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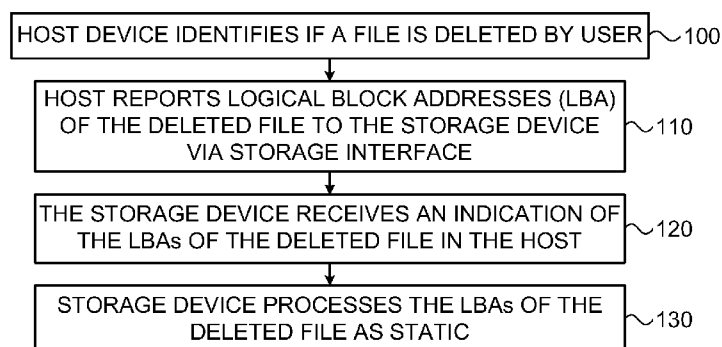

FIG. 2

(57) Abstract: A storage device includes a memory and a processor. The processor is configured to store data items for a host in respective logical addresses, to identify a first subset of the logical addresses as frequently-accessed logical addresses and a second subset of the logical addresses as rarely-accessed logical addresses, to manage the frequently-accessed logical addresses separately from the rarely-accessed logical addresses, to receive from the host an indication of one or more logical addresses, which are used for storing data that is identified by the host as having been deleted by a user, and to add the logical addresses indicated by the host to the rarely- accessed logical addresses.

HINTING OF DELETED DATA FROM HOST TO STORAGE DEVICE

FIELD OF THE INVENTION

The present invention relates generally to memory systems, and
particularly to methods for managing data in a storage device.

BACKGROUND OF THE INVENTION

Various techniques are known in the art for storing data
in memory according to the usage pattern of the data. For
example, U.S. Patent Application Publication 2009/0049234, whose
disclosure is incorporated herein by reference, describes a
storage scheme that stores data in a solid state memory
including first and second memory layers. A first assessment is
executed to determine whether received data is hot data or cold
data. Received data which is assessed as hot data is stored in
the first memory layer, and received data which is assessed as
cold data is stored in the second memory layer. Further, a
second assessment is executed to determine whether the data
stored in the first memory layer is hot data or cold data. Data
which is then assessed as cold data during the second assessment
is migrated from the first memory layer to the second memory
layer.

As another example, U.S. Patent Application Publication
2011/0010489, whose disclosure is incorporated herein
by reference, describes a logical block management method for
managing a plurality of logical blocks of a Flash memory
device. The method includes providing a Flash memory
controller, and grouping the logical blocks into a plurality
of logical zones, wherein each logical block maps to one of
the logical zones. The method also includes counting a use
count value for each logical block, and dynamically adjusting
mapping relations between the logical blocks and the logical
zones according to the use count values. Accordingly, the logical
block management method can effectively utilizing the logical
zones to determine usage patterns of the logical blocks and
use different mechanisms to write data, so as to increase the
performance of the Flash memory storage device.

Yet another example of managing hot and cold data is described by Hong and Shin, in "NAND Flash-based Disk Cache Using SLC/MLC Combined Flash Memory," 2010 International Workshop on Storage Network Architecture and Parallel I/Os, 5   May, 2010, which is incorporated herein by reference.

SUMMARY OF THE INVENTION

An embodiment of the present invention described herein provides a storage device including a memory and a processor. The 10   processor is configured to store data items for a host in respective logical addresses, to identifya first subset of the logical addresses as frequently-accessed logical addresses and a second subset of the logical addresses as rarely-accessed logical addresses, to manage the frequently-accessed 15   logical addresses separately from the rarely-accessed logical addresses, to receive from the host an indication of one or more logical addresses, which are used for storing datathat is identified by the host as having been deleted by a user, and to add the logical addresses indicated by the host to 20   the rarely-accessed logical addresses.

In some embodiments, the identified data includes a file that is stored in the one or more logical addresses and that has been deleted by the user. In other embodiments, the notification specifies to the processor that the data has been deleted. In 25   yet other embodiments, the notification specifies to the processor that the data is to be processed as rarely-accessed.

