# Linear Tape File System (LTFS) Format Specification

April 12, 2010

**LTFS Format Version** 1.0

This document presents the requirements for an interchanged tape conforming to a self describing format. This format is used by the Linear Tape File System (LTFS). This document does not describe implementation of LTFS itself.

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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 meta data 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.

## 1.1 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.***

## 1.2 Conformance

Recorded media claiming conformance to this format shall be in a consistent state when interchanged or stored. See 2.1.4 **Consistent State**.

# 2 Definitions and Acronyms

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

## 2.1 Definitions

### 2.1.1 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.

### 2.1.2 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.

### 2.1.3 Content Area

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

### 2.1.4 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.

### 2.1.5 Data Extent

A contiguous sequence of recorded blocks.

### 2.1.6 Data Partition

An LTFS partition primarily used for data files.

### 2.1.7 File

A group of logically related extents together with associated file meta-data.

### 2.1.8 generation number

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

### 2.1.9 Index

A data structure that that describes all valid data files in an LTFS volume. The Index is an XML document conforming to the XML schema shown in B **LTFS Index XML Schema**.

### 2.1.10 Index Construct

A data construct comprised of an Index and file marks.

### 2.1.11 Index Partition

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

### 2.1.12 Label Construct

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

### 2.1.13 Linear Tape File System (LTFS)

This document describes the Linear Tape File System Format.

### 2.1.14 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.

### 2.1.15 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 A LTFS Label XML Schema.

### 2.1.16 LTFS Partition

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

### 2.1.17 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 must have the same UUID. All LTFS partitions in an LTFS volume are *related partitions*.

### 2.1.18 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.

### 2.1.19 UUID

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

### 2.1.20 Volume Change Reference (VCR)

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

## 2.2 Acronyms

| | |
|---|---|
| **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 |
| **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 |

# 3 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 must contain exactly one Data Partition and exactly one Index Partition.

## 3.1 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 the figure below.


The Label Construct is described in 3.2 **LTFS Constructs** and in 6 **Label Format**. The Content Area contains some number of interleaved Index Constructs and Data Extents. These constructs are described in 3.2 **LTFS Constructs** and 7 **Index Format**. The precise layout of the partitions is defined in 3.3 **Partition Layout**.

## 3.2 LTFS Constructs

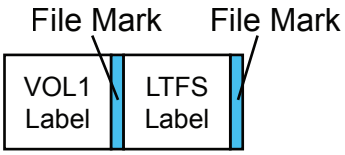
LTFS constructs are comprised of file marks and records. These are also known as 'logical objects' as found in T10 SSC specifications and are not described here. An LTFS volume contains three kinds of constructs.

- 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 meta-data 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.

### 3.2.1 Label Construct

Each partition in an LTFS volume shall contain a Label Construct with the following structure. As shown in the figure below, 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 must 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 6 **Label Format**.




### 3.2.2 Data Extent

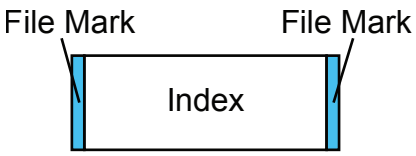
A Data Extent is a set of one or more sequential logical blocks used to store file data. The "blocksize" field of the LTFS Label defines the block size used in Data Extents. All records within a Data Extent must have this fixed block size except the last block, which may be smaller.

The use of Data Extents to store file data is specified in 4 **Data Extents**.

### 3.2.3 Index Construct

The figure below 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 must 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.



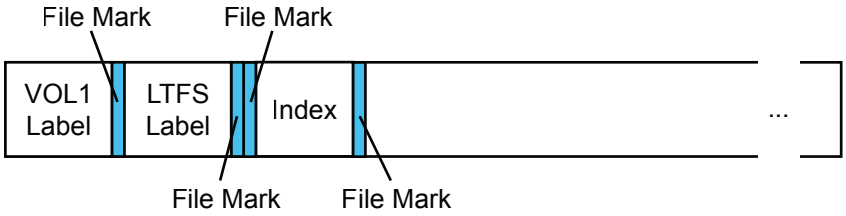

Indexes also include references to other Indexes in the volume. References to other Indexes are used to maintain consistency between partitions in a volume. These references (back pointers and self pointers) are described in 3.4 **Index Layout**.

The content of the Index is described in 7 **Index Format**.

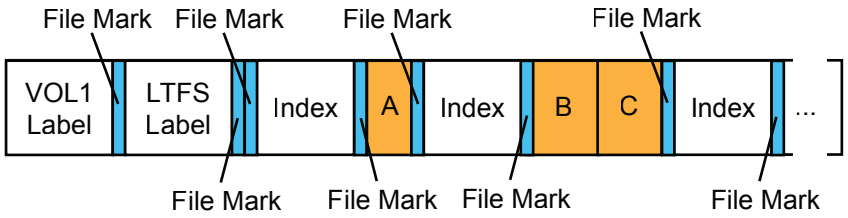
## 3.3 Partition Layout

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.

