
Information technology — Linear Tape File System (LTFS) Format Specification

*Technologies de l'information — Spécification du format de système
de fichier à bande magnétique*

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Linear Tape File System (LTFS) Format Specification

Version 2.2.0

This document has been released and approved by the SNIA. The SNIA believes that the ideas, methodologies and technologies described in this document accurately represent the SNIA goals and are appropriate for widespread distribution. Suggestions for revision should be directed to <http://www.snia.org/feedback/>

SNIA Technical Position

December 21, 2013

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- Incremented version number to 2.0.0 and updated date to March 11, 2011.
- Improvements in specification text to remove ambiguity and clarify intention of the specification. These changes were made at several locations throughout the document.
- Improvements to clarify description of MAM parameters in Section 9 Medium Auxiliary Memory.
- Removed reference to a specific version of the Unicode standard in Section 6.5 Name pattern format. This removes any requirement to use specific versions of Unicode support code in an implementation.
- Improved description of Name pattern format to remove ambiguity in Section 6.5 Name pattern format.
- Added description of LTFS Format specification version numbering in Section 2.1 Versions.
- Updated XML Schema for Label and Index to match version number format in Annex A and Annex B.
- Added specification of minimum and recommended blocksize value for LTFS Volumes to Section 7.1.2 LTFS Label.
- Added definition of allowed version numbers to Section 7.1.2 LTFS Label and Section 8.2 Index.
- Added definition of fileoffset tag in Section 8.2 Index.
- Extended description in Section 5 Data Extents to support addition of fileoffset tag and associated functionality.
- Added definition of highestfileuid tag in Section 8.2 Index.
- Added definition of fileuid tag in Section 8.2 Index.

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- Added definition of backup time tag in Section [8.2 Index](#).
- Incremented version number in Application Client Specific Information (ACSI) structure shown in [9.3 Use of Volume Coherency Information for LTFS](#). This increment allows identification of LTFS Volumes written with a LTFS v1.0 compliant implementation. A widely used v1.0 implementation wrote ambiguous ACSI values due to an implementation bug.
- Added definition of extended attributes in the ltfs.* namespace in [Annex C](#).
- Added description for handling unknown XML tags in Index to Section [8.2.10 Managing LTFS Indexes](#).

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- Expanded historical record of changes between revisions of LTFS Format Specification.
- Improved description of constraints for two Indexes having the same generation number in Section [4.4.1 Generation Number](#) to make it clear that differences in access time values is permitted between Indexes that are otherwise except for self pointer and index pointer values.
- Added note in Section [4.4.1 Generation Number](#) to explicitly state that Index generation numbers may increase by integer values other than 1.
- Expanded description of the ltfs.sync extended attribute in [Annex C](#). The expanded description explicitly states that this extended attribute triggers a sync of the in-memory data to the storage media. That is, the operation is analogous to a POSIX sync operation.

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- Added example of symlink tag use in [Annex E](#) (informative) Complete Example LTFS Index.
- Added symlink tag to [Annex B](#).
- Added description of "ltfs.vendor.X.Y" extended attribute namespace in [Annex C](#).
- Added description of software metadata section in [Annex C](#).
- Added description of drive metadata section in [Annex C](#).
- Added "ltfs.labelVersion" extended attribute in [Annex C](#).
- Added "ltfs.indexVersion" extended attribute in [Annex C](#).
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- Added Section 9.4 Use of Host-type Attributes for LTFS.
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- Added “Itfs.mamApplicationVendor” extended attribute in Annex C.4 Volume Metadata.
- Added “Itfs.mamApplicationVersion” extended attribute in Annex C.4 Volume Metadata.
- Added “Itfs.mamApplicationFormatVersion” extended attribute in Annex C.4 Volume Metadata.
- Added new Annex F Interoperability Recommendation and added File Spanning and File Permissions subsections

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1 Introduction

This document defines a Linear Tape File System (LTFS) Format separate from any implementation on data storage media. Using this format, data is stored in LTFS Volumes. An LTFS Volume holds data files and corresponding metadata to completely describe the directory and file structures stored on the volume.

The LTFS Format has these features:

- An LTFS Volume can be mounted and volume content accessed with full use of the data without the need to access other information sources.
- Data can be passed between sites and applications using only the information written to an LTFS Volume.
- Files can be written to, and read from, an LTFS Volume using standard POSIX file operations.

The LTFS Format is particularly suited to these usages:

- Data export and import.
- Data interchange and exchange.
- Direct file and partial file recall from sequential access media.
- Archival storage of files using a simplified, self-contained or “self-describing” format on sequential access media.

2 Scope

This document defines the LTFS Format requirements for interchanged media that claims LTFS compliance. Those requirements are specified as the size and sequence of data blocks and file marks on the media, the content and form of special data constructs (the LTFS Label and LTFS Index), and the content of the partition labels and use of MAM parameters.

The data content (not the physical media) of the LTFS format shall be interchangeable among all data storage systems claiming conformance to this format. Physical media interchange is dependent on compatibility of physical media and the media access devices in use.

NOTE: This document does not contain instructions or tape command sequences to build the LTFS structure.

2.1 Versions

This document describes version 2.2.0 of the Linear Tape File System (LTFS) Format Specification.

The version number for the LTFS Format Specification consists of three integer elements separated by period characters of the form *M.N.R*, where *M*, *N*, and *R* are positive integers or zero. Differences in the version number between different revisions of this specification indicate the nature of the changes made between the two revisions. Each of the integers in the format specification are incremented according to Table 1.

Table 1 — Version elements

Element	Description
<i>M</i>	Incremented when a major update has been made to the LTFS Format Specification. Major updates are defined as any change to the on-media format or specification semantics that are expected to break compatibility with older versions of the specification.
<i>N</i>	Incremented when a minor update has been made to the LTFS Format Specification. Minor updates are defined as any change to the on-media format or specification semantics that is not expected to break compatibility with older versions of the specification that have the same value for <i>M</i> in the version number.
<i>R</i>	Incremented when textual revisions are made to the LTFS Format Specification. Textual revisions are defined as revisions that improve the clarity of the specification document <i>without</i> changing the intent of the document. By definition, minor changes do not alter the on-media format or specification semantics.

NOTE 1: When any element of the specification version number is incremented, all sub-ordinate elements to the right are reset to zero. For example, if the version is 1.0.12 and *N* is incremented to 1, then *R* is set to zero resulting in version 1.1.0.

NOTE 2: The first public version of this document used version number 1.0. This value should be interpreted as equivalent to 1.0.0 in the version numbering defined in this document.

The result of comparison between two LTFS version numbers $M_A.N_A.R_A$ and $M_B.N_B.R_B$ is defined in Table 2.

Table 2 — Version comparisons

Conditional	Description
$M_A < M_B$	$M_A.N_A.R_A$ is an earlier version than $M_B.N_B.R_B$.
$M_A = M_B$ and $M_A < N_B$	$M_A.N_A.R_A$ is an earlier version than $M_B.N_B.R_B$.
$M_A = M_B$ and $N_A = N_B$ and $R_A < R_B$	$M_A.N_A.R_A$ is an earlier version than $M_B.N_B.R_B$. However, as defined above, changes that result only in a different R value are descriptive changes in the specification rather than on media changes.

2.2 Conformance

Recorded media claiming conformance to this format shall be in a consistent state when interchanged or stored. See Section 3.1.4.

Any implementation conforming to this specification should be able to correctly read Label and Index structures from all prior versions of this specification and write Label and Index structures conforming to the descriptions in this document. The current Label and Index structures are defined in Section 7 Label Format and in Section 8 Index Format.

NOTE: Where practical, any implementation supporting a given version value for M should endeavor to support LTFS volumes with version numbers containing higher values for N and R than those defined at the time of implementation.

3 Definitions and Acronyms

For the purposes of this document the following definitions and acronyms shall apply.

3.1 Definitions

3.1.1

Block Position

The position or location of a recorded block as specified by its LTFS Partition ID and logical block number within that partition.

The block position of an Index is the position of the first logical block for the Index.

3.1.2

Complete Partition

An LTFS partition that consists of an LTFS Label Construct and a Content Area, where the last construct in the Content Area is an Index Construct.

3.1.3

Content Area

A contiguous area in a partition, used to record Index Constructs and Data Extents.

3.1.4

Consistent State

A volume is consistent when both partitions are complete and the last Index Construct in the Index Partition has a back pointer to the last Index Construct in the Data Partition.

3.1.5

Data Extent

A contiguous sequence of recorded blocks.

3.1.6

Data Partition

An LTFS partition primarily used for data files.

3.1.7

File

A group of logically related extents together with associated file metadata.

3.1.8

filesystem sync

An operation during which all cached file data and metadata is flushed to the media.

3.1.9

generation number

A positive decimal integer which shall indicate the specific generation of an Index within an LTFS volume.

3.1.10**Index**

A data structure that describes all valid data files in an LTFS volume. The Index is an XML document conforming to the XML schema shown in [Annex B \(normative\) LTFS Index XML Schema](#).

3.1.11**Index Construct**

A data construct comprised of an Index and file marks.

3.1.12**Index Partition**

An LTFS partition primarily used to store Index Constructs and optionally data files.

3.1.13**Label Construct**

A data construct comprised of an ANSI VOL1 tape label, LTFS Label, and tape file marks.

3.1.14**Linear Tape File System (LTFS)**

This document describes the Linear Tape File System Format.

3.1.15**LTFS Construct**

Any of three defined constructs that are used in an LTFS partition. The LTFS constructs are: Label Construct, Index Construct, and Data Extent.

3.1.16**LTFS Label**

A data structure that contains information about the LTFS partition on which the structure is stored. The LTFS Label is an XML document conforming to the XML schema shown in [Annex A \(normative\) LTFS Label XML Schema](#).

3.1.17**LTFS Partition**

A tape partition that is part of an LTFS volume. The partition contains an LTFS Label Construct and a Content Area.

3.1.18**LTFS Volume**

A pair of LTFS partitions, one Data Partition and one Index Partition, that contain a logical set of files and directories. The pair of partitions in an LTFS Volume shall have the same UUID. All LTFS partitions in an LTFS volume are *related partitions*.

3.1.19**Medium Auxiliary Memory**

An area of non-volatile storage that is part of an individual storage medium. The method of access to this non-volatile storage is standardized as described in the T10/SPC-4 standard.

3.1.20**Partition Identifier (Partition ID)**

The logical partition letter to which LTFS data files and Indexes are assigned.

The linkage between LTFS partition letter and physical SCSI partition number is determined by the SCSI partition in which the LTFS Label is recorded. The LTFS partition letter is recorded in the LTFS Label construct, and the SCSI partition number is known by the SCSI positional context where they were read/written.

3.1.21**sparse file**

A file that has some number of empty (unwritten) data regions. These regions are not stored on the storage media and are implicitly filled with bytes containing the value zero (0x00).

3.1.22**UUID**

Universally unique identifier; an identifier use to bind a set of LTFS partitions into an LTFS volume.

3.1.23**Volume Change Reference (VCR)**

A value that represents the state of all partitions on a medium.

3.2 Acronyms

ASCII	American Standard Code for Information Interchange
CM	Cartridge Memory
DCE	Distributed Computing Environment
ISO	International Organization for Standardization
LTFS	Linear Tape File System
MAM	Media Auxiliary Memory
NFC	Normalization Form Canonical Composition
OSF	Open Software Foundation
POSIX	Portable Operating System Interface for Unix
T10/SSC-4	ISO/IEC 14776-334, SCSI Stream Commands - 4 (SSC-4) [T10/2123-D]
UTC	Coordinated Universal Time
UTF-8	8-bit UCS/Unicode Transformation Format
UUID	Universally Unique Identifier
W3C	World Wide Web Consortium
XML	Extensible Markup Language

4 Volume Layout

An LTFS volume is comprised of a pair of LTFS partitions. LTFS defines two partition types: data partition and index partition. An LTFS volume shall contain exactly one Data Partition and exactly one Index Partition.

4.1 LTFS Partitions

Each partition in an LTFS volume shall consist of a Label Construct followed by a Content Area. This logical structure is shown in Figure 1.

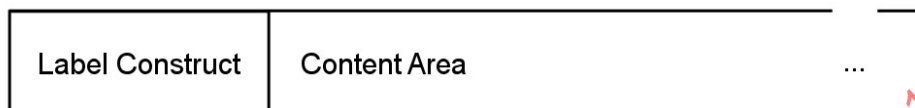


Figure 1 — LTFS Partition

The Label Construct is described in Section 4.2 LTFS Constructs and in Section 7 Label Format. The Content Area contains some number of interleaved Index Constructs and Data Extents. These constructs are described in Section 4.2 LTFS Constructs and in Section 8 Index Format. The precise layout of the partitions is defined in Section 4.3 Partition Layout.

4.2 LTFS Constructs

LTFS constructs are comprised of file marks and records. These are also known as 'logical objects' as found in T10 SSC specifications and are not described here. An LTFS volume contains three kinds of constructs.