In some embodiments, the processor is configured to define in the memory a partition for storing the data that has been identified by the host as having been deleted by the user. 30   In other embodiments, the processor is configured to receive from the host a location of the partition in the memory.

There is additionally provided, in accordance with an embodiment of the present invention, a host including a storage interface and a processor. The storage interface communicates 35   with a storage device. The processor is configured to identify data that is stored on the storage device and has been deleted by a user of the host, and to report to the storage device one or more logical addresses in which the identified data has been

stored by the host on the storage device.

There is additionally provided, in accordance with an embodiment of the present invention, a computer including a host and a storage device. The host is configured to identify data that has been deleted by a user and to send a notification that reports one or more logical addresses in which the identified data has been stored by the host on the storage device. The storage device is configured to store data items for the host in respective logical addresses, to identify a first subset of the logical addresses as frequently-accessed logical addresses and a second subset of the logical addresses as rarely-accessed logical addresses, to manage the frequently-accessed logical addresses separately from the rarely-accessed logical addresses, to receive the notification from the host, and to add the one or more logical addresses indicated in the notification to the rarely-accessed logical addresses.

There is additionally provided, in accordance with an embodiment of the present invention, a method including in a storage device, storing data items for a host in respective logical addresses. A first subset of the logical addresses is identified in the storage device as frequently-accessed logical addresses and a second subset of the logical addresses as rarely-accessed logical addresses, and the frequently-accessed logical addresses are managed separately from the rarely-accessed logical addresses. An indication of one or more logical addresses is received in the storage device from the host, which are used for storing data that is identified by the host as having been deleted by a user. The logical addresses indicated by the host are added to the rarely-accessed logical addresses.

There is additionally provided, in accordance with an embodiment of the present invention, a method including storing data items by a host in a storage device. Data that is stored on the storage device and has been deleted by a user of the host is identified in the host. A notification of one or more logical addresses in which the identified data has been stored by the host on the storage device is reported to the storage device.

The present invention will be more fully understood from
the following detailed description of the embodiments thereof,
taken together with the drawings in which:

5   BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block   diagram   that   schematically illustrates
a host device storing data in a storage device, in accordance
with an embodiment of the present invention; and
Fig. 2 is a flow chart that schematically   illustrates a
10   method for managing data in   a   storage   device after deletion
by a host device, in accordance with an embodiment of the
present invention.

                    DETAILED DESCRIPTION OF EMBODIMENTS
15

                                OVERVIEW
Some storage devices apply separate processing to frequently-
accessed ("hot") and rarely-accessed ("cold") data. This sort of
management improves the efficiency and performance of   the storage
20   device. In order to apply separate processing successfully,
however, the storage device should be able to distinguish
between hot and cold data reliably. Embodiments of the present
invention that are   described herein provide methods and
systems that enable storage devices to better distinguish between
25   frequently-accessed and rarely-accessed data.
In some hosts, data that is deleted by a user is
retained in the storage device, for example in order t o
g i v e   t h e   u ser an opportunity to un-delete it. Deleted
data may be retained in storage for long periods of time. During
30   this time, it is highly unlikely that the deleted data will
be accessed, and this data can therefore be treated   as
cold. Conventionally, however,   the   storage device is unaware of
the fact that the data is deleted, and cannot make use of this
information.
35   In the   disclosed   embodiments, when a user deleted
certain data in the host, the host sends to the storage device
a notification that identifies this data. The storage device

                                    4

classifies the data indicated in the notification as cold, and processes it accordingly. The notification typically indicates the logical addresses of the data that has been deleted in the host. In some embodiments, the notification indicates

5   explicitly that the logical addresses belong to deleted data. In other embodiments, the notification indicates that the logical addresses are to be processed as cold, without giving a reason.

When using the disclosed techniques, the storage device

10 is able to better distinguish between frequently-accessed and rarely-accessed data. Consequently, performance measures such as throughput, latency and reliability can be improved, and the operational lifetime of the storage device can be extended.

