distributed data storage operation performed in cooperation with the first core's external interface management.

BRIEF DESCRIPTION OF DRAWINGS

[0011] The accompanying figures, where like reference numerals refer to identical or functionally similar elements throughout the separate views and which together with the detailed description below are incorporated in and form part of the specification, serve to illustrate various embodiments and to explain various principles and advantages in accordance with a present embodiment.

[0012] FIG. 1, comprising FIG. 1A and FIG. 1B, illustrates top perspective drawings of storage devices, in accordance with a present embodiment, wherein FIG. 1A illustrates a Hard Disk Drive (HDD) and FIG. 1B illustrates a Solid State Drive (SSD), both the HDD and SSD having an intelligent Printed Circuit Board Assembly (PCBA).

[0013] FIG. 2, comprising FIG. 2A, FIG. 2B, and FIG. 2C, illustrates components of HDDs with an intelligent PCBA, in accordance with the present embodiment, wherein FIG. 2A illustrates a top cutaway perspective drawing of a dual actuator HDD, FIG 2B illustrates a side cross-sectional perspective drawing of disk media and dual actuators within the dual actuator HDD, and FIG. 2C illustrates a bottom cutaway perspective of a HDD.

[0014] FIG. 3 depicts a block diagram of an Active Drive (AD) with an intelligent PCBA in accordance with the present embodiment.

[0015] FIG. 4 depicts a diagram illustrating functions of the AD in accordance with the present embodiment.

[0016] FIG. 5 depicts a diagram illustrating functions performed by one or more cores of the intelligent PCBA of an AD in accordance with the present embodiment.

[0017] And FIG. 6, comprising FIG. 6A, FIG. 6B, and FIG. 6C, depict a diagram of an exemplary system of one or more storage devices in a network, in accordance with the present embodiment, wherein FIG. 6A depicts a system of one or more conventional storage devices in communication with a client and a metadata server through a network, FIG. 6B depicts one or more storage devices (i.e. active drives) in communication with a client and a metadata server through a network, and FIG. 6C depicts an exemplary operation performed in the system.

[0001] Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been depicted to scale. For example, the dimensions of some of the elements in the block diagrams or flowcharts may be exaggerated in respect to other elements to help to improve understanding of the present embodiments.

DETAILED DESCRIPTION

[0018] The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention to be bound by any theory presented in the preceding background of the invention or the following detailed description. It is the intent of the present embodiment to present an improved storage device that is able to perform independently from a disk array controller to facilitate data storage and data management in a storage network.

[0019] FIG. 1, comprising FIG. 1A (the top planar view 100) and FIG. 1B (the top planar view 150), illustrates storage devices 101, 151, wherein FIG. 1A illustrates a Hard Disk Drive (HDD) 101 and FIG. 1B illustrates a Solid State Drive (SSD) 151 with an intelligent printed circuit board assembly (PCBA). The HDD 101 in FIG. 1A comprises a printed circuit board assembly (PCBA) 102 in electrical communication with an actuator assembly 104 and an axial motor 106 in the HDD 101. Similarly, the SSD 151 in FIG. 1B comprises an intelligent PCBA 152 in electrical communication with the Non-Volatile Memory (NVM) 154 of the SSD 151. The intelligent PCBA 102, 152, controls the operations of the components 104, 106, 108, 154, within the HDD 101 and SSD 151. Further elaboration on this aspect will be provided in the description below.

[0020] FIG. 2, comprising FIG. 2A, FIG. 2B, and FIG. 2C, illustrates components of a dual actuator HDD 201, wherein FIG. 2A illustrates a top cutaway perspective view 200 of the dual actuator HDD 201, FIG. 2B illustrates a side cross-sectional perspective view 230 of disk media 202 and dual actuators 206, 208 within

the dual actuator HDD 201, and FIG. 2C illustrates a bottom cutaway perspective view 250 of the dual actuator HDD 201, in accordance with the present embodiment.