- A Label Construct contains identifying information for the LTFS volume.
- A Data Extent contains file data written as sequential logical blocks. A file consists of zero or more Data Extents plus associated metadata stored in the Index Construct.
- An Index Construct contains an Index, which is an XML data structure which describes the mapping between files and Data Extents.

4.2.1 Label Construct

Each partition in an LTFS volume shall contain a Label Construct with the following structure. As shown in Figure 2, the construct shall consist of an ANSI VOL1 label, followed by a single file mark, followed by one record in LTFS Label format, followed by a single file mark. Each Label construct for an LTFS volume shall contain identical information except for the "location" field of the LTFS Label.

The content of the ANSI VOL1 label and the LTFS Label is specified in Section 7 Label Format.

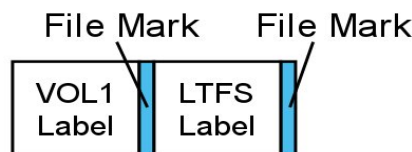


Figure 2 — Label Construct

4.2.2 Data Extent

A Data Extent is a set of one or more sequential logical blocks used to store file data. The “blocksize” field of the LTFS Label defines the block size used in Data Extents. All blocks within a Data Extent shall have this fixed block size except the last block, which may be smaller.

The use of Data Extents to store file data is specified in Section 5 Data Extents.

4.2.3 Index Construct

Figure 3 shows the structure of an Index Construct. An Index Construct consists of a file mark, followed by an Index, followed by a file mark. An Index consists of a record that follows the same rules as a Data Extent, but it does not contain file data. That is, the Index is written as a sequence of one or more logical blocks of size “blocksize” using the value stored in the LTFS Label. Each block in this sequence shall have this fixed block size except the last block, which may be smaller. This sequence of blocks records the Index XML data that holds the file metadata and the mapping from files to Data Extents. The Index XML data recorded in an Index Construct shall be written from the start of each logical block used. That is, Index XML data may not be recorded offset from the start of the logical block.



Figure 3 — Index Construct

Indexes also include references to other Indexes in the volume. References to other Indexes are used to maintain consistency between partitions in a volume. These references (back pointers and self pointers) are described in Section 4.4 Index Layout.

The content of the Index is described in Section 8 Index Format.

4.3 Partition Layout

This section describes the layout of an LTFS Partition in detail. An LTFS Partition contains a Label Construct followed by a Content Area. The Content Area contains zero or more Data Extents and Index Constructs in any order. The last construct in the Content Area of a complete partition shall be an Index Construct.

Figure 4 illustrates an empty complete partition. It contains a Label Construct followed by an Index Construct. This is the simplest possible complete partition.

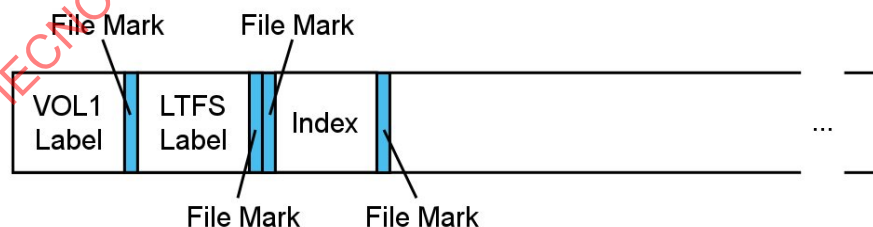


Figure 4 — Partition Layout

Figure 5 illustrates a complete partition containing data. The Content Area on the illustrated partition contains two Data Extents (the first extent comprising the block 'A', the second extent comprising blocks 'B' and 'C') and three Index Constructs.

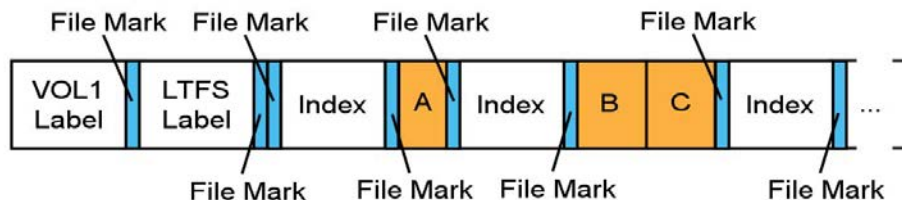


Figure 5 — Complete partition containing data

NOTE: There must not be any additional data trailing the end of the VOL1 Label, the LTFS Label, nor any Index on an LTFS Volume. The Label Construct must be recorded starting at the first logical block in each partition.

4.4 Index Layout

Each Index data structure contains three pieces of information used to verify the consistency of an LTFS volume.

- A generation number, which records the age of this Index relative to other Indexes in the volume.
- A self pointer, which records the volume to which the Index belongs and the block position of the Index within that volume.
- A back pointer, which records the block position of the last Index present on the Data Partition immediately before this Index was written.

4.4.1 Generation Number

Each Index in a volume has a generation number, a non-negative integer that increases as changes are made to the volume. In any consistent LTFS volume, the Index with the highest generation number on the volume represents the current state of the entire volume. Generation numbers are assigned in the following way:

- Given two Indexes on a partition, the one with a higher block position shall have a generation number greater than or equal to that of the one with a lower block position.
- Two Indexes in an LTFS volume may have the same generation number if and only if their contents are identical except for these elements:
 - access time values for files and directories (described in Section 8.2),
 - the self pointer (described in 4.4.2), and
 - the back pointer (described in 4.4.3).

NOTE: The value of the generation number between any two successive Indexes may increase by any positive integer value. That is, the magnitude of increase between any two successive Indexes is not assumed to be equal to 1.

The first Index on an LTFS Volume shall be generation number '1'.

4.4.2 Self Pointer

The self pointer for an Index is comprised of the following information:

- The UUID of the volume to which the Index belongs
- The block position of the Index

The self pointer is used to distinguish between Indexes and Data Extents. An otherwise valid Index with an invalid self pointer shall be considered a Data Extent for the purpose of verifying that a volume is valid

and consistent. This minimizes the likelihood of accidental confusion between a valid Index and a Data Extent containing Index-like data.

4.4.3 Back Pointer

Each Index contains at most one back pointer, defined as follows.

- If the Index resides in the Data Partition, the back pointer shall contain the block position of the preceding Index in the Data Partition. If no preceding Index exists, no back pointer shall be stored in this Index. Back pointers are stored in the Index as described in Section 8.2.
- If the Index resides in the Index Partition and has generation number N then the back pointer for the Index shall contain either the block position of an Index having generation number N in the Data Partition, or the block position of the last Index having at most generation number N-1 in the Data Partition. If no Index of generation number N-1 or less exists in the Data Partition, then the Index in the Index Partition is not required to store a back pointer.
- On a consistent volume, the final Index in the Index Partition shall contain a back pointer to the final index in the Data Partition.
- As a consequence of the rules above, no Index may contain a back pointer to itself or to an Index with a higher generation number.

On a consistent volume, the rules above require that the Indexes on the Data Partition and the final Index on the Index Partition shall form an unbroken chain of back pointers. Figure 6 illustrates this state.

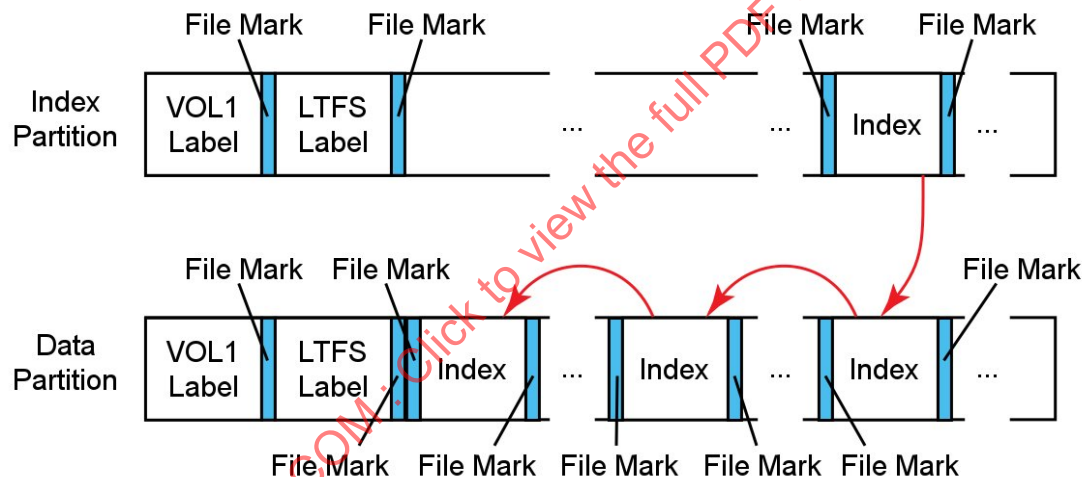


Figure 6 — Back Pointer example

5 Data Extents

A Data Extent is a set of one or more sequential records subject to the conditions listed in Section 4.2.2 [Data Extent](#). This section describes how files are arranged into Data Extents for storage on an LTFS volume. Logically, a file contains a sequence of bytes; the mapping from file byte offsets to block positions is maintained in an Index. This mapping is called the extent list.

5.1 Extent Lists

A file with zero size has no extent list.

Each entry in the extent list for a file encodes a range of bytes in the file as a range of contiguous bytes in a Data Extent. An entry in the extent list is known as an extent. Each entry shall contain the following information:

- **partition ID** – partition that contains the Data Extent comprising this extent.
- **start block** (start block number) – block number within the Data Extent where the content for this extent begins.
- **byte offset** (offset to first valid byte) – number of bytes from the beginning of the start block to the beginning of file data for this extent. This value shall be strictly less than the size of the start block. The use of byte offset is described in Section 5.2.3 [Starting and ending Data Extent in mid-block](#).
- **byte count** – number of bytes of file content in this Data Extent.
- **file offset** – number of bytes from the beginning of the file to the beginning of the file data recorded in this extent.

NOTE: Version 1.0 of this specification did not explicitly include file offsets in the extent list. When interpreting LTFS Volumes written based on the Version 1.0 specification, the file offsets shall be determined as follows.

- The first extent list entry begins at file offset 0.
- If an extent list entry begins at file offset N and contains K bytes, the following extent list entry begins at file offset N + K.

These file extent rules for version 1.0 of the specification necessarily imply that the order of extents recorded in the Index shall be preserved during any subsequent update of the Index to another version 1.0 Index.

The inclusion of the File Offset value for each extent starting from version 2.0.0 of this specification removes the significance of the order in which extents are recorded in the Index.

Implementers are encouraged to record extents in the same logical order as they exist in the represented file.

In the extent list for any file, no extent may contain bytes that extend beyond the logical end of file. The logical end of file is defined by the file length recorded in the Index. Also, in any extent list for any file, there shall not exist any pair of extents that contain overlapping logical file offsets. That is, no extent is allowed to logically overwrite any data stored in another extent.

An extent list entry shall be a byte range within a single Data Extent; that is, it shall not cross a boundary between two Data Extents. This requirement allows a deterministic mapping from any file offset to the block position where the data can be found. On the other hand, two extent list entries (in the same file or in different files) may refer to the same Data Extent.

5.2 Extents Illustrated

This section illustrates various forms of extent list entries and the mapping from files to these extents. The illustrations are not exhaustive. Other combinations of starting and ending blocks are possible.

The LTFS Partition ID is an essential element of an extent definition. For simplicity, the LTFS Partition ID and File Offset are not shown explicitly in the extents lists illustrated in Table 3, Table 4, and Table 5. Note that not all extents in an extent list shall be on the same partition.

5.2.1 Starting and ending Data Extent with full block

Figure 7 illustrates an extent of 3 full size blocks contained within a Data Extent of 3 blocks, N through $N + 2$.

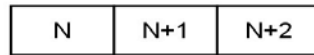


Figure 7 — Extent starting and ending with full block

The extent list entry for this extent is shown in Table 3.

Table 3 — Extent list entry starting and ending with full block

Start Block	Offset	Length
N	0	$3 \times Blk$

NOTE: Blk is the length of a full-sized block.

5.2.2 Starting Data Extent with full block and ending with fractional block

Figure 8 illustrates an extent of 2 full-size blocks and one fractional block of K bytes, contained within a Data Extent of 2 full size blocks N and $N + 1$ and one fractional block $N + 2$.

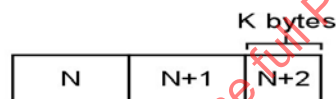


Figure 8 — Extent starting with full block and ending with fractional block

The extent list entry for this extent is shown in Table 4.

Table 4 — Extent list entry starting with full block and ending with fractional block

Start Block	Offset	Length
N	0	$(2 \times Blk) + K$

NOTE: K is the length of the fractional block, where $K < Blk$

5.2.3 Starting and ending Data Extent in mid-block

Figure 9 illustrates an extent smaller than 3 blocks, contained within a Data Extent of 3 full size blocks. Valid data begins in block N at byte number J and continues to byte number K of block $N + 2$. The last block of the extent, block $N + 2$, may be a fractional block.

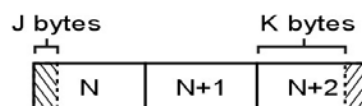


Figure 9 — Extent starting and ending in mid-block

The extent list entry for this extent is shown in Table 5.