15   SYSTEM DESCRIPTION

Fig. 1 is a block diagram that schematically illustrates a host device 10 storing data in a storage device 20, in accordance with an embodiment of the present invention. Hosts that store data on storage devices with non-volatile storage devices

20 may comprise, for example, personal computers, enterprise storage controllers, mobile phones, digital cameras, media players, removable memory cards or devices, and many others.

Host device 10 comprises a central processing unit (CPU) 25. CPU 25 runs an operating system (OS) 30 that is typically

25 programmed in software, and carries out the functions of the host. Operating system 30 comprises a file system 33, which stores information about the files whose data is stored in storage device 20. In particular, file system 33 records the logical addresses (e.g., Logical Block Addresses LBAs) in which

30 each file is stored on storage device 20. The file system communicates with storage device 20 via a storage interface 35.

In the example embodiments described herein, storage device 20 comprises a solid state drive (SSD). SSD 20 comprises an SSD controller (SSD CNTRL) 40 that relays data between the

35 host and one or more Flash memory devices 45, and performs the various storage management functions of the SSD. Controller 40 comprises a host interface 50 for communicating with host 10, a processor 55 that carries out the disclosed

management techniques, and a memory interface 60 for
communicating with Flash devices 45.

 SSD 20 manages a Logical-to-Physical (L2P) address mapping
70, which maps the LBAs to respective physical addresses, i.e.,
physical storage locations in the memory cell blocks of Flash
devices 45 where the data is stored.

 SSD 20 stores data for host 10 in a non-volatile memory,
in the present example in one or more NAND Flash memory devices
45. In alternative embodiments, the non- volatile memory in SSD
20 may comprise any other suitable type of non-volatile memory,
such as, for example, NOR Flash, Charge Trap Flash (CTF), Phase
Change RAM (PRAM), Magneto-resistive RAM (MRAM) or
Ferroelectric RAM (FeRAM).

 The configuration of Fig. 1 is an exemplary configuration,
which is shown purely for the sake of conceptual clarity,
and not by way of limitation of the embodiments of the present
invention. Any other suitable host and/or storage device
configuration can also be used. In the exemplary system
configuration shown in Fig. 1, memory devices 45 and SSD
controller 40 are implemented as separate Integrated Circuits
(ICs). In alternative embodiments, however, the memory devices
and the SSD controller may be integrated on separate
semiconductor dies in a single Multi-Chip Package (MCP) or
System on Chip (SoC), and may be interconnected by an internal
bus. Further alternatively, some or all of the SSD controller
circuitry may reside on the same die on which one or more of
memory devices 45 are disposed. Further alternatively, some or
all of the functionality of SSD controller 40 can be
implemented in software and carried out by CPU 25 or other
processor in the host. In some embodiments, CPU 25 and SSD
controller 40 may be fabricated on the same die, or on
separate dies in the same device package.

 Processor 55 of SSD controller 40 and/or CPU 25 may be
implemented in hardware. Alternatively, the SSD controller
and/or CPU may comprise a microprocessor that runs suitable
software, or a combination of hardware and software elements. In
some embodiments, processor 55 and/or CPU   25 comprises a
general-purpose processor, which is programmed in software to

carry out the functions   described   herein.   The software
may   be   downloaded to the processor in electronic form, over
a network, for example, or it may, alternatively or additionally,
be provided and/or stored on non-transitory tangible media, such
5   as magnetic, optical, or electronic memory.

