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OpenOffice.org's Documentation of the

Microsoft Compound Document File Format

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1 Introduction

1.1 License Notices

1.1.1 Public Documentation License Notice

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1.1.2 Wikipedia

Wikipedia Disclaimer: http://en.wikipedia.org/wiki/Wikipedia:General_disclaimer

1.2 Abstract

This document contains a description of the binary format of Microsoft Compound Document files.

Compound document files are used to structure the contents of a document in the file. It is possible to divide the data into several *streams*, and to store these streams in different *storages* in the file. This way compound document files support a complete file system inside the file, the streams are like files in a real file system, and the storages are like sub directories.

1.3 Used Terms, Symbols, and Formatting

• References

A reference to another chapter is symbolised by a little arrow: ➞1.1.

• Examples

An example is indented and marked with a light-grey border.

> This is an example.

• Numbers and Strings

Numerical values are shown in several number systems:

Number system	Marking	Example
Decimal	None	1234
Hexadecimal	Trailing “H”	1234_H
Binary	Trailing “2”	1001_2

Constant strings are enclosed in quotation marks. They may contain specific values (control characters, unprintable characters). These values are enclosed in angle brackets.

> Example of a string containing a control character: “abcdef<01_H>ghij”.

• Content Listings

- The term “*Not used*” means: Ignore the data on import and write zero bytes on export. The same applies for unmentioned bits in bit fields.
- The term “*Unknown*” describes data fields with fixed but unknown contents. On export these fields have to be written as shown.
- At several places a `variable` is introduced, which represents the value of this field for later use, e.g. in formulas. An example can be found in ➞4.1.

• Formulas

> Important formulas are shown in a light-grey box.

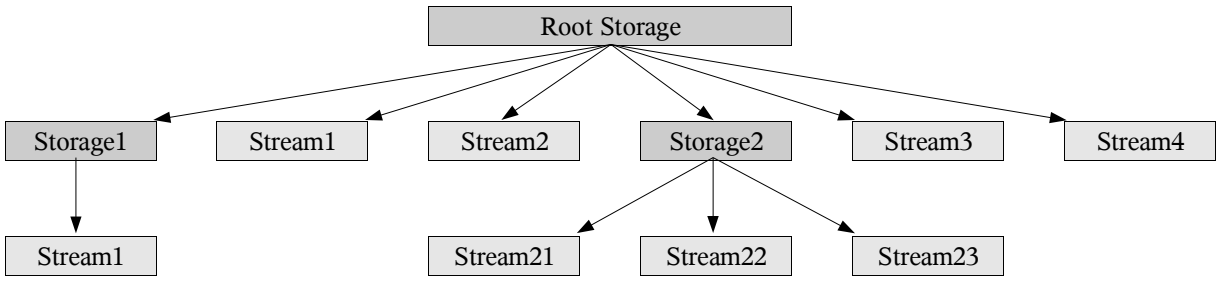
2 Storages and Streams

Compound document files work similar to real file systems. They contain a number of independent data *streams* (like files in a file system) which are organised in a hierarchy of *storages* (like sub directories in a file system).

Storages and streams are named. The names of all storages and streams that are direct members of a storage must be different. Names of streams or storages that are members of different storages may be equal.

Each compound document file contains a *root storage* that is the direct or indirect parent of all other storages and streams.

Example of a storage/stream hierarchy. The names of all direct members of a storage must be different, but it is possible that two different storages contain a stream named “Stream1”.



3 Sectors and Sector Chains

3.1 Sectors and Sector Identifiers

All streams of a compound document file are divided into small blocks of data, called *sectors*. Sectors may contain internal control data of the compound document or parts of the user data.

The entire file consists of a header structure (the compound document header, ➞4.1) and a list of all sectors following the header. The size of the sectors can be set in the header and is fixed for all sectors then.

HEADER
SECTOR 0
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4
SECTOR 5
SECTOR 6
⋮

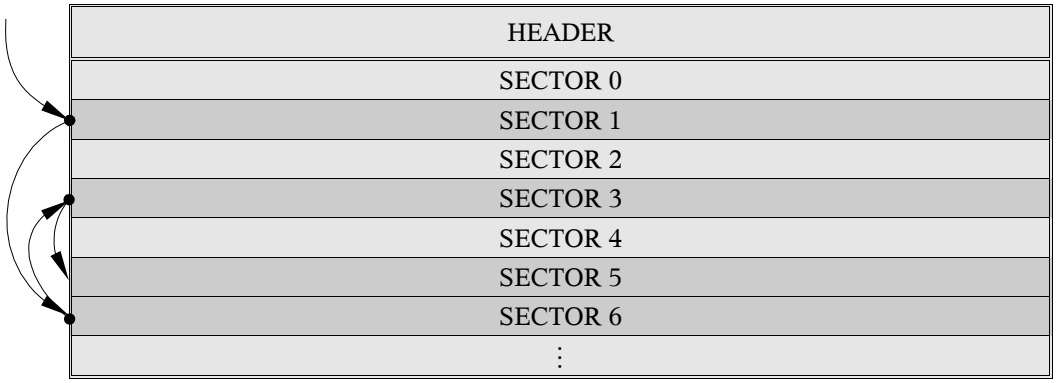
Sectors are enumerated simply by their order in the file. The (zero-based) index of a sector is called *sector identifier* (SecID). SecIDs are *signed 32-bit integer values*. If a SecID is not negative, it must refer to an existing sector. If a SecID is negative, it has a special meaning. The following table shows all valid special SecIDs:

SecID	Name	Meaning
–1	*Free SecID*	Free sector, may exist in the file, but is not part of any stream
–2	*End Of Chain SecID*	Trailing SecID in a SecID chain (➞3.2)
–3	*SAT SecID*	Sector is used by the sector allocation table (➞5.2)
–4	*MSAT SecID*	Sector is used by the master sector allocation table (➞5.1)

3.2 Sector Chains and SecID Chains

The list of all sectors used to store the data of one stream is called *sector chain*. The sectors may appear unordered and may be located on different positions in the file. Therefore an array of SecIDs, the *SecID chain*, specifies the order of all sectors of a stream. A SecID chain is always terminated by a special *End Of Chain SecID* with the value –2 (→3.1).