The figure below illustrates an empty complete partition. It contains a Label Construct followed by an Index Construct. This is the simplest possible complete partition.




The figure below illustrates a complete partition containing data. The Content Area on the illustrated partition contains two Data Extents (labeled 'A', 'B' and 'C') and three Index Constructs.




## 3.4 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.

### 3.4.1 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 the pointers described below).
- Generation number '0' should be avoided.

An implementation may find it convenient to assign generation number '1' to the first Index on an LTFS volume.

### 3.4.2 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 must 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 contenting Index-like data.

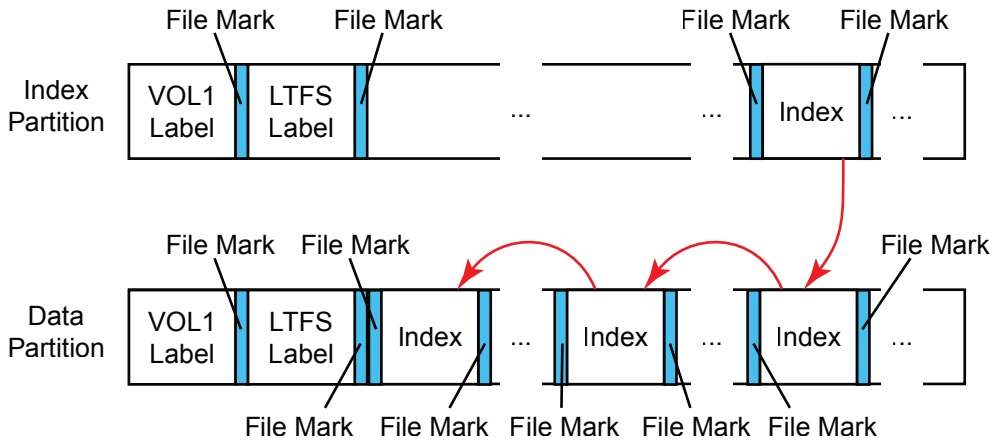
### 3.4.3 Back Pointer

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 7.2 **Index**.

- 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 must 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. The figure below illustrates this state.



# 4 Data Extents

A Data Extent is a set of one or more sequential records subject to the conditions listed in 3.2.2 **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.

## 4.1 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 must be strictly less than the size of the start block.
- **byte count** – number of bytes of file content in this Data Extent.

File offsets in the extent list are not stated explicitly; they 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 $N + K$.

***Note: these file extent rules necessarily imply that the order of extents recorded in the Index must be preserved during any subsequent update of the Index.***

An extent list entry shall be a byte range within a single Data Extent; that is, it must 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.

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

***Note: implied zeros may only appear at the end of a file; other types of sparse files are not supported. When modifying a file with implied trailing zeros, an implementation must write any zero bytes necessary to avoid leaving holes in the extent list for the file.***

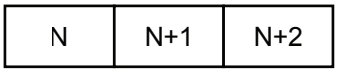
## 4.2 Extents Illustrated

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 is not shown explicitly in the extents lists illustrated below. Note that not all extents in an extent list must be on the same partition.

### 4.2.1 Starting and ending Data Extent with full block

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



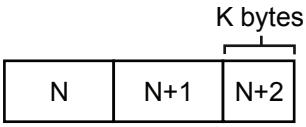

The extent list entry for this extent is:

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

***Note: Blk is the length of a full sized block.***

### 4.2.2 Starting Data Extent with full block and ending with fractional block

The following figure 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 $N + 2$.



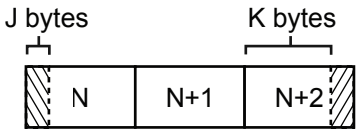

The extent list entry for this extent is:

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

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

### 4.2.3 Starting and ending Data Extent in mid-block

The following figure 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.




The extent list entry for this extent is:

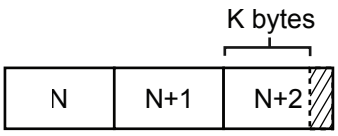
| Start Block | Byte Offset | Byte Count |
|---|---|---|
| $N$ | $J$ | $(Blk - J) + Blk + K$ |

## 4.3 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.

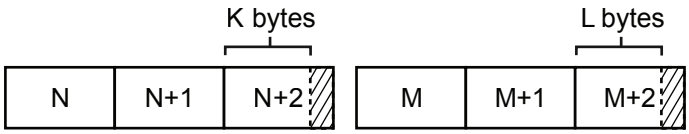
### 4.3.1 Simple Files

The following figure 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.