                IMPROVED SSD PERFORMANCE BY SEPARATING HOT AND COLD DATA
                Typically, host 10 sends each data item (e.g., file)
     for storage in SSD 20 along with one or more LBAs in which
10   the data is to be stored. In practice, some of the LBAs
     correspond to frequently-assessed data, while other LBAs
     correspond to rarely-assessed data. Frequently- assessed data is
     commonly referred to as hot or dynamic data, and rarely-assessed
     data is commonly referred to as cold or static data. Thus, LBAs
15   corresponding to frequently-assessed data are referred to herein
     as hot or dynamic LBAs, and LBAs corresponding to rarely-
     accessed data are referred to herein as cold or static LBAs.
                In some embodiments, processor 55 in SSD controller
     40 may be configured to process the hot and cold LBAs
20   separately. This sort of processing significantly improves
     the performance of the SSD. For example, in Flash   memory
     data   cannot   be   overwritten   in-place. Moreover, data is
     typically written in page units, but erased only in block
     units. For these reasons, the memory blocks in Flash devices 45
25   gradually accumulate regions of invalid data, for which up-to-
     date versions have been written into new physical storage
     locations. Processor 55 typically runs a block compaction
     ("garbage collection") process, which copies the valid data
     from   fragmented blocks into new blocks and frees the
30   fragmented blocks for erasure and new programming.
                When hot and cold data are stored in an inter-mixed
     fashion in the same memory blocks, the garbage collection process
     has to copy rarely-accessed data frequently, only because it is
     intermixed with hot data. The result is a large   number   of
35   unnecessary copy operations,   and   thus degraded performance. If,
     on the other hand, If, on the other hand, the SSD separates
     the hot and cold data, garbage collection can be performed
     with high efficiency. Thus, in some embodiments processor 55

stores hot LBAs in a first subset of the memory blocks and cold
LBAs in a second subset of the memory blocks, and performs
block compaction separately within each subset of blocks.

5   As another example, in some embodiments the SSD is
configured to operate with multi-level cell (MLC) Flash
devices that store multiple bits per memory cell. In a 2 bits/cell
device, for example, a least significant bit (LSB) and a most
significant bit (MSB) page are stored in respective bits of a
group of memory cells. Typically, LSB storage and retrieval are
10   significantly faster than MSB storage and retrieval. Thus,
in some embodiments processor 55 stores the hot data on the LSB
pages and the cold data on the MSB pages. As a result, the
average programming and readout latencies are reduced.

        The scenarios above are given purely by way of
15   example, in order to demonstrate the benefits of processing the
hot data and the cold data separately from one another. In
alternative embodiments, processor 55 may process the hot LBAs
and cold LBAs separately in any other suitable way. In order
to separate the hot and cold data, however, processor 55 should
20   be able to identify and distinguish between the frequently-
accessed and rarely-accessed LBAs. Processor 55 may identify the
LBAs of hot and cold data using various techniques, such as by
assessing the access frequencies of the various LBAs.

25   HOST INDICATION OF DELETED FILES TO STORAGE DEVICE
        In a typical host, a user may delete a file that is managed
by file system 33. The data of the deleted file should still be
retained in the SSD, e.g., to give the user an opportunity to
un-delete the file. Nevertheless, it is very unlikely that the
30   data of the deleted file will be accessed again, and this
data can therefore be treated as cold or static. The SSD,
however, is typically unaware of the file structure, e.g.,
which LBAs correspond to which files, and has no information
as to which files have been deleted.
35   In some embodiments, when a certain file in file system
33 is deleted by the user, CPU 25 sends a notification to SSD
controller 40, which indicates to the   SSD that the LBAs of
that file should be regarded and processed as cold. Upon

                                   8

receiving the notification, processor 55 classifies the reported
LBAs as cold and processes them accordingly. In many
cases, these LBAs would not be otherwise be identified as cold
by the SSD, or they may be identified as cold much later. In
5   either case, the host notification (also referred to as "hint")
enables considerable performance improvement in the SSD.

Once the LBAs of the deleted file are classified in the SSD
as cold, processor 55 may process them separately
from the hot LBAs in any suitable way, such as using the
10 techniques described above.

The host may indicate the LBAs of the deleted file to the
SSD in any suitable way and using any suitable interface. In
some embodiments, the notification indicates that the LBAs
belong to a deleted file. In other embodiments, the
15 notification indicates that the LBAs are to be processed as
cold, without specifying a reason.