Table 5 — Extent list entry starting and ending in mid-block

Start Block	Byte Offset	Byte Count
N	J	$(Blk - J) + Blk + K$

5.3 Files Illustrated

This section illustrates various possible extent lists for files. These illustrations are not exhaustive; other combinations of extent geometry and ordering are possible. The extents shown in this section are always displayed in file offset order, but they may appear in any order on a partition, or even in different partitions. As in the previous section, Partition IDs are omitted for simplicity. Unless otherwise noted these examples illustrate non-sparse files that have all file data written to the media.

5.3.1 Simple Files

Figure 10 illustrates a file contained in a single Data Extent of three blocks. The data fills the first two blocks and K bytes in the last block. The last block of the extent, block $N + 2$, may be a fractional block. This file is recorded as a regular (non-sparse) file. See Table 6.

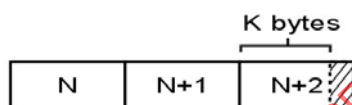


Figure 10 — File contained in a single Data Extent

Table 6 — Extent list entry for file contained in a single Data Extent

Start Block	Byte Offset	Byte Count	File Offset
N	0	$(2 \times Blk) + K$	0

Figure 11 illustrates a file contained in two Data Extents of three blocks each. The data fills the first two blocks of extent N and K bytes of block $N + 2$, and the first two blocks of extent M and L bytes of block $M + 2$. The last block of each extent, block $N + 2$ and $M + 2$, may be fractional blocks. This file is recorded as a regular (non-sparse) file. Table 7 shows file details.

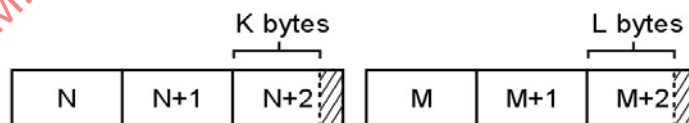


Figure 11 — File contained in two Data Extents

Table 7 — Extent list entry for a file contained in two Data Extents

Start Block	Byte Offset	Byte Count	File Offset
N	0	$(2 \times Blk) + K$	0
M	0	$(2 \times Blk) + L$	$(2 \times Blk) + K$

5.3.2 Shared Blocks

Figure 12 illustrates two full-sized blocks which are referenced by three files. Blocks may be shared among multiple files to improve storage efficiency. File 1 uses the first K bytes of block N . File 2 uses Q bytes in the mid part of block N , and $(Blk - R)$ bytes at the end of block $N + 1$. File 3 uses the last $(Blk - P - Q)$ bytes at the end of block N and the first T bytes of block $N + 1$.

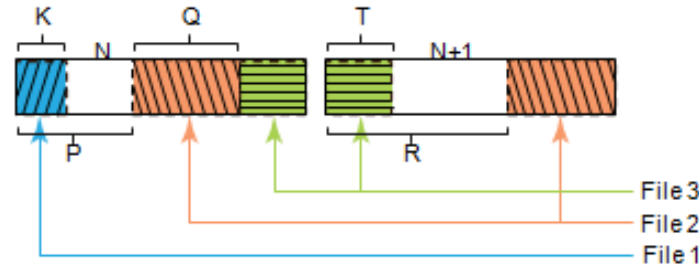


Figure 12 — Shared Blocks example

The extent lists for files 1, 2, and 3 are shown in Table 8.

Table 8 — Extent lists for Shared Blocks example

	Start Block	Byte Offset	Byte Count	File Offset
File 1	N	0	K	0
File 2	N	P	Q	0
	$N+1$	R	$Blk - R$	Q
File 3	N	$P + Q$	$Blk - P - Q + T$	0

NOTE: If N were a fractional block, File 3 would map to two entries in the extent list. As illustrated, block N is a full block, and File 3 may be mapped to the single extent list entry shown above. Alternatively, because blocks may always be treated as independent Data Extents, File 3 could be mapped to two entries in the extent list, one entry per block (N and $N + 1$).

5.3.3 Sparse Files

The length of a file, as recorded in the Index, may be greater than the total size of data encoded in that file's extent list. A file may also have non-zero size but no extent list. In both of these cases, all bytes not encoded in the extent list shall be treated as zero (0x00) bytes.

Figure 13 illustrates a sparse file that is contained in two Data Extents. In this figure, all white areas of the file are filled with bytes that are set to zero (0x00). The file starts with T bytes with value zero (0x00). The first extent stores K bytes of data which fills the file from byte T to $T + K$. The file contains R bytes with value zero (0x00) from file offset $T + K$ to $T + K + R$. The second extent contains Q file bytes representing the file content from file offset $T + K + R$ to $T + K + R + Q$. The end of the file from file offset $T + K + R + Q$ is filled with bytes set to value zero (0x00) to the defined file size P .

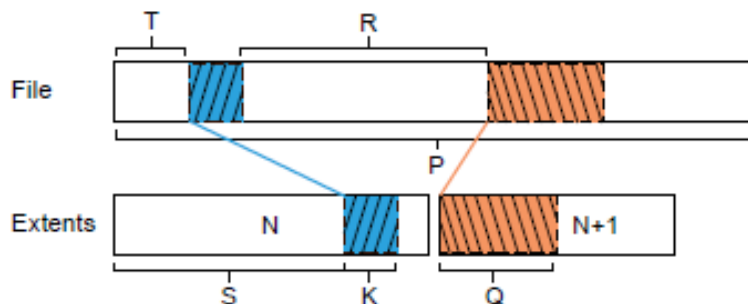


Figure 13 — Sparse files example

The extent list for this file is shown in Table 9.

Table 9 — Extent list for sparse files example

Start Block	Byte Offset	Byte Count	File Offset
N	S	K	T
$N + 1$	0	Q	$T + K + R$

NOTE 1: Version 1.0 of this specification, implied zeros could only appear at the end of a file; other types of sparse files were not supported. When appending to the end of a file that is to be stored on a volume in compliance with version 1.0 of this specification, any implied trailing zero bytes in the file must be explicitly written to the media to avoid leaving holes in the extent list for the file.

NOTE 2: Version 1.0 of this specification did not support sparse files.

5.3.4 Shared Data

Figure 14 illustrates four Data Extents which are partly shared by two files. Overlapping extent lists may be used to improve storage efficiency.

NOTE: Methods to implement data deduplication are beyond the scope of this document. Implementations must read files with overlapping extent lists correctly, but they are not required to generate such extent lists.

In Figure 14, File 1 uses all blocks in Data Extents N , M , and R . File 2 uses some of the blocks in Data Extents N , R and V . The extent lists for the two files are shown in Table 10. The two files share some of the data in blocks N , $N + 1$, $N + 2$, $R + 1$ and $R + 2$.

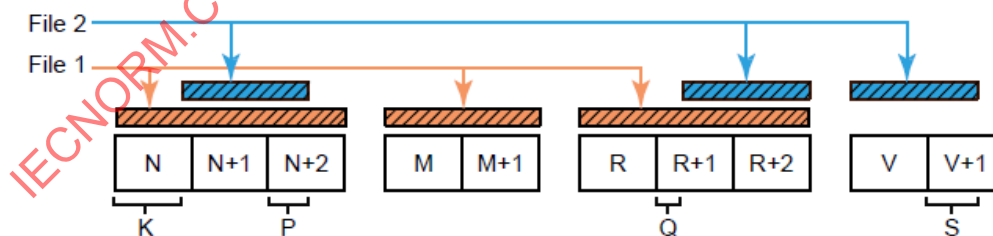


Figure 14 — Shared data example

The extent lists for files 1 and 2 are shown in Table 10.

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Table 10 — Extent lists for shared data example

	Start Block	Byte Offset	Byte Count	File Offset
File 1	N	0	$3 \times Blk$	0
	M	0	$2 \times Blk$	$3 \times Blk$
	R	0	$3 \times Blk$	$(3 \times Blk) + (2 \times Blk)$
File 2	N	K	$(Blk - K) + Blk + P$	0
	$R+1$	Q	$(Blk - Q) + Blk$ $Blk +$	$(Blk - K) + Blk + P$
	V	0	S	$(Blk - K) + Blk + P + (Blk - Q) + Blk$

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6 Data Formats

The LTFS Format uses the data formats defined in this section to store XML field values in the Index Construct and Label Construct.

6.1 Boolean format

Boolean values in LTFS structures shall be recorded using the values: “true”, “1”, “false”, and “0”. When set to the values “true” or “1”, the boolean value is considered to be set and considered to evaluate to true. When set to the values “false” or “0”, the boolean value is considered to be unset, and considered to evaluate to false.

6.2 Creator format

LTFS creator values shall be recorded in conformance with the string format defined in Section 6.6 String format with the additional constraints defined in this section.

LTFS creator values shall be recorded as a Unicode string containing a maximum of 1024 Unicode code points. The creator value shall include product identification information, the operating platform, and the name of the executable that wrote the LTFS volume.

An example of the recommended content for creator values is:

IBM LTFS 1.2.0 - Linux - mklufs

The recommended format for a creator value is a sequence of values separated by a three character separator. The separator consists of a space character, followed by a hyphen character, followed by another space character. The recommended content for the creator value is *Company Product Version - Platform - binary name* where definitions are as defined in Table 11.

Table 11 — Creator format definitions

Symbol	Description
<i>Company Product Version</i>	Identifies the product that created the volume.
<i>Platform</i>	Identifies the operating system platform for the product.
<i>binary name</i>	Identifies the executable that created the volume.

Any subsequent data in the creator format should be separated from this content by a hyphen character.

6.3 Extended attribute value format

An extended attribute value shall be recorded as one of two possible types:

1. The “text” type shall be used when the value of the extended attribute conforms to the format described in Section 6.6 String format. The encoded string shall be stored as the value of the extended attribute and the type of the extended attribute shall be recorded as “text”.
2. The “base64” type shall be used for all values that cannot be represented using the “text” type. Extended attribute values stored using the “base64” type shall be encoded as base64 according to RFC 4648, and the resulting string shall be recorded as the extended attribute value with the type recorded as “base64”. The encoded string may contain whitespace characters as defined by the W3C Extensible Markup Language (XML) 1.0 standard (space, tab, carriage return, and line feed). These characters shall be ignored when decoding the string.

6.4 Name format

File and directory names, and extended attribute keys in an LTFS Volume shall conform to the naming rules in this section.

Names shall be valid Unicode and shall be 255 code points or less after conversion to Normalization Form C (NFC). Names shall be stored in a case-preserving manner. Since names are stored in an Index, they shall be encoded as UTF-8 in NFC. Names may include any characters allowed by the W3C Extensible Markup Language (XML) 1.0 standard except for the those listed in Table 12.

Table 12 — Prohibited characters for name format

Character	Description
U+002F	slash
U+003A	colon

Note that the null character U+0000 is disallowed by *W3C XML 1.0*. See *W3C XML 1.0* for a full list of disallowed characters. The characters listed in Table 13 are allowed, but they should be avoided for reasons of cross-platform compatibility.

Table 13 — Characters which should be avoided for name format

Character	Description
U+0009, U+000A and U+000D	control codes
U+0022	double quotation
U+002A	Asterisk
U+003F	question mark
U+003C	less than sign
U+003E	greater than sign
U+005C	Backslash
U+007C	vertical line

6.5 Name pattern format

File name patterns in data placement policies shall be valid names as defined in Section 6.4 Name format. A file name pattern shall be compared to a file name using these rules:

1. Comparison shall be performed using canonical caseless matching as defined by the Unicode Standard, except for the code points U+002A and U+003F.
2. Matching of name patterns to a filenames shall be case insensitive.
3. U+002A (asterisk ‘*’) shall match zero or more Unicode grapheme clusters.
4. U+003F (question mark ‘?’) shall match exactly one grapheme cluster.

For more information on grapheme clusters, see *Unicode Standard Annex 29, Unicode Text Segmentation*.

6.6 String format

A character string encoded using UTF-8 in NFC. The string shall only contain characters allowed in element values by the W3C Extensible Markup Language (XML) 1.0 specification.

6.7 Time stamp format

Time stamps in LTFS data structures shall be specified as a string conforming to the ISO 8601 date and time representation standard. The time stamp shall be specified in UTC (Zulu) time as indicated by the 'Z' character in this example:

2013-02-01T18:35:47.866846222Z

The time shall be specified with a fractional second value that defines 9 decimal places after the period in the format.

The general time format is *YYYY-MM-DD Thh:mm:ss.nnnnnnnnn Z* where values are as described in Table 14.

Table 14 — Time stamp format

Symbol	Description
YYYY	the four-digit year as measured in the Common Era.
MM	an integer between 01 and 12 corresponding to the month.
DD	an integer between 01 and 31 corresponding to the day in the month.
hh	an integer between 00 and 23 corresponding to the hour in the day.
mm	an integer between 00 and 59 corresponding to the minute in the hour.
ss	an integer between 00 and 59 corresponding to the second in the minute.
nnnnnnnnnn	an integer between 000000000 and 999999999 measuring the decimal fractional second value.