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

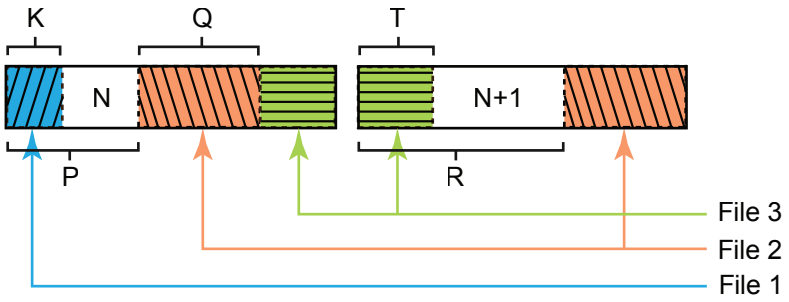
The following figure illustrates a file contained in two Data Extents of three blocks each. The data fills the first two blocks of extent $N$ and $K$ bytes of block $N + 2$, and the first two blocks of extent $M$ and $L$ bytes of block $M + 2$. The last block of each extent, block $N + 2$ and $M + 2$, may be fractional blocks.




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

### 4.3.2 Shared Blocks

The following figure 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 $N + 1$.




The extent lists for files 1, 2, and 3 are:

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

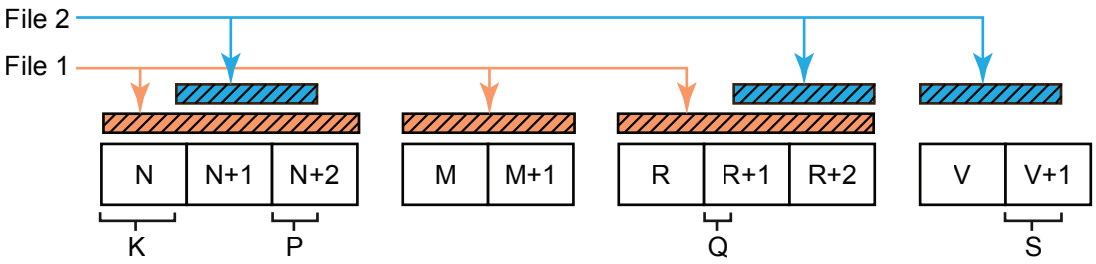
***Note: if $N$ were a fractional block, File 3 would map to two entries in the extent list. As illustrated, block $N$ is a full block, and File 3 may be mapped to the the single extent list entry shown above. Alternatively, because blocks may always be treated as independent Data Extents, File 3 could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

### 4.3.3 Shared Data

The following figure 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 the following figure, 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 below. The two files share some of the data in blocks $N$, $N+1$, $N+2$, $R+1$ and $R+2$.




The extent lists for files 1 and 2 are:

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

# 5 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.

## 5.1 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.

## 5.2 Creator format

LTFS creator values shall be recorded in conformance with the string format defined in 5.6 **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 the name of the executable that wrote the LTFS volume.

An example of the recommended content for creator values is shown below.

```
IBM LTFS 0.20 - Linux - mkltfs
```

The recommended format for a creator value is a sequence of values separated by hyphen characters. The recommended content for the creator value is *`Company Product Version - Platform - binary name`* where:

| Symbol | Description |
|---|---|
| *Company Product Version* | identifies the product that created the volume. |
| *Platform* | identifies the operating system platform for the product. |
| *binary name* | identifies the executable that created the volume. |

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

## 5.3 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 5.6 **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 must be ignored when decoding the string.

## 5.4 Name format

File and directory names, and extended attribute keys in an LTFS Volume must conform to the following naming rules.

Names must be valid Unicode and must be 255 code points or less after conversion to Normalization Form C (NFC). Names must 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 following.

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

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

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

## 5.5 Name pattern format

File name patterns in data placement policies may contain the characters allowed by 5.4 **Name format**. A file name pattern shall be compared to a file name using the following rules.

1. Comparison shall be performed using canonical caseless matching, as defined by Section 3.13 of the Unicode Standard version 5.2, 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.

## 5.6 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.

## 5.7 Time stamp format

Time stamps in LTFS data structures must be specified as a string conforming with the ISO 8601 date and time representation standard. The time stamp must be specified in UTC (Zulu) time as indicated by the 'Z' character in the example below. The time must be specified with a fractional second value that defines 9 decimal places after the period in the format.

```
2010-02-01T18:35:47.866846222Z
```

The general time format is *YYYY*`-`*MM*`-`*DD*`T`*hh*`:`*mm*`:`*ss*`.`*nnnnnnnnn*`Z` where:

| 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 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. |
| *nnnnnnnnn* | 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 must be padded to the full width of the symbol using `0` characters. For example, an integer month value of '`2`' must be recorded as '`02`' to fill the width of the *MM* symbol in the general time format.