Fig. 2 is a flow chart that schematically illustrates a
method for managing data files in a storage device after
deletion by a host device, in accordance with an
20 embodiment of the present invention. In an identifying step 100,
host device 10 identifies that a certain file has been deleted
by the user. In a reporting step 110, the host reports the
logical block addresses (LBAs) of the deleted file to the
storage device via storage interface 35. In a receiving step
25 120, the storage device receives the indication of the LBAs of
the deleted file from the host. In a processing step 130, the
storage device processes the LBAs of the deleted files as static.

In an alternative embodiment, SSD 20 comprises a
partition in the memory, which is used to archive data that
30 was deleted in the host. In this embodiment, SSD 20 receives an
indication from host 10 with the LBA range, or a dedicated
name-space of the partition identifying the location in memory
of the partition. The partition may be dynamic or static.

Although the embodiments described herein mainly address
35 deleted files, the methods and systems described herein can also
be used in other applications that do not necessarily involve
files or file systems. In other words, the host may report to the
storage device the LBAs of any kind of data that has been

deleted. For example, the host may report LBAs of files
deleted from a data base, which no longer needs to store old
copies of the files on the storage device.

It will thus be appreciated that the embodiments
5   described above are cited by way of example, and that the present
invention is not limited to what has been particularly shown and
described hereinabove. Rather, the scope of the present invention
includes both combinations and sub-combinations of the various
features described hereinabove, as well as variations and
10 modifications thereof which would occur to persons skilled in
the art upon reading the foregoing description and which are not
disclosed in the prior art. Documents incorporated by
reference in the present patent application are to be
considered an integral part of the application except that to
15 the extent any terms are defined in these incorporated documents
in a manner that conflicts with the definitions made
explicitly or implicitly in the present specification, only
the definitions in the present specification should be
considered.

WHAT IS CLAIMED IS:

1.   A storage device, comprising:
      a memory; and
      a processor, which is configured to store data items
for a host in respective logical addresses, to identify a first
subset of the logical addresses as frequently- accessed
logical addresses and a second subset of the logical addresses
as rarely-accessed logical addresses, to manage   the frequently-
accessed   logical   addresses separately from the rarely-accessed
logical addresses, to receive   from the host an indication
of one or more logical addresses, which are used for storing
data that is identified by the host as having been deleted by
a user, and to add the logical addresses indicated by the host
to the rarely-accessed logical addresses.

2.   The storage device according to claim 1, wherein the
identified data comprises a file that is stored in the one or
more logical addresses and that has been deleted by the user.

3.   The storage device according to claim 1, wherein the
notification specifies to the processor that the data has been
deleted.

4.   The storage device according to claim 1, wherein the
notification specifies to the processor that the data is
to be processed as rarely-accessed.

5.   The storage device according to claim 1, wherein the
processor is configured to define in the memory a partition for
storing the data that has been identified by the host as having
been deleted.

6.   The storage device according to claim 5, wherein the
processor is configured to receive from the host a location of the
partition in the memory.

7.   A computer, comprising:

a host, which is configured to identify data that has been deleted by a user and to send a notification that reports one or more logical addresses in which the identified data has been stored by the host on the storage device; and

a storage device, which is configured to store data items for the host in respective logical addresses, to identify a first subset of the logical addresses as frequently-accessed logical addresses and a second subset of the logical addresses as rarely-accessed logical addresses, to manage the frequently-accessed logical addresses separately from the rarely-accessed logical addresses, to receive the notification from the host, and to add the one or more logical addresses indicated in the notification to the rarely-accessed logical addresses.

8.   A method, comprising:

in a storage device, storing data items for a host in respective logical addresses;

identifying in the storage device a first subset of the logical addresses as frequently-accessed logical addresses and a second subset of the logical addresses as rarely-accessed logical addresses, and managing the frequently-accessed logical addresses separately from the rarely-accessed logical addresses;

receiving in the storage device from the host an indication of one or more logical addresses, which are used for storing data that is identified by the host as having been deleted by a user; and

adding the logical addresses indicated by the host to the rarely-accessed logical addresses.