NOTE: The characters '-', 'T', ':', '.', and 'Z' in the time stamp format are field separators. The 'Z' character indicates that the time stamp is recorded in UTC (Zulu) time.

All date and time fields in the time stamp format shall be padded to the full width of the symbol using 0 characters. For example, an integer month value of '2' shall be recorded as '02' to fill the width of the *MM* symbol in the general time format.

6.8 UUID format

LTFS UUID values shall be recorded in a format compatible with OSF DCE 1.1, using 32 hexadecimal case-insensitive digits (0-9, a-f or A-F) formatted as shown. UUID values are expected to uniquely identify the LTFS Volume, as in this example:

30a91a08-daae-48d1-ae75-69804e61d2ea

7 Label Format

This section describes the content of the Label Construct. The content of the Content Area is described in Section 4.2 LTFS Constructs and in Section 8 Index Format.

7.1 Label Construct

Each partition in an LTFS Volume shall contain a Label Construct that conforms to the structure shown in Figure 15. The construct shall consist of an ANSI VOL1 Label, followed by a single file mark, followed by one record in LTFS Label format, followed by a single file mark. There shall not be any additional data trailing the end of the ANSI VOL1 Label, nor any additional data trailing the end of the LTFS Label. The Label Construct shall be recorded starting at the first logical block in the partition. Both Label constructs in an LTFS Volume shall contain identical information with the exception of the “location” field in the XML data for the LTFS Label.

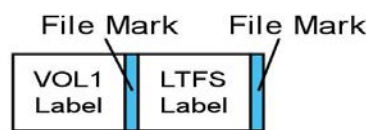


Figure 15 — Label construct

7.1.1 VOL1 Label

A VOL1 label recorded on an LTFS Volume shall always be recorded in a Label Construct as defined in Section 7.1 Label Construct.

The first record in a Label Construct is an ANSI VOL1 record. This record conforms to the ANSI Standard X 3.27. All bytes in the VOL1 record are stored as ASCII encoded characters. The record is exactly 80 bytes in length and has the structure and content shown in Table 15.

Table 15 — VOL1 Label Construct

Offset	Length	Name	Value	Notes
0	3	label identifier	'VOL'	
3	1	label number	'1'	
4	6	volume identifier	<volume serial number>	Typically matches the physical cartridge label.
10	1	volume accessibility	'L'	Accessibility limited to conformance to LTFS standard.
11	13	Reserved	all spaces	
24	13	implementation identifier	'LTFS'	Value is left-aligned and padded with spaces to length.
37	14	owner identifier	right pad with spaces	Any printable characters. Typically reflects some user specified content oriented identification.
51	28	Reserved	all spaces	
79	1	label standard version	'4'	

NOTE 1: Single quotation marks in the Value column above should not be recorded in the VOL1 label.

NOTE 2: All fields in the VOL1 label must contain the constant values shown in the table above. The only exceptions are the 'volume identifier' and 'owner identifier' fields. These two fields should contain user-provided values in conformance to the Notes provided.

7.1.2 LTFS Label

The LTFS Label is an XML data structure that describes information about the LTFS Volume and the LTFS Partition on which the LTFS Label is recorded. The LTFS Label shall conform to the LTFS Label XML schema provided in [Annex A](#). The LTFS Label shall be encoded using UTF-8 NFC.

An LTFS Label recorded on an LTFS Volume shall always be recorded in an Label Construct as defined in Section [7.1 Label Construct](#).

A complete schema for the LTFS Label XML data structure is provided in [Annex A](#). An example LTFS Label is shown here:

```
<?xml version="1.0" encoding="UTF-8"?>
<ltfslabel version="2.2.0">
  <creator>IBM LTFS 1.2.0 - Linux - mklufs</creator>
  <formattime>2013-02-01T18:35:47.866846222Z</formattime>
  <volumeuuid>30a91a08-daae-48d1-ae75-69804e61d2ea</volumeuuid>
  <location>
    <partition>b</partition>
  </location>
  <partitions>
    <index>a</index>
    <data>b</data>
  </partitions>
  <blocksize>524288</blocksize>
  <compression>true</compression>
</ltfslabel>
```

Every LTFS Label shall be an XML data structure that conforms to the W3C Extensible Markup Language (XML) 1.0 standard. Every LTFS Label shall have a first line that contains an XML Declaration as defined in the XML standard. The XML Declaration shall define the XML version and the encoding used for the Label.

The LTFS Label XML shall be recorded in a single logical data block and shall contain the following information:

- **ltfslabel**: this element defines the contained structure as an LTFS Label structure. The element shall have a **version** attribute that defines the format version of the LTFS Label in use. This document describes LTFS Label version 2.2.0.

NOTE: The LTFS Label version defines the minimum version of the LTFS Format specification with which the LTFS Volume conforms. Implicitly, the LTFS Label version defines the lowest permitted version number for all LTFS Indexes written to the volume.

- **creator**: this element shall contain the necessary information to uniquely identify the writer of the LTFS volume. The value shall conform to the creator format definition shown in Section [6.2 Creator format](#).
- **formattime**: this element shall contain the time when the LTFS Volume was formatted. The value shall conform to the format definition shown in Section [6.7 Time stamp format](#).
- **volumeuuid**: this element shall contain a universally unique identifier (UUID) value that uniquely identifies the LTFS Volume to which the LTFS Label is written. The **volumeuuid** element shall conform to the format definition shown in Section [6.8 UUID format](#).
- **location**: shall contain a single **partition** element. The **partition** element shall specify the Partition ID for the LTFS Partition on which the Label is recorded. The Partition ID shall be a lower case ASCII character between 'a' and 'z'.

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- **partitions:** this element specifies the Partition IDs of the data and index partitions belonging to this LTFS volume. It shall contain exactly one **index** element for the Index Partition and exactly one **data** element for the Data Partition, formatted as shown. A partition shall exist in the LTFS Volume with a partition identifier that matches the identifier recorded in the **index** element. Similarly, a partition shall exist in the LTFS Volume with a partition identifier that matches the identifier recorded in the **data** element.
- **blocksize:** this element specifies the block size to be used when writing Data Extents to the LTFS Volume. The **blocksize** value is an integer specifying the number of 8-bit bytes that shall be written as a record when writing any full block to a Data Extent. Partial blocks may only be written to a Data Extent in conformance with the definitions provided in Section 4.2.2 Data Extent and in Section 5 Data Extents. The minimum blocksize that may be used in an LTFS Volume is 4096 8-bit bytes.

NOTE: For general-purpose storage on data tape media the recommended blocksize is 524288 8-bit bytes.

- **compression:** this element shall contain a value conforming to the boolean format definition provided in Section 6.1 Boolean format. When the compression element is set, compression shall be enabled when writing to the LTFS Volume. When the **compression** element is unset, compression shall be disabled when writing to the LTFS Volume. The **compression** element indicates use of media-level “on-the-fly” data compression. Use of data compression on a volume is transparent to readers of the volume.

7.1.3 Managing LTFS Labels

The LTFS Label captures volume-specific values that are constant over the lifetime of the LTFS Volume. As such, the values recorded in an LTFS Label can only be set or updated at volume format time.

Implementations should handle additional unknown XML tags when they occur as children of the **ltfslabel** element. In general, such unknown tags may be ignored when mounting the LTFS Volume. This handling of unknown XML tags reduces the risk of compatibility changes when future versions of this specification are adopted. It is a strict violation of this specification to add any XML tags to the Label beyond those defined in this document.

8 Index Format

The Content Area contains zero or more Data Extents and some number of Index Constructs in any order. This section describes the content of the Index Construct. The Label Construct is described in Section 7 [Label Format](#). Data Extents are described in Section 5 [Data Extents](#).

8.1 Index Construct

Each Content Area in an LTFS Volume shall contain some number of Index Constructs that conform to the structure shown in Figure 16. The Index Construct shall contain a single file mark, followed by one or more records in Index format, followed by a single file mark. There shall not be any additional data trailing the end of the Index.

The contents of the Index are defined in Section 8.2 [Index](#).



Figure 16 — Index Construct

The Index Constructs in a Content Area may be interleaved with any number of Data Extents. A complete partition shall have an Index Construct as the last construct in the Content Area, therefore there shall be at least one Index Construct per complete partition.

8.2 Index

An Index is an XML data structure that describes all data files, directory information and associated metadata for files recorded on the LTFS Volume. An Index recorded on an LTFS Volume shall always be recorded in an Index Construct as defined in Section 8.1 [Index Construct](#).

The LTFS Index shall conform to the Index XML schema provided in [Annex B \(normative\) LTFS Index XML Schema](#). The Index shall be encoded using UTF-8 NFC.

A complete schema for the Index XML data structure is provided in [Annex B \(normative\) LTFS Index XML Schema](#). The remainder of this section describes the content of the Index using an example XML Index.

An Index consists of Preface section containing multiple XML elements followed by a single **directory** element. This **directory** element is referred to as the “root” **directory** element. The root **directory** element corresponds to the root of the file system recorded on the LTFS Volume.

Each **directory** element shall contain a **contents** element, which may contain zero or more **directory** elements and zero or more **file** elements.

8.2.1 Example index omitting the body

An example Index that omits the body of the **directory** element is shown in this section. The omitted section in this example is represented by the characters '...'.

```
<?xml version="1.0" encoding="UTF-8"?>
<ltfsindex version="2.2.0">
  <creator>IBM LTFS 1.2.0 - Linux - ltfs</creator>
  <volumeuuid>30a91a08-daae-48d1-ae75-69804e61d2ea</volumeuuid>
  <generationnumber>3</generationnumber>
  <comment>A sample LTFS Index</comment>
  <updateime>2013-01-28T19:39:57.245954278Z</updateime>
  <location>
    <partition>a</partition>
    <startblock>6</startblock>
  </location>
  <previousgenerationlocation>
    <partition>b</partition>
    <startblock>20</startblock>
  </previousgenerationlocation>
  <allowpolicyupdate>true</allowpolicyupdate>
  <dataplacementpolicy>
    <indexpartitioncriteria>
      <size>1048576</size>
      <name>*.txt</name>
    </indexpartitioncriteria>
  </dataplacementpolicy>
  <highestfileuid>4</highestfileuid>
  <directory>
    ...
  </directory>
</ltfsindex>
```

Every Index shall be an XML data structure that conforms to the W3C Extensible Markup Language (XML) 1.0 standard. Every Index shall have a first line that contains an XML Declaration as defined in the XML standard. The XML Declaration shall define the XML version and the encoding used for the Index.

8.2.2 Required elements for every index

Every Index shall contain the following elements:

- **ltfsindex**: This element defines the contained structure as an Index structure. The element shall have a **version** attribute that defines the format version of the LTFS Index in use. This document describes LTFS Index version 2.2.0.

NOTE: The LTFS Label version defines the minimum version of the LTFS Format specification with which the LTFS Volume conforms. Implicitly, the LTFS Label version defines the lowest permitted version number for all LTFS Indexes written to the volume.

An Index update occurs when an LTFS Volume containing a current Index of version *M.N.R* is written with a new Index using a version number with a higher value for *M*. The version for any LTFS Index written to an LTFS Volume shall have an *M* value that is greater than or equal to the *M* value in the current Index. When the *M* value for the new LTFS Index equals the *M* value in the current Index, the new Index may be written in conformance to any value of *N* and *R* so long as *N* and *R* match the version of a published LTFS Format Specification.

An Index downgrade occurs when an LTFS Volume containing a current Index of version *M.N.R* is written with a new Index using a version number with a lower value for *M*. Index downgrades are explicitly disallowed in an LTFS Volume. Further details on Index version numbering is shown in Section [2.1 Versions](#).

- **creator**: This element shall contain the necessary information to uniquely identify the writer of the Index. The value shall conform to the creator format definition shown in Section 6.2 Creator format.
- **volumeuuid**: This element shall contain a universally unique identifier (UUID) value that uniquely identifies the LTFS Volume to which the Index is written. The value of the **volumeuuid** element shall conform to the format definition shown in Section 6.8 UUID format. The **volumeuuid** value shall match the value of the **volumeuuid** element in the LTFS Labels written to the LTFS Volume.
- **generationnumber**: This element shall contain a non-negative integer corresponding to the generation number for the Index. The first Index on an LTFS Volume shall be generation number “1”. The **generationnumber** shall conform to the definitions provided in Section 4.4.1 Generation Number.
- **updatetime**: This element shall contain the date and time when the Index was modified. The value shall conform to the format definition shown in Section 6.7 Time stamp format.
- **location**: This element shall contain a single partition element and a single **startblock** element. The **partition** element shall specify the Partition ID for the LTFS Partition on which the Index is recorded. The **startblock** element shall specify the first logical block number, within the partition, in which the Index is recorded. The **location** element is a self-pointer to the location of the Index in the LTFS Volume.
- **allowpolicyupdate**: This element shall contain a value conforming to the boolean format definition provided in Section 6.1 Boolean format. When the **allowpolicyupdate** value is set, the writer may change the content of the **dataplacementpolicy** element. When the **allowpolicyupdate** value is unset, the writer shall not change the content of the **dataplacementpolicy** element. Additional rules for the **allowpolicyupdate** element are provided in Section 8.2.11 Data Placement Policy.
- **highestfileuid**: This element contains an integer value that is equal to the value of the largest assigned **fileuid** element in the Index. An implementation shall be able to rely on the **highestfileuid** element to determine the highest assigned **fileuid** value in the Index without traversing all **file** and **directory** elements. The valid range of values for the **highestfileuid** value is 1 through $2^{64} - 1$ with the additional special value of zero (0x0).
The **highestfileuid** can be used to determine the highest integer value assigned to the **fileuid** element for all directories and files in the Index. While the **highestfileuid** value not equal to zero (0x0), an implementation may increment the **highestfileuid** value to create unique **fileuid** values for new directory and file entries.
A **highestfileuid** element value of zero (0x0) indicates that the LTFS Volume has exhausted the contiguous range of valid values for **fileuid** elements in the Index. In this case, an implementation should use a mechanism such as traversing all **file** and **directory** elements to identify an unused and therefore unique **fileuid** value for any new **file** and **directory** elements.
- **directory**: This element corresponds to the “root” **directory** element in the Index. The content of this element is described later in this section.