## 5.8 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.

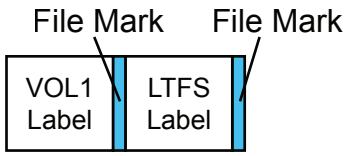
```
30a91a08-daae-48d1-ae75-69804e61d2ea
```

# 6 Label Format

This section describes the content of the Label Construct. The content of the Content Area is described in 3.2 **LTFS Constructs** and 7 **Index Format**.

## 6.1 Label Construct

Each partition in an LTFS Volume shall contain a Label Construct that conforms to the structure shown in the figure below. 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. Both Label constructs in an LTFS Volume must contain identical information with the exception of the "location" field in the XML data for the LTFS Label.




### 6.1.1 VOL1 Label

A VOL1 label recorded on an LTFS Volume shall always be recorded in a Label Construct as defined in 6.1 **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 following structure and content.

| 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: single quotation marks in the* Value *column above should not be recorded in the VOL1 label.***

### 6.1.2 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 Appendix A **LTFS Label XML Schema**. The LTFS Label shall be 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 6.1 **Label Construct**.

A complete schema for the LTFS Label XML data structure is provided in Appendix A **LTFS Label XML Schema**. An example LTFS Label is shown below.

```
<?xml version="1.0" encoding="UTF-8"?>
<ltfslabel version="1.0">
    <creator>IBM LTFS 0.20 - Linux - mkltfs</creator>
    <formattime>2010-02-01T18:35:47.866846222Z</formattime>
    <volumeuuid>30a91a08-daae-48d1-ae75-69804e61d2ea</volumeuuid>
    <location>
        <partition>b</partition>
    </location>
    <partitions>
        <index>a</index>
        <data>b</data>
    </partitions>
    <blocksize>1048576</blocksize>
    <compression>true</compression>
</ltfslabel>
```

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

The LTFS Label XML must contain the following information:

**ltfslabel**: this element defines the contained structure as an LTFS Label structure. The element must have a **version** attribute that defines the format version of the LTFS Label in use. This document describes LTFS Label version 1.0.

**creator**: this element must contain the necessary information to uniquely identify the writer of the LTFS volume. The value must conform to the creator format definition shown in 5.2 **Creator format**.

**formattime**: this element must contain the time when the LTFS Volume was formatted. The value must conform to the format definition shown in 5.7 **Time stamp format**.

**volumeuuid**: this element must contain a universally unique identifier (UUID) value that uniquely identifies the LTFS Volume to which the LTFS Label is written. The **volumeuuid** element must conform to the format definition shown in 5.8 **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 must be a lower case ASCII character between 'a' and 'z'.

**partitions**: this element specifies the Partition IDs of the data and index partitions belonging to this LTFS volume. It must contain exactly one **index** element for the Index Partition and exactly one **data** element for the Data Partition, formatted as shown. A partition must exist in the LTFS Volume with a partition identifier that matches the identifier recorded in the **index** element. Similarly, a partition must 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 must 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 3.2.2 **Data Extent** and 4 **Data Extents**.

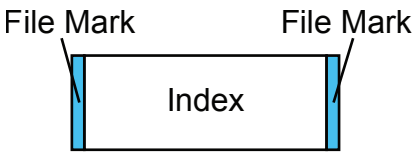
**compression**: this element shall contain a value conforming to the boolean format definition provided in 5.1 **Boolean format**. When the **compression** element is set, compression must be enabled when writing to the LTFS Volume. When the **compression** element is unset, compression must be disabled 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 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 decribed in 6 **Label Format**. Data Extents are described in 4 **Data Extents**.

## 7.1 Index Construct

Each Content Area in an LTFS Volume shall contain some number of Index Constructs that conform to the structure shown in the figure below. The Index Construct shall contain a single file mark, followed by one or more records in Index format, followed by a single file mark. The contents of the Index are defined in 7.2 **Index** below.




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

## 7.2 Index

An Index is an XML data structure that describes all data files, directory information and associated meta-data 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 7.1 **Index Construct**.

The LTFS Index shall conform to the Index XML schema provided in Appendix B **LTFS Index XML Schema**. The Index shall be be encoded using UTF-8 NFC.

A complete schema for the Index XML data structure is provided in Appendix B **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 may contain zero or more **directory** elements and zero or more **file** elements.

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

```
<?xml version="1.0" encoding="UTF-8"?>
<ltfsindex version="1.0">
    <creator>IBM LTFS 0.20 - Linux - ltfs</creator>
    <volumeuuid>30a91a08-daae-48d1-ae75-69804e61d2ea</volumeuuid>
    <generationnumber>3</generationnumber>
    <comment>A sample LTFS Index</comment>
    <updatetime>2010-01-28T19:39:57.245954278Z</updatetime>
    <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>
    <directory>
    ...
    </directory>
</ltfsindex>
```

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

Every Index must contain the following elements:

**ltfsindex**: this element defines the contained structure as an Index structure. The element must have a **version** attribute that defines the format version of the LTFS Index in use. This document describes LTFS Index version 1.0.