Example: A stream consists of 4 sectors. The SecID chain of the stream is [1, 6, 3, 5, –2]. See →4.3 on how to calculate the file offset of a sector from its SecID.



The SecID chain for each stream is built up from the sector allocation table (→5.2), with exception of short-streams (→6) and the following two internal streams:

- the master sector allocation table (→5.1), which builds its SecID chain from itself (each sector contains the SecID of the following sector), and
- the sector allocation table itself, which builds its SecID chain from the master sector allocation table.

4 Compound Document Header

The *compound document header* (simply “header” in the following) contains all data needed to start reading a compound document file.

4.1 Compound Document Header Contents

The header is always located at the beginning of the file, and its size is exactly 512 bytes. This implies that the first sector (with SecID 0) always starts at file offset 512.

Contents of the compound document header structure:

Offset	Size	Contents
0	8	Compound document file identifier: $D0_H$ CF_H 11_H $E0_H$ $A1_H$ $B1_H$ $1A_H$ $E1_H$
8	16	Unique identifier (UID) of this file (not of interest in the following, may be all 0)
24	2	Revision number of the file format (most used is $003E_H$)
26	2	Version number of the file format (most used is 0003_H)
28	2	Byte order identifier (➞4.2): FE_H FF_H = Little-Endian FF_H FE_H = Big-Endian
30	2	Size of a sector in the compound document file (➞3.1) in power-of-two (ssz), real sector size is sec_size = 2^{ssz} bytes (minimum value is 7 which means 128 bytes, most used value is 9 which means 512 bytes)
32	2	Size of a short-sector in the short-stream container stream (➞6.1) in power-of-two (sssz), real short-sector size is short_sec_size = 2^{sssz} bytes (maximum value is sector size ssz, see above, most used value is 6 which means 64 bytes)
34	10	Not used
44	4	Total number of sectors used for the sector allocation table (➞5.2)
48	4	SecID of first sector of the directory stream (➞7)
52	4	Not used
56	4	Minimum size of a standard stream (in bytes, minimum allowed and most used size is 4096 bytes), streams with an actual size smaller than (and *not* equal to) this value are stored as short-streams (➞6)
60	4	SecID of first sector of the short-sector allocation table (➞6.2), or –2 (*End Of Chain SecID*, ➞3.1) if not extant
64	4	Total number of sectors used for the short-sector allocation table (➞6.2)
68	4	SecID of first sector of the master sector allocation table (➞5.1), or –2 (*End Of Chain SecID*, ➞3.1) if no additional sectors used
72	4	Total number of sectors used for the master sector allocation table (➞5.1)
76	436	First part of the master sector allocation table (➞5.1) containing 109 SecIDs

4.2 Byte Order

All data items containing more than one byte may be stored using the Little-Endian or Big-Endian method[1], but in real world applications only the Little-Endian method is used. The Little-Endian method stores the least significant byte first and the most significant byte last. This applies for all data types like 16-bit integers, 32-bit integers, and Unicode characters.

Example: The 32-bit integer value $13579BDF_H$ is converted into the Little-Endian byte sequence $DF_H\ 9B_H\ 57_H\ 13_H$, or to the Big-Endian byte sequence $13_H\ 57_H\ 9B_H\ DF_H$.

4.3 Sector File Offsets

With the values from the header it is possible to calculate a file offset from a SecID:

$$sec_pos(SecID) = 512 + SecID \cdot sec_size = 512 + SecID \cdot 2^{ssz}$$

Example with $ssz = 10$ and $SecID = 5$:
$sec_pos(SecID) = 512 + SecID \cdot 2^{ssz} = 512 + 5 \cdot 2^{10} = 512 + 5 \cdot 1024 = 5632$.

[1] For more information see http://en.wikipedia.org/wiki/Endianness.

5 Sector Allocation

5.1 Master Sector Allocation Table

The *master sector allocation table* (MSAT) is an array of SecIDs of all sectors used by the sector allocation table (SAT, ➞5.2), which finally is needed to read any other stream in the file. The size of the MSAT (number of SecIDs) is equal to the number of sectors used by the SAT. This value is stored in the header (➞4.1).

The first 109 SecIDs of the MSAT are contained in the header too. If the MSAT contains more than 109 SecIDs, additional sectors are used to store the following SecIDs. The header contains the SecID of the first sector used for the MSAT then (otherwise there is the special *End Of Chain SecID* with the value –2, ➞3.1).