[0021] In FIG 2A, the HDD 201 for data storage comprises one or more disk platters 202. Each of the one or more disk platters 202 has magnetic disk media on one or both sides, where the read/write heads of the actuators 206, 208 are positioned to read/write data onto the magnetic disk media. In an embodiment, the positioning of the dual actuators 260, 280 are 180 degrees from each other, as seen in FIG. 2B. Variations of the position of the dual actuators 260, 280 are also possible. An axial motor 204 provides rotation for the one or more disk platters 202 during operation.

[0022] FIG. 2C shows an external communication interface 256 coupled to an actuator assembly 206. In an alternative embodiment, more than one external communication interfaces 256 are present in the HDD 201, wherein each of the external communication interfaces 256 are coupled to a corresponding actuator 206, 208. Multi interface, multi actuator hard disk drives provide an advantageous means to increase data throughput to and from the storage device 201. The intelligent PCBA 252 is coupled 254 to the axial motor 204, the one or more actuators 206, 208, and the one or more interfaces 256. The arrangement in the present embodiment provides an advantageous connection between the intelligent PCBA 252 with the actuators 206, 208, the axial motor 204, and the external connection interfaces 256 enabling the intelligent PCBA 252 control over the components 202, 204, 206, 208, 256 within the HDD 201. The person skilled in the art of storage devices would understand that in various embodiments, components within a hybrid drive or SSD are connected in a similar manner as the present embodiment.

[0023] FIG. 3 depicts a block diagram 300 of a storage device, hereinafter Active Drive (AD) 302, comprising one or more disk platters 310, an NVM 320, and an intelligent PCBA 330 in accordance with the present embodiment. The intelligent PCBA 330 comprises a multi core processor with one or more cores 332, 334, 336, 338. The one or more cores 332, 334, 336, 338 are configured, to manage and perform various operations of the AD 302. In an embodiment, the first core 332 and the second core 334 are configured to perform external interface management 340, while the third core 336 and the fourth core 338 are configured to perform internal data management 350. In a further embodiment, third core 336 of the multi-core processor of the PCBA 330 cooperates with the fourth core 338 for the internal data management and file system management. The person skilled in the art of storage devices would understand that various other configurations are possible. For example, the cores 332, 334, 336, 338 of the processor are able to distribute external interface management 340 and internal data management 350 within each other, or redirect processing to any one or a combination of cores 332, 334, 336, 338.

[0024] The skilled person would further understand that in alternative embodiments, the AD 302 is a HDD, SSD or Hybrid drive with an intelligent PCBA 330. In an embodiment, an AD 302 comprising a hybrid drive with an intelligent PCBA 330 utilizes both magnetic disk media on the disk platter 310 and NVM 320 for hybrid data storage. Any one or a combination of cores 332, 334, 336, 338 of the multi-core processor of the PCBA 302 is devoted to servo management to control the movement of the actuators or axial motors within the HDD. Devoting one or more cores to external interface management 340, internal data management 350, and/or servo management advantageously provides an efficient means of resource allocation by eliminating the dependency on disk array controllers to perform the

operations. Additionally, as each of the ADs 302 is able to perform interface management 340, internal data management 350, and servo management independently, this advantageously allows for a scalable network of ADs 302 to be connected together.

[0025] FIG. 4 depicts a diagram 400 illustrating functions of an AD 402 in accordance with the present embodiment. In the present embodiment, the AD 402 performs data management operations related to a distributed file system 410, such as restriction of access to the local file system 430 of the AD 402 depending on access lists, or listing directories within the AD 402. In the present embodiment, the AD 402 performs data management operations 420, such as caching of data 422 and compression of data 424 are performed, in accordance with instructions or predetermined protocols of the distributed file system 410 or automatically. The AD 402 can also have client installable program 411 to be installed and executed. Further, the AD 402 performs local file system 430 operations such as file space allocation and management of file names. The processing of the various operations 410, 420, 422, 424, and 430 are performed by any one or more of the cores of the multi-core processor of the PCBA within the AD 402. This advantageously allows the AD 402 to operate as an independent drive without relying on a disk array controller or storage server (i.e. server computer).