**creator**: this element must contain the necessary information to uniquely identify the writer of the Index. The value must conform to the creator format definition shown in 5.2 **Creator format**.

**volumeuuid**: this element must 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 must conform to the format definition shown in 5.8 **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 number "0" is a valid **generationnumber** value. It is recommended that LTFS implementations avoid use of **generationnumber** with value "0". The **generationnumber** must conform to the definitions provided in 3.4.1 **Generation Number**.

**updatetime**: this element shall contain the date and time when the Index was modified. The value must conform to the format definition shown in 5.7 **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.

**allowpolicyupdate**: this element shall contain a value conforming to the boolean format definition provided in 5.1 **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 7.2.3 **Data Placement Policy**.

**directory**: this element corresponds to the "root" **directory** element in the Index. The content of this element is described later in this section.

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 5.6 **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.

**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 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 must conform to the definitions provided in 3.4 **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 5.5 **Name pattern format**. A description of the rules associated with the **dataplacementpolicy** element is provided in 7.2.3 **Data Placement Policy**.

An example Index that omits the Preface section of the Index is shown below. 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="1.0">
    ...
    <directory>
        <name>LTFS Volume Name</name>
        <creationtime>2010-01-28T19:39:50.715656751Z</creationtime>
        <changetime>2010-01-28T19:39:55.231540960Z</changetime>
        <modifytime>2010-01-28T19:39:55.231540960Z</modifytime>
        <accesstime>2010-01-28T19:39:50.715656751Z</accesstime>
        <contents>
            <directory>
                <name>directory1</name>
                <creationtime>2010-01-28T19:39:50.740812831Z</creationtime>
                <changetime>2010-01-28T19:39:56.238128620Z</changetime>
                <modifytime>2010-01-28T19:39:54.228983707Z</modifytime>
                <accesstime>2010-01-28T19:39:50.740812831Z</accesstime>
                <readonly>false</readonly>
                <contents>
                    <directory>
                        <name>subdir1</name>
                        <readonly>false</readonly>
                        <creationtime>2010-01-28T19:39:54.228983707Z</creationtime>
                        <changetime>2010-01-28T19:39:54.228983707Z</changetime>
                        <modifytime>2010-01-28T19:39:54.228983707Z</modifytime>
                        <accesstime>2010-01-28T19:39:54.228983707Z</accesstime>
                        <contents/>
                    </directory>
                </contents>
            </directory>
            <file>
                <name>testfile.txt</name>
                <length>5</length>
                <creationtime>2010-01-28T19:39:51.744583047Z</creationtime>
                <changetime>2010-01-28T19:39:57.245291730Z</changetime>
                <modifytime>2010-01-28T19:39:57.245291730Z</modifytime>
                <accesstime>2010-01-28T19:39:57.240774456Z</accesstime>
                <readonly>true</readonly>
                <extendedattributes>
                </extendedattributes>
                <extentinfo>
                    <extent>
                        <partition>a</partition>
                        <startblock>4</startblock>
                        <byteoffset>0</byteoffset>
                        <bytecount>5</bytecount>
                    </extent>
                </extentinfo>
            </file>
        </contents>
    </directory>
</ltfsindex>
```

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) must contain the following information:

**name**: this element must contain the name of the directory. A directory name must conform to the format specified in 5.4 **Name format**.

**creationtime**: this element must contain the date and time when the directory was created in the LTFS Volume. The value must conform to the format definition shown in 5.7 **Time stamp format**.

**changetime**: this element must contain the date and time when the extended attributes or readonly element for the directory was last altered. The value must conform to the format definition shown in 5.7 **Time stamp format**.

**modifytime**: this element must contain the date and time when the content of the directory was most recently altered. The value must conform to the format definition shown in 5.7 **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 must conform to the format definition shown in 5.7 **Time stamp format**.

**readonly**: this element shall contain a value conforming to the boolean format definition provided in 5.1 **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 **dictionary** elements and zero or more **file** elements. The elements contained in the **contents** element are children of the directory.

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 7.2.1 `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.

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

**name**: this element must contain the name of the file. A file name must conform to the format specified in 5.4 **Name format**.

**length**: this element must contain the integer length of the file. The length is measured in bytes.

**creationtime**: this element must contain the date and time when the file was created in the LTFS Volume. The value must conform to the format definition shown in 5.7 **Time stamp format**.

**changetime**: this element must contain the date and time when the extended attributes or readonly element for the file was last altered. The value must conform to the format definition shown in 5.7 **Time stamp format**.

**modifytime**: this element must contain the date and time when the content of the file was most recently altered. The value must conform to the format definition shown in 5.7 **Time stamp format**.

**accesstime**: this element may contain the date and time when the content of the file 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 must conform to the format definition shown in 5.7 **Time stamp format**.

**readonly**: this element shall contain a value conforming to the boolean format definition provided in 5.1 **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.

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 7.2.1 `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.

Every **extent** element shall describe the location where a file extent is recorded in the LTFS Volume. Every **extent** element must contain one **partition** element, one **startblock** element, one **byteoffset** element, and one **bytecount** element. The values recorded in elements contained by the **extentinfo** element must conform to the definitions provided in 3.2.2 **Data Extent** and 4 **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 order of **extent** elements within an **extentinfo** element is important. The order be preserved during any subsequent update of the Index. The definition of how extent values are determined and used is provided in section 4 **Data Extents** and 4.1 **Extent Lists**.

### 7.2.1 `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**.

An example **directory** element is shown below 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>
    <name>directory1</name>
    <creationtime>2010-01-28T19:39:50.740812831Z</creationtime>
    <changetime>2010-01-28T19:39:56.238128620Z</changetime>
    <modifytime>2010-01-28T19:39:54.228983707Z</modifytime>
    <accesstime>2010-01-28T19:39:50.740812831Z</accesstime>
    <extendedattributes>
        <xattr>
            <key>binary_xattr</key>
            <value type="base64">/42n2QaEWDSX+g==</value>
        </xattr>
        <xattr>
            <key>empty_xattr</key>
            <value/>
        </xattr>
        <xattr>
            <key>document_name</key>
            <value type="text">LTFS Format Specification</>
        </xattr>
    </extendedattributes>
    <contents>
    </contents>
</directory>
...
```