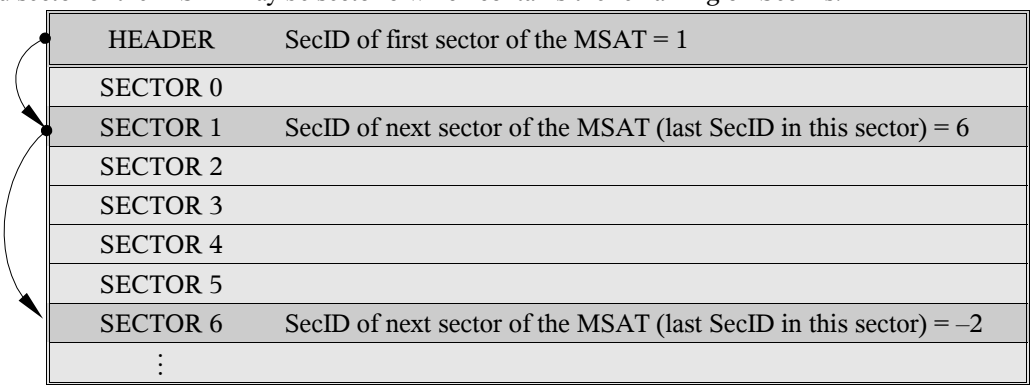
The last SecID in each sector of the MSAT refers to the next sector used by the MSAT. If no more sectors follow, the last SecID is the special *End Of Chain SecID* with the value –2 (➞3.1).

Contents of a sector of the MSAT (`sec_size` is the size of a sector in bytes, see ➞4.1):

Offset	Size	Contents
0	`sec_size` – 4	Array of (`sec_size` – 4) / 4 SecIDs of the MSAT
`sec_size` – 4	4	SecID of the next sector used for the MSAT, or –2 if this is the last sector

The last sector of the MSAT may not be used completely. Unused space is filled with the special *Free SecID* with the value –1 (➞3.1). The MSAT is built up by concatenating all SecIDs from the header and the additional MSAT sectors.

Example: A compound document file contains a SAT that needs 300 sectors to be stored. The header specifies a sector size of 512 bytes. This implies that a sector is able to store 128 SecIDs. The MSAT consists of 300 SecIDs (number of sectors used for the SAT). The first 109 SecIDs are stored in the header. The remaining 191 SecIDs of the MSAT need additional two sectors. In this example the first sector of the MSAT may be sector 1 which contains the next 127 SecIDs of the MSAT (the 128th SecID points to the next MSAT sector), and the second sector of the MSAT may be sector 6 which contains the remaining 64 SecIDs.



5.2 Sector Allocation Table

The *sector allocation table* (SAT) is an array of SecIDs. It contains the SecID chain (→3.2) of all user streams (except short-streams, →6) and of the remaining internal control streams (the short-stream container stream, →6.1, the short-sector allocation table, →6.2, and the directory, →7). The size of the SAT (number of SecIDs) is equal to the number of existing sectors in the compound document file.

5.2.1 Reading the Sector Allocation Table

The SAT is built by reading and concatenating the contents of all sectors given in the MSAT (→5.1). The sectors have to be read according to the order of the SecIDs in the MSAT.

Contents of a sector of the SAT (`sec_size` is the size of a sector in bytes, see →4.1):

Offset	Size	Contents
0	`sec_size`	Array of `sec_size`/4 SecIDs of the SAT

5.2.2 Using the Sector Allocation Table

When building a SecID chain (→3.2) for a specific stream, the *current position* (array index) in the SAT array refers to the current sector, while the SecID *contained at this position* specifies the following sector in the sector chain.

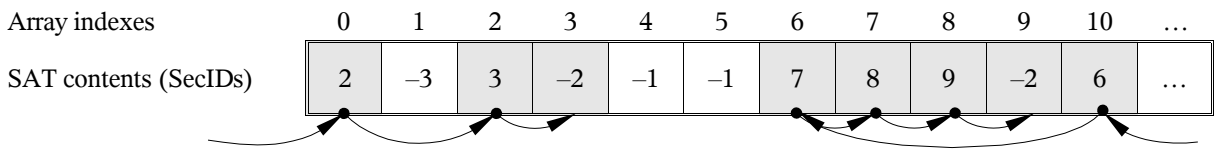
The SAT may contain special *Free SecIDs* with the value –1 (→3.1) at any position. These sectors are not used by a stream. The position referring to the last sector of a stream contains the special *End Of Chain SecID* with the value –2. Sectors used by the SAT itself are not chained, but are marked with the special *SAT SecID* with the value –3. Finally, sectors used by the MSAT are marked with the special *MSAT SecID* with the value –4.

The entry point of a SecID chain has to be obtained somewhere else, e.g. from the directory entry (→7.2) of a user stream, or from the header (→4.1) for internal control streams such as the short-sector allocation table (→6.2), or the directory stream itself (→7.1).

Example: A compound document file contains one sector needed for the SAT (sector 1) and two streams. Sector 1 contains the SecID array of the SAT shown below. The SAT contains the special *SAT SecID* (value –3) at position 1 which marks this sector being part of the SAT.

One stream is the internal directory stream. In this example, the header may specify that it starts with sector 0. The SAT contains the SecID 2 at position 0, the SecID 3 at position 2, and the SecID –2 at position 3. Therefore the SecID chain of the directory stream is [0, 2, 3, –2], and the directory stream is stored in 3 sectors.

The directory contains (amongst others) the entry of a user stream that may start with sector 10. This results in the SecID chain [10, 6, 7, 8, 9, –2] for this stream.



6 Short-Streams

Whenever a stream is shorter than a specific length (specified in the header, →4.1), it is stored as a *short-stream*. Short-streams do not directly use sectors to store their data, but are all embedded in a specific internal control stream, the short-stream container stream.