[0026] FIG. 5 depicts a diagram 500 illustrating functions 512, 514, 516, 522, 532, 534, 536, 538, 542, performed by one or more cores 510, 520, 530, 540 of the intelligent PCBA within an AD in accordance with the present embodiment. Various operations are allocated to the cores 510, 520, 530, 540 of the intelligent PCBA. For example, a first core 510 is devoted to managing operations related to the distributed file system 512, including cluster management 514, and data interfacing 516 to the

client that is providing the data 502. A second core is devoted to managing operations involving the local file system 522. A third core is devoted to internal data management operations such as caching and tiering of data 532, compression of data 534, managing Quality of Service (QoS) operations such as error rates, bandwidth, throughput, transmission, delay, availability, and jitter, and placement of data within the disk media or NVM of the AD. A fourth core is devoted to program execution 542 of applications installed on the disk media or NVM of the AD. The program can be run time uploaded and installed into AD 402 by client terminal. With the intelligent PCBA of an AD performing the functions 512, 514, 516, 522, 532, 534, 536, 538, 542, disk array controllers are advantageously eliminated as data can be directly transferred to the AD. For example, tasks such as storage management are now performed by one or more cores of the multi core processor of the intelligent PCBA of the AD. This advantageously provides a highly scalable and cost effective means to construct an AD distributed file system, wherein a plurality of ADs are independently in communication with the client via a network. This network of drives advantageously allows for a reduction in cost, power consumption, and physical space required. Furthermore, a dedicated core of the multi core processor devoted to critical operations (e.g. Quality of service operations), advantageously allows an increased reliability of the ADs as compared to conventional drives.

[0027] FIG. 6, comprising FIG. 6A, FIG. 6B, and FIG. 6C, depict a diagram of a system 600, 650 of one or more storage devices 634, 654 in a network 602, wherein FIG. 6A depicts a system 600 of one or more conventional storage devices 634 in communication with a client 610 and a metadata server 620 through a network 602, FIG. 6B depicts a system 650 with one or more storage devices (i.e. ADs) 654, in accordance with the present embodiment, in communication with a client 610 and a

metadata server 620 through a network 602, and FIG. 6C depicts an exemplary operation 670 performed in the system 650 in accordance with the present embodiment.

[0028] In the system 600, a plurality of conventional storage devices 634 are connected to a network 602 via a disk array controller (e.g. RAID controller) 636. The plurality of storage devices 634 are presented to the client 610 as a storage unit 638. Each of the storage units 638 requires a storage server for data interface and management in each of the storage units 638. This results in an inefficient architecture for scaling.

[0029] The system 650, provides an advantageous alternative to the conventional distributed storage system. In the system 650, the storage devices 654 within the network 602 are ADs, each comprising an intelligent PCBA in accordance with the preceding embodiments. The intelligent PCBA comprises an NVM and a multi-core processor, wherein a first core of the multi-core processor is devoted to external interface management and a second core of the multi-core processor is devoted to internal data management of the corresponding one of the one or more storage devices 654. The one or more storage devices 654 and the one or more client terminals 610 are coupled network 602 and configured to perform data storage operations within the one or more storage devices 654 in response to a request by any one of the one or more client terminals 610. In the present embodiment, the distributed data storage operation is performed in cooperation with the first core's external interface management. Distributed data storage operations and/or external interface management within the storage device 654 itself eliminates the dependency on a disk controller 636 or storage server for managing these operations. Dedicating one or more cores to each of these operations allows for a distributed workload, and

therefore an advantageous improvement in efficiency and throughput of the storage devices 654 within the network 602.

[0030] In an embodiment, the first core of the multi-core processor of the PCBA of each of the one or more storage devices 654 is configured to perform data interfacing to the client terminal 610. In conventional servers, disk array controllers perform the task of data interfacing with the client terminal 610. Enabling the storage devices 604 to perform data interfacing operations advantageously allows parallel data access between individual storage devices 654 and the client terminals 610.