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

Each **xattr** element must 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 must

conform to the format specified in 5.4 **Name format**. Extended attribute names must 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 5.3 **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 C **Reserved Extended Attribute definitions**.

### 7.2.2 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 sematic, an implementor 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.***

### 7.2.3 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 Parition.

An example Index that shows the elements that define the Data Placement Policy for an LTFS Volume is shown below. 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="1.0">
    ...
    <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.

Every **dataplacementpolicy** element must contain exactly one **indexpartitioncriteria** element.

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

Every **indexparitioncriteria** 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 5.5 **Name pattern format**.

### 7.2.4 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 7.2.3 **Data Placement Policy**.

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

#### 7.2.4.1 Allow Policy Update is set

If the current Allow Policy Update value is set, as defined in 7.2.3 **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 7.2.3 **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 7.2.3 **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 7.2.3 **Data Placement Policy**, a writer may record an Index without any **dataplacementpolicy** element.

#### 7.2.4.2 Allow Policy Update is unset

If the current Allow Policy Update value is unset, as defined in 7.2.3 **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 7.2.3 **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 7.2.3 **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.

### 7.2.5 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 7.2.3 **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 7.2.3 **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 5.5 **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 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 5.5 **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 7.2 **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.***

# 8 MAM Parameters

An LTFS Volume may use standard MAM parameters to store auxiliary information with the volume to improve Index retrieval efficiency. MAM parameters are stored on the medium in non-volatile storage. Use of the MAM parameters enhance performance but are not required for LTFS Format compliance; an LTFS Volume may still be read and written if the MAM parameters become inaccessible or are not updated.

LTFS uses VCR (a standardized mechanism) and Index generation number to establish partition completeness and volume consistency checks without requiring Indexes to be read from both partitions. This is achieved by recording VCR, Index generation number and Index location in the VOLUME COHERENCY INFORMATION MAM parameter for each partition.

For performance reasons, it is strongly recommended that implementations use MAM parameters as described in 8.3 **Use of Volume Coherency** if such usage is supported by the underlying storage technology.

## 8.1 Volume Change Reference (VCR)

Volume Change Reference (VCR) is a non-repeating, unique value associated with a volume coherency point. The following is for information only. 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 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.

## 8.2 Volume Coherency

The Volume Coherency Information attribute contains information used to maintain coherency of information on a volume. It has six fields as follows. There shall be one Volume Coherency Information attribute for each LTFS Partition on a logical volume. The following is for information only; see the T10 SSC4 Standard for a complete description of the Volume Coherency Information attribute.

The correspondence between LTFS nomenclature and T10 SSC4 nomenclature is:

| **LTFS Name** | **T10 SSCR 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 |

- VCR Length: this field contains the length of the VCR field. The VCR Length field is a one-byte field.
- 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.
- generation number: this field contains the generation number of the Index which is pointed to by the block position field. The generation number field is an 8-byte field.
- block number: this field contains the logical block number of an Index on this partition for which coherency is desired. This field and the partition ID of this partition comprise the block position of an Index on this partition. A value of zero is invalid. The block number field is an 8-byte field.

- 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.
- 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.