8.2.3 Optional elements for every index

Every Index may contain the following elements:

- **comment**: This element, if it exists, shall contain a valid UTF-8 encoded string value. The value of this element shall be used to store a user-provided description of this generation of the Index for the volume. The value of this element shall conform to the format definition provided in Section 6.6 String format. An Index may have at most one **comment** element. The writer of an Index may remove or replace the **comment** element when recording a new Index. The value of this element shall not exceed 64KiB in size.
- **previousgenerationlocation**: This element, if it exists, defines the back pointer for the Index. The **previousgenerationlocation** element shall contain a single **partition** element and a single **startblock** element. The value of the **partition** element shall specify the Partition ID for the LTFS

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Partition on which the back pointed Index is recorded. The **startblock** element shall specify the first logical block number, within the partition, in which the back pointed Index is recorded. If the Index does not have a back pointer there shall be no **previousgenerationlocation** element in the Index. Every Index that does have a back pointer shall have a **previousgenerationlocation**. All data values recorded in the **previousgenerationlocation** element shall conform to the definitions provided in Section 4.4 Index Layout.

- **dataplacementpolicy**: This element, if it exists, shall contain a single **indexpartitioncriteria** element. The **indexpartitioncriteria** element shall contain a single **size** element and zero or more **name** elements. The value of the **size** element shall define the maximum size of files that may be stored on the Index Partition. Each **name** element shall specify a file name pattern. The file name pattern value shall conform to the name pattern format provided in Section 6.5 Name pattern format. A description of the rules associated with the dataplacementpolicy element is provided in Section 8.2.11 Data Placement Policy.

8.2.4 Example Index that omits the Preface section

An example Index that omits the Preface section of the Index is shown in this section. The omitted section in this example is represented by the characters '...'. This example shows the root **directory** element for the Index.

```
<?xml version="1.0" encoding="UTF-8"?>
<ltfsindex version="2.2.0">
  ...
  <directory>
    <fileuid>1</fileuid>
    <name>LTFS Volume Name</name>
    <creationtime>2013-01-28T19:39:50.715656751Z</creationtime>
    <changetime>2013-01-28T19:39:55.231540960Z</changetime>
    <modifytime>2013-01-28T19:39:55.231540960Z</modifytime>
    <accesstime>2013-01-28T19:39:50.715656751Z</accesstime>
    <backuptime>2013-01-28T19:39:50.715656751Z</backuptime>
    <contents>
      <directory>
        <fileuid>2</fileuid>
        <name>directory1</name>
        <creationtime>2013-01-28T19:39:50.740812831Z</creationtime>
        <changetime>2013-01-28T19:39:56.238128620Z</changetime>
        <modifytime>2013-01-28T19:39:54.228983707Z</modifytime>
        <accesstime>2013-01-28T19:39:50.740812831Z</accesstime>
        <backuptime>2013-01-28T19:39:50.740812831Z</backuptime>
        <readonly>false</readonly>
        <contents>
          <directory>
            <fileuid>3</fileuid>
            <name>subdir1</name>
            <readonly>false</readonly>
            <creationtime>2013-01-28T19:39:54.228983707Z</creationtime>
            <changetime>2013-01-28T19:39:54.228983707Z</changetime>
            <modifytime>2013-01-28T19:39:54.228983707Z</modifytime>
            <accesstime>2013-01-28T19:39:54.228983707Z</accesstime>
            <backuptime>2013-01-28T19:39:54.228983707Z</backuptime>
          </directory>
        </contents>
      </directory>
    </contents>
  </directory>
  <file>
    <fileuid>4</fileuid>
    <name>testfile.txt</name>
```

```

<length>5</length>
<creationtime>2013-01-28T19:39:51.744583047Z</creationtime>
<changetime>2013-01-28T19:39:57.245291730Z</changetime>
<modifytime>2013-01-28T19:39:57.245291730Z</modifytime>
<accesstime>2013-01-28T19:39:57.240774456Z</accesstime>
<backuptime>2013-01-29T20:21:45.424385077Z</backuptime>
<readonly>true</readonly>
<extendedattributes>
</extendedattributes>
<extentinfo>
  <extent>
    <partition>a</partition>
    <startblock>4</startblock>
    <byteoffset>0</byteoffset>
    <bytecount>5</bytecount>
    <fileoffset>0</fileoffset>
  </extent>
</extentinfo>
</file>
</contents>
</directory>
</ltfsindex>

```

8.2.5 Required directory elements

An Index shall have exactly one **directory** element recorded as a child of the **ltfsindex** element in the Index. The **directory** element recorded as a child of the **ltfsindex** element in the Index shall represent the root of the filesystem on the LTFS Volume.

Every **directory** element (at any level) shall contain the following information:

- **fileuid**: This element shall contain an integer value that is a unique identifier with respect to directories and files in the Index. The valid range of values for the **fileuid** value is 1 through $2^{64} - 1$.
An example of how to calculate this unique value is provided in the description of **highestfileuid** above. The **directory** element corresponding to the root of the filesystem shall have a **fileuid** value of one (0x1).
- **name**: This element shall contain the name of the directory. A directory name shall conform to the format specified in Section 6.4 Name format.
- **creationtime**: This element shall contain the date and time when the directory was created in the LTFS Volume. The value shall conform to the format definition shown in Section 6.7 Time stamp format.
- **changetime**: This element shall contain the date and time when the extended attributes or readonly element for the directory was last altered. The value shall conform to the format definition shown in Section 6.7 Time stamp format.
- **modifytime**: This element shall contain the date and time when the content of the directory was most recently altered. The value shall conform to the format definition shown in Section 6.7 Time stamp format.
- **accesstime**: This element may contain the date and time when the content of the directory was last read. Implementators of the LTFS Format may choose to avoid or otherwise minimize recording Index updates that only change the **accesstime** element. The value shall conform to the format definition shown in Section 6.7 Time stamp format.
- **backuptime**: This element may contain the date and time when the content of the directory was last archived or backed up. If the directory has never been archived or backed up this element shall contain a value equal to the value of the **createttime** element. The value shall conform to the format definition shown in Section 6.7 Time stamp format.

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- **readonly**: This element shall contain a value conforming to the boolean format definition provided in Section 6.1 [Boolean format](#). When the **readonly** element is set, the directory shall not be modified by any writer. When the **readonly** element is unset, the directory may be modified by any writer. The following operations are considered to be modifications to a directory:
 - adding a child file or directory
 - removing a child file or directory, and
 - any change to the **extendedattributes** element.
- **contents**: This element shall contain zero or more **directory** elements and zero or more **file** elements. The elements contained in the **contents** element are children of the directory.

8.2.6 Optional directory elements

Every **directory** element may contain the following elements:

- **extendedattributes**: This element, if it exists, may contain zero or more **xattr** elements. The **xattr** elements are described in Section 8.2.9 [extendedattributes elements](#). A **directory** element may have zero or one **extendedattributes** elements.

The value of the name element for the root directory element in an Index shall be used to store the name of the LTFS Volume.

8.2.7 Required file elements

Every **file** element shall contain the following information:

- **fileuid**: This element shall contain an integer value that is a unique identifier with respect to directories and files in the Index. The valid range of values for the **fileuid** value is 2 through $2^{64} - 1$. An example of how to calculate this unique value is provided in the description of **highestfileuid** above.

NOTE: The value of the 'fileuid' element for the root directory is one (0x01) as defined in Section 9.2.5

All 'fileuid' elements shall be unique in the index therefore no file may have a 'fileuid' less than 2.

- **name**: This element shall contain the name of the file. A file name shall conform to the format specified in Section 6.4 [Name format](#).
- **length**: for file elements containing an **extentinfo** element or file elements describing a regular file with no **extentinfo** element (zero length or sparse files), the **length** element shall contain the integer length of the file. The length is measured in bytes. For **file** elements containing a **symlink** element, the length element shall contain the integer length of the **symlink** target path.
- **creationtime**: This element shall contain the date and time when the file was created in the LTFS Volume. The value shall conform to the format definition shown in Section 6.7 [Time stamp format](#).
- **changetime**: This element shall contain the date and time when the extended attributes or readonly element for the file was last altered. The value shall conform to the format definition shown in Section 6.7 [Time stamp format](#).
- **modifytime**: This element shall contain the date and time when the content of the file was most recently altered. The value shall conform to the format definition shown in Section 6.7 [Time stamp format](#).
- **accesstime**: This element may contain the date and time when the content of the file was last read. Implementers of the LTFS Format may choose to avoid or otherwise minimize recording Index updates that only change the **accesstime** element. The value shall conform to the format definition shown in Section 6.7 [Time stamp format](#).

- **backuptime**: This element may contain the date and time when the content of the file was last archived or backed up. If the file has never been archived or backed up, this element shall contain a value equal to the value of the **createtime** element. The value shall conform to the format definition shown in Section 6.7 Time stamp format.
- **readonly**: This element shall contain a value conforming to the boolean format definition provided in Section 6.1 Boolean format. When the **readonly** element is set, the file shall not be modified by any writer. When the **readonly** element is unset, the file may be modified by any writer. The **readonly** element is ignored for file elements containing a symlink element.

8.2.8 Optional file elements

Every **file** element may contain the following elements:

- **extendedattributes**: This element, if it exists, may contain zero or more **xattr** elements. The **xattr** elements are described in Section 8.2.9 extendedattributes elements. A **file** element may have zero or one **extendedattributes** elements.
- **extentinfo**: This element, if it exists, may contain zero or more **extent** elements. A **file** element may have zero or one **extentinfo** elements, however a file element shall not have both an **extentinfo** element and a **symlink** element.

Every **extent** element shall describe the location where a file extent is recorded in the LTFS Volume. Every **extent** element shall contain one **partition** element, one **startblock** element, one **byteoffset** element, one **bytecount** element, and one **fileoffset** element. The values recorded in elements contained by the **extentinfo** element shall conform to the definitions provided in Section 4.2.2 Data Extent and in Section 5 Data Extents. The **partition** element shall contain the Partition ID corresponding to the LTFS partition in which the Data Extent is recorded. The **startblock** element shall specify the first logical block number, within the partition, in which the Data Extent is recorded. The **byteoffset** element shall specify the offset into the start block within the Data Extent at which the valid data for the extent is recorded. The **bytecount** element shall specify the number of bytes that comprise the extent. The **fileoffset** element shall specify the offset into the file where the data stored in this Data Extent starts.

The order of **extent** elements within an **extentinfo** element is not significant. Implementors are encouraged to record **extentinfo** in the same order that the extents occur in the file. The definition of how extent values are determined and used is provided in Section 5 Data Extents and in Section 5.1 Extent Lists.

- **symlink**: This element, if it exists, shall contain either the fully qualified path from the root of the file system tree to the target file, or shall contain a relative path to the target file. Path strings shall be stored using the Unix-style forward slash as the path delimiter. A **file** element may have zero or one **symlink** elements, however a **file** element shall not have both an **extentinfo** element and a **symlink** element.

NOTE: It is possible that an older implementation of LTFS could create a tape that violates the mutual exclusivity requirement for **extentinfo** and **symlink** elements. In this case, the LTFS volume will not conform to this specification; it is recommended that an LTFS implementation encountering such a volume perform a recovery action before mounting or using the volume.

8.2.9 extendedattributes elements

All **directory** and **file** elements in an Index may specify zero or more extended attributes. These extended attributes are recorded as **xattr** elements in the **extendedattributes** element for the **directory** or **file**.