[0031] In the present embodiment, the multi-core processor of the PCBA of each of the one or more storage devices 654 is configured to perform autonomous data clustering in response to a request by any one of the one or more client terminals 610. In a data clustering operation, the intelligent PCBA allocates contiguous groups of sectors, i.e. clusters, within the disk media of the storage device 654. Clustering reduces the overhead of managing on-disk data structures, and when performed independently by the intelligent PCBA, advantageously allows for an increased efficiency of the clustering operation.

[0032] The multi-core processor of the PCBA of each of the one or more storage devices 654 is also configured to execute a program stored on any one or more storage devices 654 in response to a request by any one or more client terminals 610. Users are able to access the application installed on any one of the storage devices 654 through the client terminals 610. One or more cores of the multi-core processor of the intelligent PCBA may be devoted to the running of the application during the period of the request. This advantageously provides a means for the users to gain access to software applications and processes via the network 602 remotely. Further, processing of the application is performed by the intelligent

PCBA of the storage device 654, which advantageously reduces the dependency of the Central Processing Unit (CPU) of the server for running of applications.

[0033] As in previous embodiments, cores of the multi-core processors of the PCBA of each of the storage devices 654 a devoted to servo management. Another core of the multi-core processor cooperates with the second core for the internal data management and file system management. Further, another core of the multi-core processor is devoted to caching and tiering. Dedicating one or more cores to each of these operations allows for a distributed workload, and therefore an advantageous improvement in efficiency and throughput of the storage devices 654 within the network 602.

[0034] In an embodiment, the system 650 further comprises a metadata server 620 coupled to the network 602. In FIG 6C, an exemplary operation of the system 650 of storage devices 654 is depicted. A client 610, performs a request to retrieve data from a storage device 654 within the system 650. The request is received in the distributed file system 672 of the client and processed against a lookup table 674 to retrieve the meta data 676 stored in the meta data server 620. Using the meta data 676, comprising information of where the data is stored, the distributed file server accesses the cluster 678 at which the storage device 654, or plurality of storage devices 654, stores the data 680. The data set 680 is retrieved for further processing by an application on the client's terminal 610. In an alternative embodiment, the client 610 may instruct an application installed on the storage device 654 within the cluster 678 to access the data set 680 to and perform operations on the data set 680. In an alternative embodiment, the client only gets the map of storage cluster which consisting of multiple AD 654 from meta data server, and then computes the data location by its self, and then retrieve the data directly from the AD 654. In the present

embodiment, communication between the storage device 654 and the client terminal 610 is devoted to one core of the multi-core processor of the PCBA within the storage device 654. In a further embodiment, another core of the multi-core processor is dedicated to running of the application and performing operations on the data set 680.

[0035] The skilled person would understand that in alternative embodiments, the storage device 654 comprises any one or more of Active Drives, including multi actuator multi disk HDDs, SSDs, and Hybrid disks having NVM that is used with disk media of the HDD for hybrid data storage.

[0036] Thus, in accordance with the present embodiment, a novel, advantageous and efficient method for surgical resection planning of a mass has been presented, which overcomes the drawback of prior art.

[0037] While exemplary embodiments have been presented in the foregoing detailed description of the invention, it should be appreciated that a vast number of variations exist. For example, those skilled in the art will realize from the teachings herein that the present technology may also be applied to any part in the gastrointestinal tract or any part the skeletomuscular system.

[0038] It should further be appreciated that the exemplary embodiments are only examples, and are not intended to limit the scope, applicability, operation, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment of the invention, it being understood that various changes may be made in the function and arrangement of elements and method of operation described in an exemplary embodiment without departing from the scope of the invention as set forth in the appended claims.