## 8.3 Use of Volume Coherency

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 Application Client Specific Information for an LTFS partition shall be formatted as follows. All offsets and lengths are in bytes.

| Offset | Length | Value | Notes |
|---|---|---|---|
| 0 | 4 | 'LTFS' | |
| 4 | 1 | 0x00 | string terminator (binary) |
| 5 | 36 | <volume UUID> | as defined in 5.8 **UUID format** |
| 41 | 1 | 0x00 | string terminator (binary) |
| 42 | 1 | 0x00 | version number (binary) |

***Note: single quotation marks in the* Value *column above 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.

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 Index on the partition, both 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. Applications should update the VCI attribute for all complete partitions immediately after fully writing an Index Construct to any partition. In this case, the recommended order of operations is:

1. Write an Index Construct to either 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), write VCI attributes containing that 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 volume. This allows an application to determine the state of an LTFS Volume quickly by reading that single 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 volume cannot be determined from the values in the VCI attributes of its partitions. In the example order of operations below, exactly one partition has a VCI attribute containing an up-to-date VCR instance, but the volume is not consistent.

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

# 9 Certification

*TBD*

*Voluntary certification of compliance to the LTFS can be obtained by submitting Volume images to ...*

*Certified compliance allows the display of the "LTFS Compliant" logo.*

# Appendices

# A 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="xs:positiveInteger"/>
        <xs:element name="compression" type="xs:boolean"/>
      </xs:all>
      <xs:attribute name="version" use="required" type="version"/>
    </xs:complexType>
  </xs:element>

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

# B 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 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="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="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="name" type="xs:string"/>
        <xs:element name="length" type="xs:nonNegativeInteger"/>
        <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="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:all>
              </xs:complexType>
            </xs:element>
          </xs:sequence>
        </xs:complexType>
      </xs:element>
    </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]+"/>
    </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>
```

# C Reserved Extended Attribute definitions

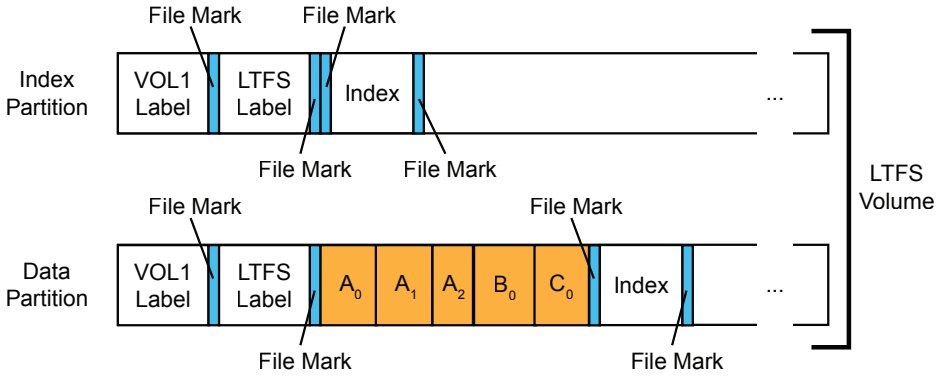
In an LTFS Index, all extended attribute names that start with the prefix "`ltfs`" with any capitalization are reserved for use by the LTFS Format. (That is, any name starting with a case-insensitive match for the letters "ltfs" are reserved.)

Any writer of an LTFS Volume shall only use reserved extended attribute names to store extended attribute values in conformance with the list below. This section describes meaning of defined, reserved extended attributes.

| **Extended Attribute name** | **Value description** |
|---|---|
| `ltfs.TBD` | *TBD* |

# D Example of Valid Simple Complete LTFS Volume

The following figure shows the content of a simple LTFS volume. This volume contains three files “A”, “B”, and “C”. File “A” is comprised of three extents. Files “B” and “C” each have one extent.



# E Complete Example LTFS Index

The following Index shows the important features of the Index format. Notes:

- The file `directory2/binary_file.bin` has a length (20000000 bytes) greater than that of its extent list (10485760 bytes). The extra length is implicitly filled with zero bytes as described in 4.1 **Extent Lists**.
- Block 8 of partition 'b' is shared. The first 720000 bytes of the block are used by `directory2/binary_file.bin` and `directory2/binary_file2.bin`. The next 105008 bytes are used only by `directory2/binary_file2.bin`. This form of sharing data between files is described in 4.3.3 **Shared Data**.

```
<?xml version="1.0" encoding="UTF-8"?>
<ltfsindex version="1.0">
    <creator>IBM LTFS 0.20 - Linux - ltfs</creator>
    <volumeuuid>5d217f76-53e6-4d6f-91d1-c4213d94a742</volumeuuid>
    <generationnumber>3</generationnumber>
    <updatetime>2010-02-16T19:13:49.532656726Z</updatetime>
    <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>
    <directory>
        <name>LTFS Volume Name</name>
        <readonly>false</readonly>
        <creationtime>2010-02-16T19:13:42.986549106Z</creationtime>
        <changetime>2010-02-16T19:13:47.517309274Z</changetime>
        <modifytime>2010-02-16T19:13:47.517309274Z</modifytime>
        <accesstime>2010-02-16T19:13:42.986549106Z</accesstime>
        <contents>
            <directory>
                <name>directory1</name>
                <readonly>false</readonly>
                <creationtime>2010-02-16T19:13:43.006599071Z</creationtime>
                <changetime>2010-02-16T19:13:48.524075283Z</changetime>
                <modifytime>2010-02-16T19:13:46.514736591Z</modifytime>
                <accesstime>2010-02-16T19:13:43.006599071Z</accesstime>
                <extendedattributes>
```