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An example **directory** element is shown in the following paragraph, with three extended attributes recorded. The `empty_xattr` and `document_name` extended attributes in this example both record string values. The `binary_xattr` attribute is an example of storing a binary extended attribute value. This example omits parts of the Index outside of the directory. The omitted sections in this example are represented by the characters "...".

```
...
<directory>
  <fileuid>2</fileuid>
  <name>directory1</name>
  <creationtime>2013-01-28T19:39:50.740812831Z</creationtime>
  <changetime>2013-01-28T19:39:56.238128620Z</changetime>
  <modifytime>2013-01-28T19:39:54.228983707Z</modifytime>
  <accesstime>2013-01-28T19:39:50.740812831Z</accesstime>
  <backuptime>2013-01-28T19:39:50.740812831Z</backuptime>
  <extendedattributes>
    <xattr>
      <key>binary_xattr</key>
      <value type="base64">/42n2QaEWSX+g==</value>
    </xattr>
    <xattr>
      <key>empty_xattr</key>
      <value/>
    </xattr>
    <xattr>
      <key>document_name</key>
      <value type="text">LTFS Format Specification</value>
    </xattr>
  </extendedattributes>
  <contents>
  </contents>
</directory>
...
```

Each **extendedattributes** element may contain zero or more **xattr** elements.

Each **xattr** element shall contain one **key** element and one **value** element. The **key** element shall contain the name of the extended attribute. The name of the extended attribute shall conform to the format specified in Section 6.4 Name format. Extended attribute names shall be unique within any single **extendedattributes** element. The **value** element shall contain the value of the extended attribute. The **value** element may have a **type** attribute that defines the type of the extended attribute value. If the **type** attribute is omitted then the type for the extended attribute value shall be "text". The value of the extended attribute shall conform to the format specified in Section 6.3 Extended attribute value format.

All extended attribute names that match the prefix "ltfs" with any capitalization are reserved for use by the LTFS Format. (That is, any name starting with a case-insensitive match for the letters "ltfs" are reserved.) Any writer of an LTFS Volume shall only use reserved extended attribute names to store extended attribute values in conformance with the reserved extended attribute definitions shown in Annex C.

8.2.10 Managing LTFS Indexes

An Index is a snapshot representation of the entire content of the LTFS Volume at a given point in time. Any alteration of an LTFS Volume shall record a complete snapshot of the entire content of the LTFS Volume.

NOTE: In practice, to maintain this snapshot semantic, an implementer generally should read the current Index from an LTFS Volume, make necessary changes to the Index and write the modified Index back to the LTFS Volume.

Implementations should handle additional unknown XML tags when they occur as children of the **ltfsindex**, **directory**, and **file** elements. These additional tags shall be preserved when a new generation of the Index is written to the LTFS Volume. This handling of unknown XML tags reduces the risk of

compatibility changes when future versions of this specification are adopted. It is a strict violation of this specification to add any XML tags to the Index beyond those defined in this document.

8.2.11 Data Placement Policy

An Index may specify a Data Placement Policy. This policy defines when the Data Extents for a file may be placed on the Index Partition. A Data Placement Policy specifies the conditions under which it is allowed to place Data Extents on the Index Partition.

An example Index that shows the elements that define the Data Placement Policy for an LTFS Volume is shown in this section. This example omits part of the Preface section and the root directory element. The omitted sections in this example are represented by the characters '...'.
<?xml version="1.0" encoding="UTF-8"?>

```
<ltfsindex version="2.2.0">
  ...
  <allowpolicyupdate>true</allowpolicyupdate>
  <dataplacementpolicy>
    <indexpartitioncriteria>
      <size>1048576</size>
      <name>*.txt</name>
      <name>*.bin</name>
    </indexpartitioncriteria>
  </dataplacementpolicy>
  <directory>
    ...
  </directory>
</ltfsindex>
```

The Data Placement Policy for an LTFS Volume shall be defined in a **dataplacementpolicy** element in an Index. An Index may contain zero or one **dataplacementpolicy** elements.

Every **dataplacementpolicy** element shall contain exactly one **indexpartitioncriteria** element. This means that the **dataplacementpolicy** constructs **<dataplacementpolicy/>** and **<dataplacementpolicy></dataplacementpolicy>** are explicitly disallowed.

Every **indexpartitioncriteria** element shall contain exactly one **size** element. The **size** element shall define the maximum file size for the Data Placement Policy.

Every **indexpartitioncriteria** element may contain zero or more **name** elements. The value of each **name** element shall define a Filename Pattern for the Data Placement Policy. The Filename Pattern value shall conform to the format defined in Section 6.5 Name pattern format.

8.2.12 Data Placement Policy Alteration

An LTFS Volume shall have an associated Allow Policy Update value. The current Allow Policy Update value for an LTFS Volume shall be defined in the current Index as described in Section 8.2.11 Data Placement Policy.

This section describes the conditions under which the Data Placement Policy and Allow Policy Update values may be altered.

8.2.13 Allow Policy Update is set

If the current Allow Policy Update value is set, as defined in Section 8.2.11 Data Placement Policy, a writer may record an Index that indicates the Allow Policy Update value is set or unset.

If the current Allow Policy Update value is set, as defined in Section 8.2.11 Data Placement Policy, a writer may record an Index with the same **dataplacementpolicy** values recorded in the previous generation of the Index.

If the current Allow Policy Update value is set, as defined in Section 8.2.11 Data Placement Policy, a writer may record an Index with **dataplacementpolicy** values that differ from the **dataplacementpolicy** values recorded in the previous generation of the Index.

If the current Allow Policy Update value is set, as defined in Section 8.2.11 Data Placement Policy, a writer may record an Index without any **dataplacementpolicy** element.

8.2.14 Allow Policy Update is unset

If the current Allow Policy Update value is unset, as defined in Section 8.2.11 Data Placement Policy, a writer shall only record an Index that indicates the Allow Policy Update is unset.

If the current Allow Policy Update value is unset, as defined in Section 8.2.11 Data Placement Policy, a writer shall only record an Index without a **dataplacementpolicy** element when the previous generation of the Index does not contain a **dataplacementpolicy** element.

If the current Allow Policy Update value is unset, as defined in Section 8.2.11 Data Placement Policy, a writer shall only record an Index with **dataplacementpolicy** values when those values exactly match the **dataplacementpolicy** values recorded in the previous generation of the Index.

8.2.15 Data Placement Policy Application

An LTFS Volume may have an associated Data Placement Policy. The current Data Placement Policy for an LTFS Volume shall be defined in the current Index as described in Section 8.2.11 Data Placement Policy. This section describes how the current Data Placement Policy and current Allow Policy Update value shall affect the valid placement options for Data Extents when adding files to an LTFS Volume.

The Data Placement Policy defines criteria controlling the conditions under which Data Extents may be recorded to the Index Partition. The current Data Placement Policy only affects the placement of Data Extents for new files written to the LTFS Volume. The Data Placement Policy has no impact on Data Extents already written to the LTFS Volume. Similarly, the Data Placement Policy does not imply any constraint on Data Extents previously written to the LTFS Volume.

The Data Placement Policy in use for an LTFS Volume does not require that Data Extents conforming to the policy be written to the Index Partition. A Data Placement Policy only defines the conditions under which it is valid to write Data Extents to the Index Partition. When the Data Placement Policy in use does not allow a Data Extent to be written to the Index Partition the Data Extent shall be written to the Data Partition. Any Data Extent may be written to the Data Partition regardless of the Data Placement Policy in use.

Any LTFS Volume without a defined Data Placement Policy, as described in Section 8.2.11 Data Placement Policy, shall have a NULL Data Placement Policy.

A NULL Data Placement Policy shall mean that no criteria exist to control the conditions under which Data Extents may be recorded to the Index Partition. When a NULL Data Placement Policy is in effect, any Data Extent may be written to the Index Partition. In general, it is recommended that implementations should avoid use of NULL Data Placement Policies.

A Data Placement Policy other than the NULL policy shall define the criteria under which the Data Extents for a new file may be written to the Index Partition.

A non-NULL Data Placement Policy shall define a maximum file size for the policy. The maximum file size may be "0" or any positive integer.

A non-NULL Data Placement Policy may define zero or more Filename Pattern values for the policy. The Filename Pattern values shall be defined and interpreted as file name patterns conforming to the format defined in Section 6.5 Name pattern format.

A non-NULL Data Placement Policy shall “match” the Data Extents being recorded to an LTFS Volume if and only if all of the following conditions are met:

- the size of the file being recorded is smaller than the maximum file size for the Data Placement Policy in effect, and
- the file name of the file being recorded matches any of the file name patterns defined in the Data Placement Policy. The rules for matching file name patterns to file names are provided in Section 6.5 [Name pattern format](#).

NOTE: Files with a size of 0 bytes have no Data Extents recorded anywhere in the volume. Therefore, a Data Placement Policy with size value of “0” indicates that no file shall have Data Extents stored on the Index Partition.

As described in Section 8.2 [Index](#), every Index shall contain a boolean **allowpolicyupdate** element corresponding to the Allow Policy Update value for the Index. When Allow Policy Update is unset, a writer shall not modify an LTFS Volume unless the modification conforms with the Data Placement Policy defined for the Index. Any writer unable to comply with the current Data Placement Policy shall leave the LTFS Volume unchanged.

Writers are encouraged to comply with the current Data Placement Policy at all times. However, when Allow Policy Update is set, a writer is permitted to violate the Data Placement Policy. Violating the policy in this case is equivalent to changing the Policy, modifying the Volume, then changing the Policy back to the original Policy.

NOTE: It is always valid to write a non-empty Data Extent to the Data Partition. This results from the Data Placement Policy and Allow Policy Update values defining when it is permitted to write Data Extents to the Index Partition rather than these values defining when it is required that Data Extents be written to the Index Partition.

9 Medium Auxiliary Memory

An LTFS Volume may use standard Medium Auxiliary Memory (MAM) to store auxiliary information with the volume to improve the efficiency of LTFS Index retrieval and to aid the identification and management of an LTFS Volume. Values stored in the MAM are stored on the volume in non-volatile storage as MAM attributes. Use of these attributes can enhance performance of an implementation but are not required for compliance to the LTFS Format Specification. That is, an LTFS Volume may still be correctly read and written if the MAM attributes become inaccessible or are not updated.

For each partition, LTFS stores a standardized Volume Coherency Information (VCI) value in a MAM attribute. This attribute contains a standardized value known as the Volume Change Reference (VCR), together with the Index generation number for the current Index and the on-media location of the current Index. These values can be used to determine whether a partition is complete and to verify volume consistency without requiring that the Index be read from both partitions. This allows an implementation to avoid the cost of seeking to the end of both partitions when verifying the consistency of an LTFS Volume.

For performance reasons, it is strongly recommended that LTFS implementers use the MAM attributes as described in Section 9.3 [Use of Volume Coherency Information for LTFS](#) if such usage is supported by the underlying storage technology.

Standard MAM attributes can be used to identify the volume as containing LTFS format, and it is strongly recommended that LTFS implementers populate the attributes described in Section 9.4 [Use of Host-type Attributes for LTFS](#). Note that some of the attributes are mandatory for implementations which claim compliance to revision 2.2.0 or later of the LTFS format specification and where MAM attributes are supported by the underlying storage technology.

NOTE: For consistency with the referenced specifications, throughout Section 9 Medium Auxiliary Memory, the word *Volume* is used to refer to a data storage medium (e.g., a tape cartridge). The words *LTFS Volume* is used when referencing an 'LTFS Volume' as defined in Section 3.1.18

LTFS Volume and throughout this document.

9.1 Volume Change Reference

Volume Change Reference (VCR) is a non-repeating, unique value associated with a volume coherency point. This section contains a partial description of the VCR (for informational purposes). See the T10/SSC4 Standard for a complete description of the VCR.

The VCR attribute indicates changes in the state of the medium related to logical objects or format specific symbols of the currently mounted volume. There is one value for the volume change reference. The VCR attribute for each partition shall use the same single VCR value. The VCR attribute value shall:

- be written to non-volatile medium auxiliary memory before the change on medium is valid for reading, and
- change in a non-repeating fashion (i.e., never repeat for the life of the volume).

The VCR attribute value shall change when:

- the first logical object for each mount is written on the medium in any partition;
- the first logical object is written after GOOD status has been returned for a READ ATTRIBUTE command with the SERVICE ACTION field set to ATTRIBUTE VALUES (i.e., 0x00) and the FIRST ATTRIBUTE IDENTIFIER field set to VOLUME CHANGE REFERENCE (i.e., 0x0009);
- any logical object on the medium (i.e., in any partition) is overwritten; or
- the medium is formatted.

The VCR attribute may change at other times when the contents on the medium change. The VCR attribute should not change if the logical objects on the medium do not change.

A binary value of all zeros (e.g., 0x0000) in the VCR attribute indicates that the medium has not had any logical objects written to it (i.e., the volume is blank and has never been written to) or the value is unknown. A binary value of all ones (e.g., 0xFFFF) in the VCR attribute indicates that the VCR attribute has overflowed and is therefore unreliable. In this situation, the VCR value shall not be used.

9.2 Volume Coherency Information

The Volume Coherency Information (VCI) attribute contains information used to maintain coherency of information for a volume. The VCI has six fields as listed in Table 16. There shall be one VCI attribute for each LTFS Partition that is part of an LTFS Volume. The correspondence between LTFS nomenclature and T10/SSC-4 nomenclature is shown in Table 16.