CLAIMS

1. A printed circuit board assembly (PCBA) for a storage device comprising:
 - a non-volatile memory (NVM); and
 - a multi-core processor;
 - wherein a first core of the multi-core processor is devoted to external interface management; and
 - a second core of the multi-core processor is devoted to internal data management.
2. The PCBA in accordance with claim 1, wherein another core of the multi-core processor is devoted to servo management.
3. The PCBA in accordance with any one of claims 1 or 2, wherein another core of the multi-core processor cooperates with the second core for the internal data management and file system management.
4. The PCBA in accordance with any one of claims 1 to 3, wherein another core of the multi-core processor is devoted to caching and tiering.
5. A hard disk drive (HDD) comprising the PCBA of any one of claims 1 to 4.
6. The HDD in accordance with claim 5, wherein the NVM is used with disk media of the HDD for hybrid data storage.

7. A multi actuator, multi HDD comprising the PCBA of any one of claims 1 to 4.
8. A Solid State Drive (SSD) comprising the PCBA of any one of claims 1 to 4.
9. A HDD for data storage comprising:
 - one or more disk platters, each of the one or more disk platters having magnetic disk media on one or both sides;
 - an axial motor for rotating the one or more disk platters;
 - one or more actuators for reading and writing data from the one or more disk platters;
 - one or more interfaces coupled to the one or more actuators; and
 - a PCBA coupled to the axial motor, the one or more actuators, and the one or more interfaces, wherein the PCBA comprises:
 - an NVM; and
 - a multi-core processor, wherein a first core of the multi-core processor being devoted to external interface management and a second core of the multi-core processor being devoted to internal data management.
10. The HDD for data storage in accordance with claim 9, wherein another core of the multi-core processor of the PCBA is devoted to servo management.
11. The HDD for data storage in accordance with any one of claims 9 or 10, wherein another core of the multi-core processor of the PCBA cooperates with the second core for the internal data management and file system management.

12. The HDD for data storage in accordance with any one of claims 9 to 11, wherein another core of the multi-core processor of the PCBA is devoted to caching and tiering.

13. The HDD for data storage in accordance with any one of claims 9 to 12, wherein the NVM is used with the magnetic disk media for hybrid data storage.

14. A system for distributed data storage, the system comprising:

one or more storage devices, the one or more storage devices comprising a PCBA, the PCBA comprising:

an NVM; and

a multi-core processor, wherein a first core of the multi-core processor is devoted to external interface management and a second core of the multi-core processor is devoted to internal data management of the corresponding one of the one or more storage devices;

one or more client terminals, wherein the one or more storage devices and the one or more client terminals are coupled to a network and configured to perform a distributed data storage operation within the one or more storage devices in response to a request by any one of the one or more client terminals, the distributed data storage operation performed in cooperation with the first core's external interface management.

15. The system for distributed data storage in accordance with claim 14, wherein the network further comprises one or more metadata servers coupled to the network.

16. The system for distributed data storage in accordance with any one of claims 14 to 15, wherein the multi-core processor of the PCBA of each of the one or more storage devices is configured to perform autonomous data clustering in response to a request by any one of the one or more client terminals.
17. The system for distributed data storage in accordance with any one of claims 14 to 16, wherein the multi-core processor of the PCBA of each of the one or more storage devices is configured to execute a program on any one or more storage devices in response to a request by any one or more client terminals.
18. The system for distributed data storage in accordance with any one of claim 14 to 17, wherein the first core of the multi-core processor of the PCBA of each of the one or more storage devices is configured to perform data interfacing to the client terminal.
19. The PCBA in accordance with any one of claims 14 to 18, wherein another core of the multi-core processor is devoted to servo management.
20. The PCBA in accordance with any one of claims 14 to 19, wherein another core of the multi-core processor cooperates with the second core for the internal data management and file system management.
21. The PCBA in accordance with any one of claims 14 to 20, wherein another core of the multi-core processor is devoted to caching and tiering.

22. The system for distributed data storage in accordance with any one of claims 14 to 21, wherein the one or more storage devices is a HDD.

23. The system for distributed data storage in accordance with claim 22, wherein the HDD is a multi actuator, multi disk HDD.

24. The system for distributed data storage in accordance with any one of claims 22 and 23, wherein the NVM is used with disk media of the HDD for hybrid data storage.

25. The system for distributed data storage in accordance with any one of claims 14 to 21, wherein the one or more storage devices is an SSD.