```
            <xattr>
                <key>binary_xattr</key>
                <value type="base64">yDaaBPBdIUqMhg==</value>
            </xattr>
            <xattr>
                <key>empty_xattr</key>
                <value/>
            </xattr>
        </extendedattributes>
        <contents>
            <directory>
                <name>subdir1</name>
                <readonly>false</readonly>
                <creationtime>2010-02-16T19:13:46.514736591Z</creationtime>
                <changetime>2010-02-16T19:13:46.514736591Z</changetime>
                <modifytime>2010-02-16T19:13:46.514736591Z</modifytime>
                <accesstime>2010-02-16T19:13:46.514736591Z</accesstime>
                <contents/>
            </directory>
        </contents>
    </directory>
    <directory>
        <name>directory2</name>
        <readonly>false</readonly>
        <creationtime>2010-02-16T19:13:43.007872849Z</creationtime>
        <changetime>2010-02-16T19:13:46.512350773Z</changetime>
        <modifytime>2010-02-16T19:13:46.512350773Z</modifytime>
        <accesstime>2010-02-16T19:13:43.007872849Z</accesstime>
        <contents>
            <file>
                <name>binary_file.bin</name>
                <length>20000000</length>
                <readonly>false</readonly>
                <creationtime>2010-02-16T19:13:45.012828533Z</creationtime>
                <changetime>2010-02-16T19:13:46.509553802Z</changetime>
                <modifytime>2010-02-16T19:13:46.509553802Z</modifytime>
                <accesstime>2010-02-16T19:13:45.012828533Z</accesstime>
                <extentinfo>
                    <extent>
                        <partition>b</partition>
                        <startblock>8</startblock>
                        <byteoffset>0</byteoffset>
                        <bytecount>720000</bytecount>
                    </extent>
                    <extent>
                        <partition>b</partition>
                        <startblock>18</startblock>
                        <byteoffset>0</byteoffset>
                        <bytecount>600000</bytecount>
                    </extent>
                    <extent>
                        <partition>b</partition>
                        <startblock>9</startblock>
```

```
                    <byteoffset>271424</byteoffset>
                    <bytecount>9165760</bytecount>
                </extent>
            </extentinfo>
        </file>
        <file>
            <name>binary_file2.bin</name>
            <length>825008</length>
            <readonly>false</readonly>
            <creationtime>2010-02-16T19:13:46.512350773Z</creationtime>
            <changetime>2010-02-16T19:13:46.513510263Z</changetime>
            <modifytime>2010-02-16T19:13:46.513510263Z</modifytime>
            <accesstime>2010-02-16T19:13:46.000000000Z</accesstime>
            <extentinfo>
                <extent>
                    <partition>b</partition>
                    <startblock>8</startblock>
                    <byteoffset>0</byteoffset>
                    <bytecount>825008</bytecount>
                </extent>
            </extentinfo>
        </file>
    </contents>
</directory>
<file>
    <name>testfile.txt</name>
    <length>5</length>
    <readonly>false</readonly>
    <creationtime>2010-02-16T19:13:44.009581288Z</creationtime>
    <changetime>2010-02-16T19:13:49.532111261Z</changetime>
    <modifytime>2010-02-16T19:13:49.532111261Z</modifytime>
    <accesstime>2010-02-16T19:13:49.527726902Z</accesstime>
    <extendedattributes>
        <xattr>
            <key>author_name</key>
            <value>Michael Richmond</value>
        </xattr>
    </extendedattributes>
    <extentinfo>
        <extent>
            <partition>a</partition>
            <startblock>4</startblock>
            <byteoffset>0</byteoffset>
            <bytecount>5</bytecount>
        </extent>
    </extentinfo>
</file>
<file>
    <name>read_only_file</name>
    <length>0</length>
    <readonly>true</readonly>
    <creationtime>2010-02-16T19:13:47.517309274Z</creationtime>
    <changetime>2010-02-16T19:13:47.519534438Z</changetime>
```

```
                <modifytime>2010-02-16T19:13:47.000000000Z</modifytime>
                <accesstime>2010-02-16T19:13:47.000000000Z</accesstime>
                <extendedattributes>
                    <xattr>
                        <key>author_name</key>
                        <value>Brian Biskeborn</value>
                    </xattr>
                </extendedattributes>
            </file>
        </contents>
    </directory>
</ltfsindex>
```