Table 16 shows a partial listing of the Volume Coherency Information attribute (for informational purposes). See the T10/SSC-4 Standard for a complete description of the Volume Coherency Information attribute.

Table 16 — Volume Coherency Information

LTFS Name	T10 SSC-4 Name
VCR Length	VOLUME CHANGE REFERENCE VALUE LENGTH
VCR	VOLUME CHANGE REFERENCE VALUE
generation number	VOLUME COHERENCY COUNT
block number	VOLUME COHERENCY SET IDENTIFIER
Application Client Specific Information Length	APPLICATION CLIENT SPECIFIC INFORMATION LENGTH
Application Client Specific Information	APPLICATION CLIENT SPECIFIC INFORMATION

Notes for Table 16:

1. VCR Length: this field contains the length of the VCR field. The VCR Length field is a one-byte field.
2. VCR: this field contains the value returned in the VCR attribute after all information for which coherency is desired was written to the volume. The length of this field is specified by the value of the VCR Length field.
3. generation number: this field contains the generation number of the LTFS Index that is pointed to by the block number field. The generation number field is an 8-byte field. The value stored in this field shall be a big-endian binary integer value.
4. block number: this field contains the logical block number of the LTFS Index on this partition for which coherency is desired. Typically coherency is desired for the most recently written LTFS Index. This field and the partition ID of this partition comprise the position of the LTFS Index on the media. A value of zero is invalid. The block number field is an 8-byte field.
5. Application Client Specific Information Length: this field contains the length of the Application Client Specific Information field. The Application Client Specific Information Length field is a two-byte field.
6. Application Client Specific Information: this field contains information the application client associates with this coherency set. The length of this field is specified by the value of the Application Client Specific Information Length field.

9.3 Use of Volume Coherency Information for LTFS

Use of the Volume Coherency Information (VCI) attribute with the LTFS format is optional, but it is recommended to improve performance. If the VCI attribute is stored for an LTFS Partition, it shall be used as described in this section.

The VCI attribute for each volume partition contains the Application Client Specific Information (ACSI) for the LTFS Partition stored on the volume partition. The ACSI for LTFS shall be formatted as shown in Table 17. All offsets and lengths are measured in bytes.

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Table 17 — ACSI format for LTFS

Offset	Length	Value	Notes
0	4	'LTFS'	
4	1	0x00	string terminator (binary)
5	36	<volume UUID>	as defined in Section 6.8 UUID format
41	1	0x00	string terminator (binary)
42	1	0x01	version number (binary)

NOTE: Single quotation marks in the 'Value' column shall not be recorded in the Application Client Specific Information.

The first 43 bytes of the Application Client Specific Information will retain their current meaning in all future versions of the LTFS Format. A future version of the LTFS Format may define additional content to be appended to the Application Client Specific Information, in which case the version number field will be incremented.

NOTE: The version number stored at offset 42 has been incremented from **0x0** in IBM LTFS Format Specification version 1.0 to **0x1** for LTFS Format Specification version 2.0.0. This increment allows identification of LTFS Volumes created with incorrect MAM values by an implementation of the IBM LTFS Format Specification version 1.0.

An application may write the VCI attribute for an LTFS Partition at any time when the partition is complete. The attribute shall contain the VCR of the cartridge and the generation number of the last LTFS Index on the partition, with both values determined at the time the attribute is written. When writing the VCI attribute for any LTFS Partition, an application should write the VCI attribute for all complete partitions. Implementations of the LTFS Format Specification should update the VCI attribute for all complete partitions immediately after fully writing an Index Construct to any partition. The recommended order of operations is:

1. Write an Index Construct to a partition.
2. Ensure that all pending write requests are flushed to the medium. The procedure for doing this may depend on the underlying storage technology.
3. Read the VCR attribute immediately (before issuing any additional write requests to the medium).
4. If the VCR attribute value is valid (i.e., does not contain a binary value of all ones or all zeros), compute and write the VCI attributes containing the read VCR value for all complete partitions.

A VCR instance in a VCI attribute is up-to-date if it equals the VCR value of the cartridge. Any LTFS Partition with a corresponding VCI attribute that contains an up-to-date VCR instance is complete. If all partitions in an LTFS Volume have VCI attributes containing up-to-date VCR instances, the attribute with the highest generation number determines the block position of the current Index for the LTFS Volume. This allows an implementation to determine the state of an LTFS Volume quickly by reading that single LTFS Index.

If any partition in an LTFS Volume has a VCI attribute containing a VCR instance which is not up-to-date, that partition is not guaranteed to be complete. In this case, the consistency of the LTFS Volume cannot be determined from the values in the VCI attributes for each partition. For example, the following sequence of operations results in exactly one partition having a VCI attribute containing an up-to-date VCR instance but the LTFS Volume is not consistent:

1. An implementation writes an Index Construct to partition 'a', then writes the VCI attribute for partition 'a'.
2. The implementation appends a Data Extent to partition 'a'. The VCI attribute for partition 'a' now contains an out-of-date VCR instance.
3. The implementation Writes an Index Construct to partition 'b', then writes the VCI attribute for partition 'b'.

In this case, the current Index for the LTFS Volume cannot be identified without reading Indexes from both partitions and comparing their generation numbers.

9.4 Use of Host-type Attributes for LTFS

The T10 technical committee of INCITS owns the specification for MAM attributes (published in the SCSI Primary Commands standard SPC-4), and these attributes include a category known as Host-type Attributes intended to provide host-settable information describing the volume. For full details of these attributes refer to the T10/SPC-4 Standard.

The relevant attributes are shown in Table 18. The “Support” column indicates whether implementations which claim compliance to revision 2.2.0 or later of the LTFS format specification should support (O – optional) or shall support (M- mandatory) the corresponding attribute.

Table 18 — Relevant Host-type Attributes for LTFS

Attribute Name	Identifier	Size	Format	Support
APPLICATION VENDOR	0800h	8 bytes	ASCII	M
APPLICATION NAME	0801h	32 bytes	ASCII	M
APPLICATION VERSION	0802h	8 bytes	ASCII	M
USER MEDIUM TEXT LABEL	0803h	160 bytes	TEXT	O
TEXT LOCALIZATION IDENTIFIER	0805h	1 byte	BINARY	O
BARCODE	0806h	32 bytes	ASCII	O
APPLICATION FORMAT VERSION	080Bh	16 bytes	ASCII	M

When accessing these attributes, the PARTITION NUMBER field in the READ ATTRIBUTE and WRITE ATTRIBUTE SCSI commands shall be set to 0.

IMPORTANT NOTE: The Mandatory attributes are required to be set by the application which formats the volume. Some storage technology may have insufficient available capacity to store all the attributes in MAM, in which case writing the Mandatory attributes should take precedence over the Optional attributes. However an implementation which attempts to mount the volume should not fail just because these attributes are not set or are unreadable.

9.4.1 Application Vendor

This attribute shall be set to indicate the manufacturer of the LTFS software which formatted the volume. It shall be consistent with the Company name (if any) used in the Creator format in LTFS label and index constructs (see Section 6.2 Creator format). The attribute shall be left-aligned, and shall be padded with ASCII space (20h) characters if the company name is less than 8 characters in length. If the company name exceeds 8 ASCII characters then the 8 left-most characters of the name shall be used.

9.4.2 Application Name

This attribute shall be set to the ASCII string “LTFS”, left-aligned and followed by at least one ASCII space (20h) character. This may be followed by a vendor-specific ASCII string further identifying the application, also left-aligned and padded with ASCII space characters. If no further identification is desired then ASCII space characters shall be added to pad to the width of the field. Both of the following are valid uses of this attribute:

“LTFS ”
 “LTFS Standalone XYZ ”

9.4.3 Application Version

This attribute shall be set to indicate the application version used to format the volume and shall be consistent with the Version identifier (if any) used in the Creator format in LTFS label and index constructs (see Section 6.2 Creator format). The attribute shall be left-aligned and padded with ASCII

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space (20h) characters. The LTFS format specification does not define any particular style or content for the value of this attribute.

9.4.4 Text Localization Identifier

This defines the character set used for the User Medium Text Label attribute (see Section 9.4.5 User Medium Text Label), in accordance with the table in the T10/SPC-4 draft standard (SPC-4 r36e Table 448). If this attribute is not set then the default assumed value shall be ASCII (value 00h).

NOTE: It is strongly recommended that the attribute should be set to indicate UTF-8 encoding (value 81h) for compatibility with the encoding used in the rest of the LTFS format.

9.4.5 User Medium Text Label

This attribute may be used to record the volume name. If set, it shall be left-aligned and null-terminated, and its value should be consistent with the value of the **name** element for the root directory element in an index construct (see Section 8.2 Index). If the number of bytes required to store the root directory name exceeds the available attribute storage size of 160 bytes, then the name stored in the attribute shall be truncated at the most appropriate character boundary. If this attribute is set, and the **name** is updated by writing to the VEA `ltfs.volumeName`, then this attribute shall be updated to maintain consistency.

9.4.6 Barcode

It is recommended that this attribute should be set to match the physical cartridge label (if any). If set, it shall be left-aligned and padded with ASCII space (20h) characters.

NOTE: This attribute is related to the volume identifier in the VOL1 label (see Section 7.1.1) but without the restriction of six characters; the attribute can hold up to 32 characters.

9.4.7 Application Format Version

This attribute shall be set to indicate the version of the LTFS format specification with which this volume was formatted. It shall be consistent with the version attribute of the **ltfslabel** element as found in the LTFS label construct (see Section 7.1.2 LTFS Label). It shall be left-aligned and padded with ASCII space (20h) characters.

NOTE: In the special case where a volume is migrated to a newer version of the format, this attribute should be updated to continue to provide an accurate view of the volume. In this case, the attribute may no longer be consistent with the version attribute of the **ltfslabel** element.

9.4.8 Example attributes

An implementation that populates all of the attributes described in Section 9.4 Use of Host-type Attributes for LTFS would follow the pattern shown in Table 19:

Table 19 — Example of Host-type Attributes

Name	1	2	3	4	5	6	7	8	...	...
Application Vendor	"H"	"P"	20h	20h	20h	20h	20h	20h		
Application Name	"L"	"T"	"F"	"S"	20h	20h	20h	20h	...	20h
Application Version	"1"	"."	"2"	"."	"3"	20h	20h	20h		
User Medium Text Label	"M"	"y"	"T"	"a"	"p"	"e"	"V"	"o"	"I"	00h
Text Localization Identifier	81h									
Barcode	"A"	"B"	"1"	"2"	"3"	"4"	"L"	"5"	...	20h
Application Format Version	"2"	"."	"2"	"."	"0"	20h	20h	20h	...	20h

Annex A (normative) LTFS Label XML Schema

This annex shows the LTFS Label XML Schema.

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
  <xs:element name="ltfslabel">
    <xs:complexType>
      <xs:all>
        <xs:element name="creator" type="xs:string"/>
        <xs:element name="formattime" type="datetime"/>
        <xs:element name="volumeuuid" type="uuid"/>
        <xs:element name="location">
          <xs:complexType>
            <xs:sequence>
              <xs:element name="partition" type="partitionid"/>
            </xs:sequence>
          </xs:complexType>
        </xs:element>
        <xs:element name="partitions">
          <xs:complexType>
            <xs:all>
              <xs:element name="index" type="partitionid"/>
              <xs:element name="data" type="partitionid"/>
            </xs:all>
          </xs:complexType>
        </xs:element>
        <xs:element name="blocksize" type="blocksize"/>
        <xs:element name="compression" type="xs:boolean"/>
      </xs:all>
      <xs:attribute name="version" use="required" type="version"/>
    </xs:complexType>
  </xs:element>

  <xs:simpleType name="blocksize">
    <xs:restriction base="xs:integer">
      <xs:minInclusive value="4096"/>
    </xs:restriction>
  </xs:simpleType>

  <xs:simpleType name="version">
    <xs:restriction base="xs:string">
      <xs:pattern value="[0-9]+\.[0-9]+\.[0-9]"/>
      <xs:enumeration value="2.2.0"/>
    </xs:restriction>
  </xs:simpleType>

  <xs:simpleType name="datetime">
    <xs:restriction base="xs:string">
      <xs:pattern value="[0-9]{4}-[0-9]{2}-[0-9]{2}T[0-9]{2}:[0-9]{2}:[0-9]{2}\.[0-9]{9}Z"/>
    </xs:restriction>
  </xs:simpleType>

  <xs:simpleType name="partitionid">
    <xs:restriction base="xs:string">
```

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```
<xs:pattern value="[a-z]"/>
</xs:restriction>
</xs:simpleType>

<xs:simpleType name="uuid">
  <xs:restriction base="xs:string">
    <xs:pattern
      value="[a-fA-F0-9]{8}-[a-fA-F0-9]{4}-[a-fA-F0-9]{4}-[a-fA-F0-9]{4}-[a-fA-
F0-9]{12}"/>
    </xs:restriction>
  </xs:simpleType>
</xs:schema>
```

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Annex B (normative) LTFS Index XML Schema

This annex shows the LTFS Index XML schema.