6.1 Short-Stream Container Stream

The *short-stream container stream* is stored like any other (long) user stream: The first used sector has to be obtained from the root storage entry in the directory (→7.2), and its SecID chain (→3.2) is contained in the SAT (→5.2). The data of all sectors used by the short-stream container stream are concatenated in order of its SecID chain. In the next step this stream is virtually divided into short-sectors, similar to sectors in the main compound document file (→3.1), but without a header structure. Therefore the first short-sector (with SecID 0) is always located at offset 0 inside the short-stream container stream. The size of the short-sectors is contained in the header (→4.1). With this information it is possible to calculate an offset in the short-stream container stream from a SecID:

$$\texttt{short_sec_pos(SecID)} = \texttt{SecID} \cdot \texttt{short_sec_size} = \texttt{SecID} \cdot 2^{\texttt{sssz}}$$

Example with $\texttt{sssz} = 6$ and $\texttt{SecID} = 5$:
$\texttt{short_sec_pos(SecID)} = \texttt{SecID} \cdot 2^{\texttt{sssz}} = 5 \cdot 2^6 = 5 \cdot 64 = 320$.

6.2 Short-Sector Allocation Table

The *short-sector allocation table* (SSAT) is an array of SecIDs and contains the SecID chains (→3.2) of all short-streams, similar to the sector allocation table (→5.2) that contains the SecID chains of standard streams.

The first SecID of the SSAT is contained in the header (→4.1), the remaining SecID chain is contained in the SAT. The SSAT is built by reading and concatenating the contents of all sectors.

Contents of a sector of the SSAT (sec_size is the size of a sector in bytes, see →4.1):

Offset	Size	Contents
0	sec_size	Array of sec_size/4 SecIDs of the SSAT

The SSAT will be used similarly to the SAT (→5.2) with the difference that the SecID chains refer to short-sectors in the short-stream container stream (→6.1).

7 Directory

7.1 Directory Structure

The *directory* is an internal control stream that consists of an array of *directory entries* (➞7.2). Each directory entry refers to a storage or a stream in the compound document file (➞2). Directory entries are enumerated in order of their appearance in the stream. The zero-based index of a directory entry is called *directory entry identifier* (DirID).

DIRECTORY ENTRY 0
DIRECTORY ENTRY 1
DIRECTORY ENTRY 2
DIRECTORY ENTRY 3
⋮

The position of a directory entry will not change as long as the referred storage or stream exists in the compound document. This implies that the DirID of a storage or stream never changes regardless how many other objects are inserted to or removed from the compound document. If a storage or stream is removed, the corresponding directory entry is marked as empty. There is a special directory entry at the beginning of the directory (with the DirID 0). It represents the root storage and is called *root storage entry*.

The directory organises direct members (storages and streams) of each storage in a separate red-black tree[2]. Shortly, nodes in a red-black tree have to fulfil *all* of the following conditions:

- The root node is black.
- The parent of a red node is black.
- The paths from the root node to all leaves contain the same number of black nodes.
- The left child of a node is less than the node, the right child is greater.

But note that not all implementations follow these rules. The safest way to read directory entries is to ignore the node colours and to rebuild the red-black tree from scratch.

Example: Taking the example from ➞2, the directory would have the following structure:

- The root storage is represented by the root storage entry. It does not have a parent directory entry, therefore there are no other entries that can be organised in a red-black tree.
- All members of the root storage (“Storage1”, “Storage2”, “Stream1”, “Stream2”, “Stream3”, and “Stream4”) are inserted into a red-black tree. The DirID of the root node of this tree is stored in the root storage entry.
- The storage “Storage1” contains one member “Stream1” which is inserted into a separate red-black tree. The directory entry of “Storage1” contains the DirID of “Stream1”.
- The storage “Storage2” contains three members “Stream21”, “Stream22”, and “Stream23”. These directory entries are organised in a separate red-black tree. The directory entry of “Storage2” contains the DirID of the root node of this tree.

[2] See http://en.wikipedia.org/wiki/Red_black_tree.

This results in the fact that each directory entry contains up to three DirIDs: The first is the DirID of the left child of the red-black tree containing this entry, the second is the DirID of the right child in the tree, and (if this entry is a storage) the third is the DirID of the root node of another red-black tree containing all sub streams and sub storages.

Nodes are compared by name to decide whether they become the left or right child of another node:

- A node is less than another node, if the name is shorter; and greater, if the name is longer.
- If both names have the same length, they are compared character by character (case insensitive).

> Examples: The name “VWXYZ” is less than the name “ABCDEFG” because the length of the former name is shorter (regardless of the fact that the character V is greater than the character A). The name “ABCDE” is less than the name “ABCFG” because the lengths of both names are equal, and comparing the names shows that the fourth character of the former name is less then the fourth character of the latter name.

7.2 Directory Entries

7.2.1 Directory Entry Structure

The size of each directory entry is exactly 128 bytes. The formula to calculate an offset in the directory stream from a DirID is as follows:

```
dir_entry_pos(DirID) = DirID · 128
```

Contents of the directory entry structure:

Offset	Size	Contents
0	64	Character array of the name of the entry, always 16-bit Unicode characters, with trailing zero character (results in a maximum name length of 31 characters)
64	2	Size of the used area of the character buffer of the name (not character count), including the trailing zero character (e.g. 12 for a name with 5 characters: (5+1)·2 = 12)
66	1	Type of the entry: 00_H = Empty, 01_H = User storage, 02_H = User stream, 03_H = LockBytes (unknown), 04_H = Property (unknown), 05_H = Root storage
67	1	Node colour of the entry: 00_H = Red, 01_H = Black
68	4	DirID of the left child node inside the red-black tree of all direct members of the parent storage (if this entry is a user storage or stream, →7.1), –1 if there is no left child
72	4	DirID of the right child node inside the red-black tree of all direct members of the parent storage (if this entry is a user storage or stream, →7.1), –1 if there is no right child
76	4	DirID of the root node entry of the red-black tree of all storage members (if this entry is a storage, →7.1), –1 otherwise
80	16	Unique identifier, if this is a storage (not of interest in the following, may be all 0)
96	4	User flags (not of interest in the following, may be all 0)
100	8	Time stamp of creation of this entry (→7.2.3). Most implementations do not write a valid time stamp, but fill up this space with zero bytes.
108	8	Time stamp of last modification of this entry (→7.2.3). Most implementations do not write a valid time stamp, but fill up this space with zero bytes.
116	4	SecID of first sector or short-sector, if this entry refers to a stream (→7.2.2), SecID of first sector of the short-stream container stream (→6.1), if this is the root storage entry, 0 otherwise
120	4	Total stream size in bytes, if this entry refers to a stream (→7.2.2), total size of the short-stream container stream (→6.1), if this is the root storage entry, 0 otherwise
124	4	Not used

7.2.2 Starting Position of a Stream

The directory entry of a stream contains the SecID of the first sector or short-sector containing the stream data. All streams that are shorter than a specific size given in the header (→4.1) are stored as a short-stream, thus inserted into the short-stream container stream (→6.1). In this case the SecID specifies the first short-sector inside the short-stream container stream, and the short-sector allocation table (→6.2) is used to build up the SecID chain (→3.2) of the stream.

7.2.3 Time Stamp

The *time stamp* field is an unsigned 64-bit integer value that contains the time elapsed since 1601-Jan-01 00:00:00 (Gregorian calendar[3]). One unit of this value is equal to 100 nanoseconds (10^{-7} seconds). That means, each second the time stamp value will be increased by 10 million units.

When calculating the date from a time stamp, the correct rules of leap year handling have to be respected[4]:

- a year divisible by 4 is a leap year;
- with the exception that a year divisible by 100 is not a leap year (e.g. 1900 was no leap year);
- with the exception that a year divisible by 400 is a leap year (e.g. 2000 was a leap year).

Example: The time stamp value is $01A5E403C2D59C00_H$.

Calculation step	Formula	Result
Conversion to decimal		t_0 = 118,751,670,000,000,000
Fractional amount of a second	r_{frac} = t_0 modulo 10,000,000	r_{frac} = 0
Remaining entire seconds	t_1 = t_0 / 10,000,000	t_1 = 11,875,167,000
Seconds in a minute	r_{sec} = t_1 modulo 60	r_{sec} = 0
Remaining entire minutes	t_2 = t_1 / 60	t_2 = 197,919,450
Minutes in an hour	r_{min} = t_2 modulo 60	r_{min} = 30
Remaining entire hours	t_3 = t_2 / 60	t_3 = 3,298,657
Hours in a day	r_{hour} = t_3 modulo 24	r_{hour} = 1
Remaining entire days	t_4 = t_3 / 24	t_4 = 137,444
Entire years from 1601-Jan-01[5]	r_{year} = 1601 + number of full years in t_4	r_{year} = 1601 + 376 = 1977
Remaining days in year 1977	t_5 = t_4 – (number of days from 1601-Jan-01 to 1977-Jan-01)	t_5 = 137,444 – 137,331 = 113
Entire months from 1977-Jan-01	r_{month} = 1 + number of full months in t_5	r_{month} = 1 + 3 = 4 = April
Remaining days in month April	t_6 = t_5 – (number of days from 1977-Jan-01 to 1977-Apr-01)	t_6 = 113 – 90 = 23
Resulting day of month April	r_{day} = 1 + t_6	r_{day} = 1 + 23 = 24

The final result is 1977-Apr-24 01:30:00. Guess what it is…

[3] See http://en.wikipedia.org/wiki/Gregorian_calendar.

[4] See http://en.wikipedia.org/wiki/Leap_year for some background information.

[5] You may use your favourite date/time manipulation library to perform the following steps.

8 Example

This chapter shows a possible way to open a compound document file. The file that is processed here is a simple spreadsheet document in Microsoft Excel file format, written by OpenOffice.org Calc.

8.1 Compound Document Header

The first step is to read the compound document header (➞4.1). The first 512 bytes of the file may look like this:

```
00000000H  D0 CF 11 E0 A1 B1 1A E1 00 00 00 00 00 00 00 00
00000010H  00 00 00 00 00 00 00 00 3B 00 03 00 FE FF 09 00
00000020H  06 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00
00000030H  0A 00 00 00 00 00 00 00 00 10 00 00 02 00 00 00
00000040H  01 00 00 00 FE FF FF FF 00 00 00 00 00 00 00 00
00000050H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000060H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000070H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000080H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000090H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000000A0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000000B0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000000C0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000000D0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000000E0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000000F0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000100H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000110H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000120H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000130H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000140H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000150H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000160H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000170H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000180H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000190H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000001A0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000001B0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000001C0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000001D0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000001E0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000001F0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
```

1) 8 bytes containing the fixed compound document file identifier:

```
00000000H  D0 CF 11 E0 A1 B1 1A E1 00 00 00 00 00 00 00 00
```

2) 16 bytes containing a unique identifier, followed by 4 bytes containing a revision number and a version number. These values can be skipped:

```
00000000H  D0 CF 11 E0 A1 B1 1A E1 00 00 00 00 00 00 00 00
00000010H  00 00 00 00 00 00 00 00 3B 00 03 00 FE FF 09 00
```

3) 2 bytes containing the byte order identifier. It should always consist of the byte sequence FE_H FF_H:

```
00000010H  00 00 00 00 00 00 00 00 3B 00 03 00 FE FF 09 00
```