9.   The method according to claim 8, wherein the identified data comprises a file that is stored in the one or more logical addresses and that has been deleted by the user.

10.   The method according to claim 8, wherein the notification specifies to the storage device that the data has been deleted.

11.   The method according to claim 8, wherein the notification specifies to the storage device that the data is to be processed as rarely-accessed.

5   12.   The method according to claim 8, wherein storing the data items comprises defining in the memory a partition for storing the data that has been identified by the host as having been deleted.

10   13.   The method according to claim 12, and comprising receiving from the host a location of the partition in the storage device.
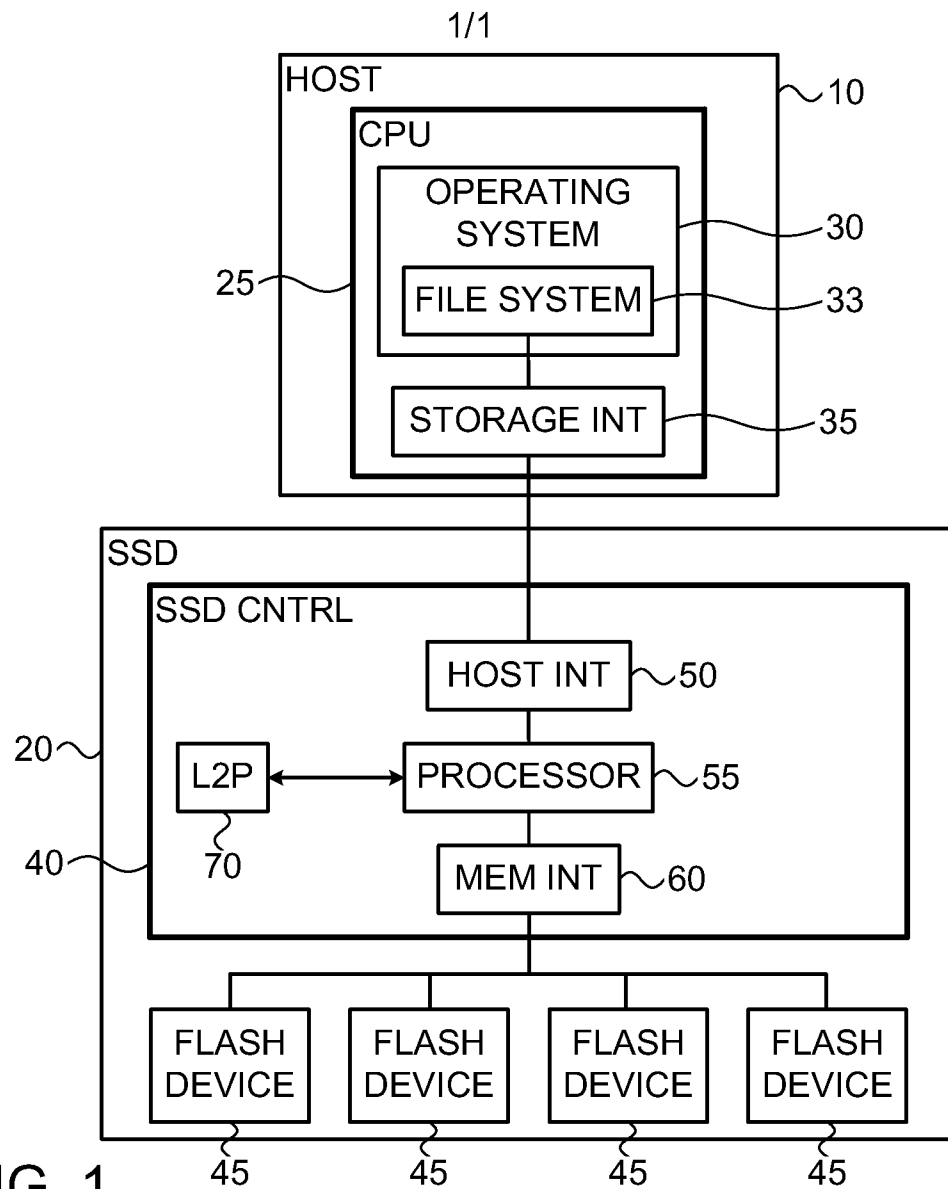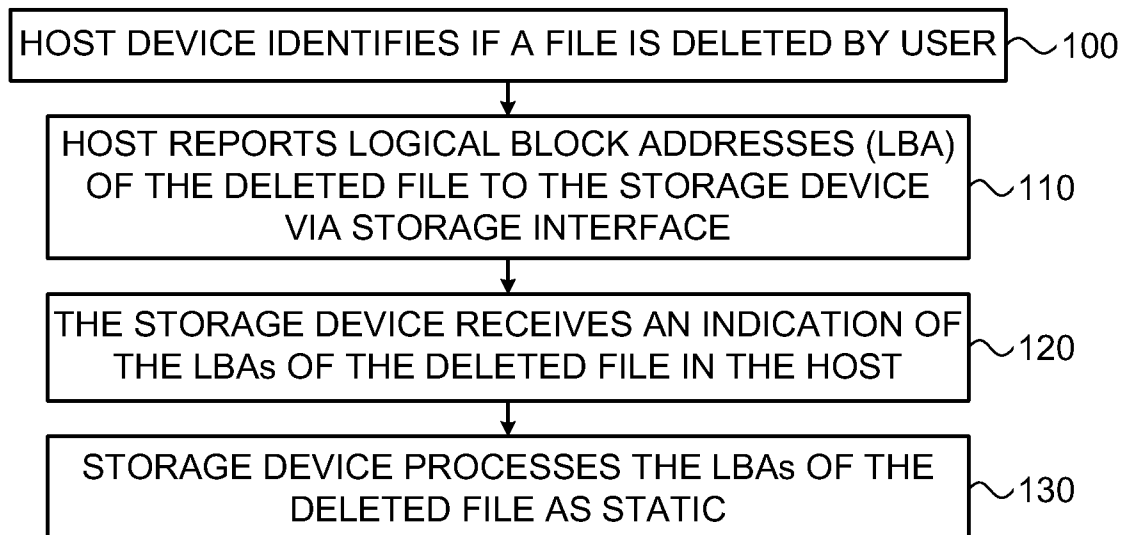
1/1