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
  <xs:element name="ltfsindex">
    <xs:complexType>
      <xs:all>
        <xs:element name="creator" type="xs:string"/>
        <xs:element name="comment" type="xs:string" minOccurs="0"/>
        <xs:element name="volumeuuid" type="uuid"/>
        <xs:element name="generationnumber" type="xs:nonNegativeInteger"/>
        <xs:element name="updatetime" type="datetime"/>
        <xs:element name="location" type="tapeposition"/>
        <xs:element name="previousgenerationlocation" type="tapeposition"
minOccurs="0"/>
        <xs:element name="allowpolicyupdate" type="xs:boolean"/>
        <xs:element name="dataplacementpolicy" type="policy" minOccurs="0"/>
        <xs:element name="highestfileuid" type="xs:nonNegativeInteger"/>
        <xs:element ref="directory"/>
      </xs:all>
      <xs:attribute name="version" use="required" type="version"/>
    </xs:complexType>
  </xs:element>

  <xs:element name="directory">
    <xs:complexType>
      <xs:all>
        <xs:element name="fileuid" type="xs:nonNegativeInteger"/>
        <xs:element name="name" type="xs:string"/>
        <xs:element name="creationtime" type="datetime"/>
        <xs:element name="changetime" type="datetime"/>
        <xs:element name="modifytime" type="datetime"/>
        <xs:element name="accesstime" type="datetime"/>
        <xs:element name="backuptime" type="datetime"/>
        <xs:element name="readonly" type="xs:boolean"/>
        <xs:element ref="extendedattributes" minOccurs="0"/>
        <xs:element name="contents">
          <xs:complexType>
            <xs:choice minOccurs="0" maxOccurs="unbounded">
              <xs:element ref="directory"/>
              <xs:element ref="file"/>
            </xs:choice>
          </xs:complexType>
        </xs:element>
      </xs:all>
    </xs:complexType>
  </xs:element>

  <xs:element name="file">
    <xs:complexType>
      <xs:all>
        <xs:element name="fileuid" type="xs:nonNegativeInteger"/>
        <xs:element name="name" type="xs:string"/>
        <xs:element name="length" type="xs:nonNegativeInteger"/>
      </xs:all>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

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```

<xs:element name="creationtime" type="datetime"/>
<xs:element name="changetime" type="datetime"/>
<xs:element name="modifytime" type="datetime"/>
<xs:element name="accesstime" type="datetime"/>
<xs:element name="backuptime" type="datetime"/>
<xs:element name="readonly" type="xs:boolean"/>
<xs:element ref="extendedattributes" minOccurs="0"/>
<xs:element name="extentinfo" minOccurs="0">
  <xs:complexType>
    <xs:sequence minOccurs="0" maxOccurs="unbounded">
      <xs:element name="extent">
        <xs:complexType>
          <xs:all>
            <xs:element name="partition" type="partitionid"/>
            <xs:element name="startblock" type="xs:nonNegativeInteger"/>
            <xs:element name="byteoffset" type="xs:nonNegativeInteger"/>
            <xs:element name="bytecount" type="xs:positiveInteger"/>
            <xs:element name="fileoffset" type="xs:nonNegativeInteger"/>
          </xs:all>
        </xs:complexType>
      </xs:element>
    </xs:sequence>
  </xs:complexType>
</xs:element>
<xs:element name="symlink" type="xs:string" minOccurs="0"/>
</xs:all>
</xs:complexType>
</xs:element>

<xs:element name="extendedattributes">
  <xs:complexType>
    <xs:sequence minOccurs="0" maxOccurs="unbounded">
      <xs:element name="xattr">
        <xs:complexType>
          <xs:all>
            <xs:element name="key" type="xs:string"/>
            <xs:element name="value">
              <xs:complexType mixed="true">
                <xs:attribute name="type">
                  <xs:simpleType>
                    <xs:restriction base="xs:token">
                      <xs:enumeration value="base64"/>
                      <xs:enumeration value="text"/>
                    </xs:restriction>
                  </xs:simpleType>
                </xs:attribute>
              </xs:complexType>
            </xs:element>
          </xs:all>
        </xs:complexType>
      </xs:element>
    </xs:sequence>
  </xs:complexType>
</xs:element>

<xs:complexType name="policy">

```

```

<xs:sequence>
  <xs:element name="indexpartitioncriteria">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="name" type="xs:string" minOccurs="0"
maxOccurs="unbounded"/>
        <xs:element name="size" type="xs:nonNegativeInteger"/>
        <xs:element name="name" type="xs:string" minOccurs="0"
maxOccurs="unbounded"/>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
</xs:sequence>
</xs:complexType>

<xs:complexType name="tapeposition">
  <xs:all>
    <xs:element name="partition" type="partitionid"/>
    <xs:element name="startblock" type="xs:nonNegativeInteger"/>
  </xs:all>
</xs:complexType>

<xs:simpleType name="version">
  <xs:restriction base="xs:string">
    <xs:pattern value="[0-9]+\.[0-9]+\.[0-9]"/>
    <xs:enumeration value="2.2.0"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="datetime">
  <xs:restriction base="xs:string">
    <xs:pattern
value="[0-9]{4}-[0-9]{2}-[0-9]{2}T[0-9]{2}:[0-9]{2}:[0-9]{2}\.[0-9]{9}Z"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="partitionid">
  <xs:restriction base="xs:string">
    <xs:pattern value="[a-z]"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="uuid">
  <xs:restriction base="xs:string">
    <xs:pattern
value="[a-fA-F0-9]{8}-[a-fA-F0-9]{4}-[a-fA-F0-9]{4}-[a-fA-F0-9]{4}-[a-fA-
F0-9]{12}"/>
  </xs:restriction>
</xs:simpleType>
</xs:schema>

```

Annex C (normative) Reserved Extended Attribute definitions

In an LTFS Index, all extended attribute names that start with the prefix “ltfs” with any capitalization are reserved for use by the LTFS Format; i.e., any names starting with a case-insensitive match for the letters “ltfs” are reserved.

Any writer of an LTFS Volume shall only use reserved extended attribute names to store extended attribute values in conformance with the lists in Table C. 1 through Table C. 5. However, two extended attribute namespaces are reserved for implementation-specific information.

The extended attribute namespace “ltfs.permissions.<type>” shall be used only for storing permissions as described in [F.2 File Permissions in LTFS](#).

The extended attribute namespace “ltfs.vendor.X.Y” shall be used for implementation-specific attributes, where X identifies a company, organization or technology standard and Y is an attribute name.

NOTE: The Storage Networking Industry Association (SNIA) maintains a list of registered vendor names at <http://www.snia.org/ltfs>.

This section describes the meaning of defined, reserved extended attributes.

Support for each of these defined, reserved extended attributes is optional for implementations in compliance with this specification.

C.1 Software Metadata

Table C. 1 describes the extended attribute values for software metadata.

Table C. 1 — Reserved extended attribute definitions: Software metadata

Extended Attribute	Value description
ltfs.softwareProduct	Product name of this software
ltfs.softwareVendor	Software vendor of this software
ltfs.softwareVersion	LTFS version number
ltfs.softwareFormatSpec	LTFS Format spec version supported by this software

C.2 Drive Metadata

Table C. 2 describes the extended attribute values for drive metadata.

Table C. 2 — Reserved extended attribute definitions: Drive metadata

Extended Attribute	Value description
ltfs.driveEncryptionState	Current encryption status of the drive ("true", "false", or "unknown").
ltfs.driveEncryptionMethod	Current encryption method of the drive.
ltfs.driveCaptureDump	Writing any value to this extended attribute shall trigger a drive dump on any implementation that supports this extended attribute.

C.3 Object Metadata

Table C. 3 describes the extended attribute values for object metadata.

Table C. 3 — Reserved extended attribute definitions: Object metadata

Extended Attribute	Value description
ltfs.accessTime	Date and time of last access to object.
ltfs.backupTime	Date and time of last archive or backup of object.
ltfs.changeTime	Date and time of last status change to object.
ltfs.createTime	Date and time of object creation.
ltfs.fileUID	Integer identifier for objects in the filesystem. Guaranteed to be unique within the LTFS Volume.
ltfs.modifyTime	Date and time of last object modification.
ltfs.partition	Partition on which the first extent of the file is stored.
ltfs.startblock	Block address where the first extent of the file is stored.
ltfs.spannedFileOffset	The logical file offset of the first byte of the segment relative to the full file. See Annex F.1 for full description.

C.4 Volume Metadata

Table C. 4 describes the extended attribute values for volume metadata.

Table C. 4 — Reserved extended attribute definitions: Volume metadata

Extended Attribute	Value description
ltfs.commitMessage	Commit message for the last Index on the LTFS Volume.
ltfs.indexVersion	LTFS format version string for the Index. This string provides a human-readable identifier for the LTFS format version that generated the Index.
ltfs.indexCreator	Creator string for the Index. This string provides a human-readable identifier for the product that generated the Index. As defined in Section 6.2 Creator format .
ltfs.indexGeneration	Last LTFS Index generation number written to media.
ltfs.indexLocation	Location of the last Index on the media in the form 'p:l', where p is an alphabetic character value indicating the internal LTFS partition identifier, and l is the logical block number within the partition. For example, the value 'a:1000' indicates that the last Index starts at logical block 1000 on partition a.
ltfs.indexPrevious	Location of the previous Index on the media in the form 'p:l', where p is an alphabetic character value indicating the internal LTFS partition identifier, and l is the logical block number within the partition. For example, the value 'b:55' indicates that the previous Index starts at logical block 55 on partition b.
ltfs.indexTime	Date and time of when last LTFS Index was written to media.
ltfs.labelVersion	LTFS format version string for the LTFS label. This string provides a human-readable identifier for the LTFS format version that generated the LTFS label.
ltfs.labelCreator	Creator string for the LTFS Label. This string provides a human-readable identifier for the product that generated the LTFS Label. As defined in Section 6.2 Creator format .
ltfs.partitionMap	The on media partition layout for the LTFS Volume. Value is of the form "W:x,Y:z" where W and Y have the value 'I' indicating an index partition, or 'D' indicating a data partition. x and y are an alphabetic character value indicating the internal LTFS partition identifier. For example, the value "I:a,D:b" indicates that LTFS Partition 'a' is used as the index partition, and LTFS Partition 'b' is

LTFS Format Specification

Extended Attribute	Value description
	used as the data partition.
ltfs.policyAllowUpdate	Indicates whether the data placement policy for the volume may be updated.
ltfs.policyExists	Indicates whether a data placement policy has been set for the volume.
ltfs.policyMaxFileSize	Maximum file size for files that match the data placement policy for the volume.
ltfs.sync	Writing any value to this extended attribute shall trigger a filesystem sync on any implementation that supports this extended attribute. A filesystem sync is an operation that causes all in-memory filesystem changes to be flushed to the storage medium. The sync operation is not required to produce a consistent LTFS Volume. The sync operation shall ensure that sufficient data is written to the medium so as to allow the LTFS Volume to be recovered to a consistent state without loss of data.
ltfs.volumeBlocksize	Blocksize for the LTFS Volume specified at format time.
ltfs.volumeCompression	Compression setting for the LTFS Volume.
ltfs.volumeFormatTime	Date and time when the LTFS Volume was formatted.
ltfs.volumeName	Name of the LTFS Volume.
ltfs.volumeSerial	Serial number for the LTFS Volume specified at format time.
ltfs.volumeUUID	UUID for the LTFS Volume.
ltfs.mamBarcode	The MAM attribute value stored as BARCODE
ltfs.mamApplicationVendor	The MAM attribute value stored as APPLICATION VENDOR
ltfs.mamApplicationVersion	The MAM attribute value stored as APPLICATION VERSION
ltfs.mamApplicationFormatVersion	The MAM attribute value stored as APPLICATION FORMAT VERSION

NOTE 1: The USER MEDIUM TEXT LABEL MAM attribute is available as ltfs.volumeName.

NOTE 2: The VEAs ltfs.softwareVendor, ltfs.softwareProduct, ltfs.softwareVersion, and ltfs.softwareFormatSpec refer to the currently executing software, whereas the above names ltfs.mamApplicationVendor etc refers to the values stored in the MAM at format time.

NOTE 3: Setting or updating the VEA ltfs.mamBarcode after the volume has been formatted should update the MAM attribute but shall not modify the VOL1 label nor the value reported for the VEA ltfs.volumeSerial.

C.5 Media Metadata

Table C. 5 describes the extended attribute values for media metadata.

Table C. 5 — Reserved extended attribute definitions: Media metadata

Extended Attribute	Value description
ltfs.mediaBeginningMediumPasses	Total number of times the beginning of medium position has been passed. If the storage hardware cannot report this data the value will be -1.
ltfs.mediaDataPartitionAvailableSpace	Total available space in the Data Partition on the medium. Value is an integer count measured in units of 1048576 bytes.
ltfs.mediaDataPartitionTotalCapacity	Total capacity of the Data Partition on the medium. Value is an integer count measured in units of 1048576 bytes.
ltfs.mediaDatasetsRead	Total number of datasets read from the medium over the lifetime of the media. If the storage hardware cannot report this data the value will be -1.