4) 2 bytes containing the size of sectors, 2 bytes containing the size of short-sectors. The sector size is 512 bytes, and the short-sector size is 64 bytes here:

```
00000010H  00 00 00 00 00 00 00 00 3B 00 03 00 FE FF 09 00
00000020H  06 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00
```

5) 10 bytes without valid data, can be ignored:

```
00000020H  06 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00
```

6) 4 bytes containing the number of sectors used by the sector allocation table (→5.2). The SAT uses only one sector here:

```
00000020H  06 00 00 00 00 00 00 00 00 00 00 00 01 00 00 00
```

7) 4 bytes containing the SecID of the first sector used by the directory (→7). The directory starts at sector 10 here:

```
00000030H  0A 00 00 00 00 00 00 00 00 10 00 00 02 00 00 00
```

8) 4 bytes without valid data, can be ignored:

```
00000030H  0A 00 00 00 00 00 00 00 00 10 00 00 02 00 00 00
```

9) 4 bytes containing the minimum size of standard streams. This size is 00001000_H = 4096 bytes here:

```
00000030H  0A 00 00 00 00 00 00 00 00 10 00 00 02 00 00 00
```

10) 4 bytes containing the SecID of the first sector of the short-sector allocation table (→6.2), followed by 4 bytes containing the number of sectors used by the SSAT. In this example the SSAT starts at sector 2 and uses one sector:

```
00000030H  0A 00 00 00 00 00 00 00 00 10 00 00 02 00 00 00
00000040H  01 00 00 00 FE FF FF FF 00 00 00 00 00 00 00 00
```

11) 4 bytes containing the SecID of the first sector of the master sector allocation table (→5.1), followed by 4 bytes containing the number of sectors used by the MSAT. The SecID here is –2 (*End Of Chain SecID*, →3.1) which states that there is no extended MSAT in this file:

```
00000040H  01 00 00 00 FE FF FF FF 00 00 00 00 00 00 00 00
```

12) 436 bytes containing the first 109 SecIDs of the MSAT. Only the first SecID is valid, because the SAT uses only one sector (see above). Therefore all remaining SecIDs are set to the special *Free SecID* with the value –1 (→3.1). The only sector used by the SAT is sector 0:

```
00000040H  01 00 00 00 FE FF FF FF 00 00 00 00 00 00 00 00
00000050H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000060H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
    ⋮                                 ⋮
```

8.2 Master Sector Allocation Table

The header contains the entire MSAT (→5.1), therefore nothing else can be done here. The MSAT consists of the SecID chain [0, –2].

8.3 Sector Allocation Table

To build the SAT (→5.2), all sectors specified in the MSAT have to be read. In this example this is only sector 0. It starts at file offset 00000200_H = 512 (→4.3) and may look like this:

```
00000200H  FD FF FF FF FF FF FF FF FE FF FF FF 04 00 00 00
00000210H  05 00 00 00 06 00 00 00 07 00 00 00 08 00 00 00
00000220H  09 00 00 00 FE FF FF FF 0B 00 00 00 FE FF FF FF
00000230H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000240H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000250H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000260H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000270H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000280H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000290H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000002A0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000002B0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000002C0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000002D0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000002E0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000002F0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000300H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000310H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000320H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000330H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000340H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000350H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000360H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000370H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000380H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000390H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000003A0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000003B0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000003C0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000003D0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000003E0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000003F0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
```

This results in the following SecID array for the SAT:

Array indexes	0	1	2	3	4	5	6	7	8	9	10	11	12	…
SecID array	–3	–1	–2	4	5	6	7	8	9	–2	11	–2	–1	…

As expected, sector 0 is marked with the special *SAT SecID* (→3.1). Sector 1 and all sectors starting with sector 12 are not used (special *Free SecID* with value –1).

8.4 Short-Sector Allocation Table

The SSAT (→6.2) starts at sector 2 and consists only of this one sector as specified in the header. This is in line with the SAT that contains the *End Of Chain SecID* at position 2. The SecID chain of the SSAT is therefore [2, –2]. Sector 2 starts at file offset 00000600_H = 1536 (→4.3) and may look like this:

```
00000600H  01 00 00 00 02 00 00 00 03 00 00 00 04 00 00 00
00000610H  05 00 00 00 06 00 00 00 07 00 00 00 08 00 00 00
00000620H  09 00 00 00 0A 00 00 00 0B 00 00 00 0C 00 00 00
00000630H  0D 00 00 00 0E 00 00 00 0F 00 00 00 10 00 00 00
00000640H  11 00 00 00 12 00 00 00 13 00 00 00 14 00 00 00
00000650H  15 00 00 00 16 00 00 00 17 00 00 00 18 00 00 00
00000660H  19 00 00 00 1A 00 00 00 1B 00 00 00 1C 00 00 00
00000670H  1D 00 00 00 1E 00 00 00 1F 00 00 00 20 00 00 00
00000680H  21 00 00 00 22 00 00 00 23 00 00 00 24 00 00 00
00000690H  25 00 00 00 26 00 00 00 27 00 00 00 28 00 00 00
000006A0H  29 00 00 00 2A 00 00 00 2B 00 00 00 2C 00 00 00
000006B0H  2D 00 00 00 FE FF FF FF 2F 00 00 00 FE FF FF FF
000006C0H  FE FF FF FF 32 00 00 00 33 00 00 00 34 00 00 00
000006D0H  35 00 00 00 FE FF FF FF FF FF FF FF FF FF FF FF
000006E0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000006F0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000700H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000710H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000720H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000730H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000740H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000750H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000760H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000770H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000780H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
00000790H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000007A0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000007B0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000007C0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000007D0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000007E0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
000007F0H  FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
```

This results in the following SecID array for the SSAT:

Array indexes	0	1	2	3	4	5	6	7	8	9	10	11	…	41	42	43	44	45	46	47	48	49	50	51	52	53	54	…
SecID array	1	2	3	4	5	6	7	8	9	10	11	12	…	42	43	44	45	–2	47	–2	–2	50	51	52	53	–2	–1	…

All short-sectors starting with sector 54 are not used (special *Free SecID* with value –1).