HOST ~10

CPU

OPERATING
SYSTEM ~30

25 FILE SYSTEM ~33

STORAGE INT ~35

SSD

SSD CNTRL

HOST INT ~50

20

L2P ←→ PROCESSOR ~55

40

70

MEM INT ~60

| FLASH DEVICE | FLASH DEVICE | FLASH DEVICE | FLASH DEVICE |

45   45   45   45

FIG. 1

HOST DEVICE IDENTIFIES IF A FILE IS DELETED BY USER ~100

HOST REPORTS LOGICAL BLOCK ADDRESSES (LBA)
OF THE DELETED FILE TO THE STORAGE DEVICE ~110
VIA STORAGE INTERFACE

THE STORAGE DEVICE RECEIVES AN INDICATION OF
THE LBAs OF THE DELETED FILE IN THE HOST ~120

STORAGE DEVICE PROCESSES THE LBAs OF THE
DELETED FILE AS STATIC ~130

FIG. 2

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06F3/06   G06F17/30
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/049234 A1 (OH MOON-WOOK [KR] ET AL) 19 February 2009 (2009-02-19) cited in the application paragraphs [0002] - [0014], [0023] - [0027], [0039], [0041] - [0059]; figures 1-3,6-8	1-13
A	US 2006/010150 A1 (SHAATH KAMEL [CA] ET AL) 12 January 2006 (2006-01-12) paragraphs [0002] - [0014], [0035] - [0046], [0090], [0091]; figure 2	1-13

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 January 2014	05/02/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Limacher, Rolf

Form PCT/ISA/210 (second sheet) (April 2005)

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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