8.5 Directory

The header contains the SecID of the first sector that contains the directory (➞7), which is sector 10 in this example. The directory is always contained in standard sectors, never in short-sectors. Therefore the SAT is used to build up the SecID chain of the directory: [10, 11, –2]. Sector 10 starts at file offset 00001600_H = 5632, and sector 11 starts at file offset 00001800_H = 6144 (➞4.3). In this example, a sector has a size of 512 bytes, therefore each sector contains 4 directory entries (each entry uses exactly 128 bytes), and the entire directory contains 8 entries.

The following example shows what is contained in the first two directory entries (➞7.2). The other entries are read accordingly.

8.5.1 Root Storage Entry

The first directory entry always represents the root storage entry. It may look like this:

```
00001600H  52 00 6F 00 6F 00 74 00 20 00 45 00 6E 00 74 00
00001610H  72 00 79 00 00 00 00 00 00 00 00 00 00 00 00 00
00001620H  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00001630H  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00001640H  16 00 05 00 FF FF FF FF FF FF FF FF 01 00 00 00
00001650H  10 08 02 00 00 00 00 00 C0 00 00 00 00 00 00 46
00001660H  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00001670H  00 00 00 00 03 00 00 00 80 0D 00 00 00 00 00 00
```

1) 64 bytes containing the character array of the entry name (16-bit characters, terminated by the first <00_H> character). The name of this entry is “Root Entry” here:

```
00001600H  52 00 6F 00 6F 00 74 00 20 00 45 00 6E 00 74 00
00001610H  72 00 79 00 00 00 00 00 00 00 00 00 00 00 00 00
00001620H  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00001630H  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

2) 2 bytes containing the valid range of the previous character array (22 bytes here, resulting in 10 valid characters):

```
00001640H  16 00 05 00 FF FF FF FF FF FF FF FF 01 00 00 00
```

3) 1 byte containing the type of the entry. Must be 05_H for the root storage entry.

```
00001640H  16 00 05 00 FF FF FF FF FF FF FF FF 01 00 00 00
```

4) 1 byte containing the node colour of the entry. It is red in this example, breaking the rule that the root storage entry should always be black:

```
00001640H  16 00 05 00 FF FF FF FF FF FF FF FF 01 00 00 00
```

5) 4 bytes containing the DirID of the left child node, followed by 4 bytes containing the DirID of the right child node. Should both be –1 in the root storage entry:

```
00001640H  16 00 05 00 FF FF FF FF FF FF FF FF 01 00 00 00
```

6) 4 bytes containing the DirID of the root node entry of the red-black tree of all members of the root storage. It is 1 in this example:

```
00001640H  16 00 05 00 FF FF FF FF FF FF FF FF 01 00 00 00
```

7) 16 bytes containing a unique identifier, followed by 4 bytes containing additional flags, and two time stamps, 8 bytes each, containing the creation time and last modification time of the storage (➞7.2.3). This data can be skipped:

```
00001650H  10 08 02 00 00 00 00 00 C0 00 00 00 00 00 00 46
00001660H  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00001670H  00 00 00 00 03 00 00 00 80 0D 00 00 00 00 00 00
```

8) 4 bytes containing the SecID of the first sector or short-sector of a stream, followed by 4 bytes containing the stream size. In case of the root storage entry, this is the SecID of the first sector and the size of the short-stream container stream (➞6.1). It starts at sector 3 and has a size of $00000D80_H$ = 3456 bytes in this example:

```
00001670H  00 00 00 00 03 00 00 00 80 0D 00 00 00 00 00 00
```

9) 4 bytes without valid data, can be skipped:

```
00001670H  00 00 00 00 03 00 00 00 80 0D 00 00 00 00 00 00
```

8.5.2 Second Directory Entry

The second directory entry (with DirID 1) may look like this:

```
00001680H  57 00 6F 00 72 00 6B 00 62 00 6F 00 6F 00 6B 00
00001690H  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
000016A0H  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
000016B0H  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
000016C0H  12 00 02 00 02 00 00 00 04 00 00 00 FF FF FF FF
000016D0H  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
000016E0H  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
000016F0H  00 00 00 00 00 00 00 00 51 0B 00 00 00 00 00 00
```

Important data is highlighted. The name of this entry is “Workbook”, it represents a stream, the DirID of the left child node is 2, the DirID of the right child node is 4, the SecID of the first sector is 0, and the stream size is 00000B51H = 2897 bytes. The stream is shorter than 4096 bytes, therefore it is stored in the short-stream container stream.

8.5.3 Remaining Directory Entries

The remaining directory entries are read similar to the examples above, resulting in the following directory:

DirID	Name	Type	DirID of left child	DirID of right child	DirID of first member	SecID of first sector	Stream size	Allocation table
0	Root Entry	root	none	none	1	3	3456	SAT
1	Workbook	stream	2	4	none	0	2897	SSAT
2	<01_H>CompObj	stream	3	none	none	46	73	SSAT
3	<01_H>Ole	stream	none	none	none	48	20	SSAT
4	<05_H>SummaryInformation	stream	none	none	none	49	312	SSAT
5		empty						
6		empty						
7		empty						

Starting with the first member directory entry specified in the root storage entry (here: DirID 1) it is possible to find all members of the root storage. Entry 1 has two child nodes with DirID 2 and DirID 4. DirID 2 has one child node with DirID 3. The child nodes with the DirIDs 3 and 4 do not specify more child nodes. Therefore the directory entries with the DirIDs 1, 2, 3, and 4 represent members of the root storage.

8.5.4 SecID Chains of the Streams

The short-stream container stream (→6.1) is always stored in standard sectors. All user streams are shorter than 4096 bytes (the minimum size of standard streams specified in the header, →4.1), therefore they are stored in the short-stream container stream, and the SSAT is used to build the SecID chains of the streams.

DirID	Stream name	Allocation table	SecID chain
0	*Short-stream container stream*[6]	SAT	[3, 4, 5, 6, 7, 8, 9, –2]
1	Workbook	SSAT	[0, 1, 2, 3, 4, 5, …, 43, 44, 45, –2]
2	<01$_H$>CompObj	SSAT	[46, 47, –2]
3	<01$_H$>Ole	SSAT	[48, –2]
4	<05$_H$>SummaryInformation	SSAT	[49, 50, 51, 52, 53, –2]

8.5.5 Short-Stream Container Stream

The short-stream container stream is read by concatenating all sectors specified in the SecID chain of the root storage entry in the directory. In this example, the sectors 3, 4, 5, 6, 7, 8, and 9 have to be read in this order, resulting in a stream with a size of 3584 bytes, but only the first 3456 bytes are used (as specified in the root storage entry). These 3456 bytes are divided into short-sectors with a size of 64 bytes each, resulting in 54 short-sectors.

8.5.6 Reading a Stream

Now the stream "<01$_H$>CompObj" may be read. The SecID chain of this stream is [46, 47, –2], the stream is a short-stream. The two short-sectors 46 and 47 contain the user data. Short-sector 46 starts at offset 2944 in the short-stream container stream, short-sector 47 starts at offset 3008 (→6.1).

[6] The actual name of this directory entry may be "Root Entry" or similar, but it *refers* to the short-stream container stream too.

9 Glossary

Term	Description	Chapter
Byte order	The order in which single bytes of a bigger data type are represented or stored.	→4.2
Compound document	File format used to store several objects in a single file, objects can be organised hierarchically in *storages* and *streams*.	→1.2
Compound document header	Structure in a *compound document* containing initial settings.	→4.1
Control stream	*Stream* in a *compound document* containing internal control data.	→5, →6, →7
Directory	List of *directory entries* for all *storages* and *streams* in a compound document.	→7.1
Directory entry	Part of the directory containing relevant data for a *storage* or a *stream*.	→7.2
Directory entry identifier (DirID)	Zero-based index of a *directory entry*.	→7.1
Directory stream	*Sector chain* containing the *directory*.	→7.1
DirID	Zero-based index of a *directory entry* (short for "*directory entry identifier*").	→7.1
End Of Chain SecID	Special *sector identifier* used to indicate the end of a *SecID chain*.	→3.1
File offset	Physical position in a file.	→4.3
Free SecID	Special *sector identifier* for unused *sectors*.	→3.1
Header	Short for "*compound document header*".	→4.1
Master sector allocation table (MSAT)	*SecID chain* containing *sector identifiers* of all *sectors* used by the *sector allocation table*.	→5.1
MSAT	Short for "*master sector allocation table*".	→5.1
MSAT SecID	Special *sector identifier* used to indicate that a *sector* is part of the *master sector allocation table*.	→3.1
Red-black tree	Tree structure used to organise direct members of a *storage*.	→7.1
Root storage	Built-in *storage* that contains all other objects (*storages* and *streams*) in a *compound document*.	→2
Root storage entry	*Directory entry* representing the *root storage*.	→7.1
SAT	Short for "*sector allocation table*".	→5.2
SAT SecID	Special *sector identifier* used to indicate that a *sector* is part of the *sector allocation table*.	→3.1
SecID	Zero-based index of a *sector* (short for "*sector identifier*").	→3.1
SecID chain	An array of *sector identifiers* (SecIDs) specifying the *sectors* that are part of a *sector chain* and thus enumerates all *sectors* used by a *stream*.	→3.2
Sector	Part of a compound document with fixed size that contains any kind of *stream* (user stream or *control stream*) data.	→3.1

Term	Description	Chapter
Sector allocation table (SAT)	Array of *sector identifiers* containing the *SecID chains* of all user *streams* and a few internal *control streams*.	→5.2
Sector chain	An array of *sectors* that forms a *stream* as a whole.	→3.2
Sector identifier (SecID)	Zero-based index of a *sector*.	→3.1
Short-sector	Part of the *short-stream container stream* with fixed size that contains one part of a *short-stream*.	→6.1
Short-sector allocation table (SSAT)	Array of *sector identifiers* containing the *SecID chains* of all *short-streams*.	→6.2
Short-stream	A user *stream* shorter than a specific size.	→6
Short-stream container stream	An internal *stream* that contains all *short-streams*.	→6.1
SSAT	Short for "*short-sector allocation table*".	→6.2
Storage	Part of a *compound document* used to separate *streams* into different groups, similar to directories in a file system.	→2
Stream	Part of a *compound document* containing user data or internal control data, similar to files in a file system.	→2
Stream offset	Virtual position in a *stream*.	→6.1, →7.2
Time stamp	Value specifying date and time.	→7.2.3
User stream	*Stream* in a *compound document* containing user data.	→2