Resilient File System (ReFS)

Analysis of the Windows Resilient File System

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Summary

The Resilient File System (ReFS) was introduced in Windows 8 server pre release, which became Windows 2012 server, and was added to Windows 8.1. ReFS is a new file system to the Windows NT platform. This specification is based on some available documentation but mainly on reverse engineering of the file system format.

This document is intended as a working document for the ReFS format. Which should allow existing Open Source forensic tooling to be able to process this type of file system.

Document information

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Abstract: This document contains information about the Resilient File System (ReFS)

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License

Version

Version	Author	Date	Comments
0.0.1	J.B. Metz	May 2012	Initial version.
0.0.2	J.B. Metz	September 2012	Additional information.
0.0.3	J.B. Metz	November 2013	Additional information.

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1. Overview

The Resilient File System (ReFS) was introduced in Windows 8 server pre release, which became Windows 2012 server, and was added to Windows 8.1. ReFS is a new file system to the Windows NT platform.

Characteristics	Description
Byte order	little-endian
Date and time values	FILETIME in UTC
Character string	ASCII strings are stored in extended ASCII (with a codepage?) Unicode strings are stored in UTF-16 little-endian without the byte order mark (BOM).

1.1. Test version

The following version of programs were used to test the information within this document:

- Windows 8 Server
- Windows 2012 Server

2. The volume

The volume consists of:

- a volume header
- metadata blocks
- file and directory data
- a copy of the volume header

2.1. The volume header

The volume header is stored at the start of the volume.

The volume header is 512 bytes of size and consists of:

offset	size	value	description
0	3		Unknown (empty values) Probably backward compatibility for: Boot entry point
3	8	“ReFS\x00\x00\x00\x00”	Signature
11	5		Unknown (empty values)
16	4	“FSRS”	Unknown
20	2	0x0200	Unknown (volume header size?) > 0x58
22	2		Unknown This value will change over time
24	8		Number of sectors

offset	size	value	description
32	4		Sector size
36	4		Sectors per block (allocation unit) Default is 64k
40	4	0x00000101 0x00000201	Unknown (flags?)
44	4	0x00000000 0x0000000a	Unknown
48	8		Unknown (empty values)
56	8		Unknown (Checksum?) bytes 3 – 512 ?
64	448		Unknown (empty values)

Note that the size of the partition can be larger then the number of sectors in the volume.

A copy of volume header in last sector of the partition.

The first 4 bytes of the checksum value are interpreted as the volume serial number by Windows, note that this value can change.

The first 16k of the volume after the volume header, contains zero bytes, and seems to be unused.

offset	size	value	description
512	15424		Unknown (empty values)

3. Metadata block

The volume metadata is stored in 16k blocks.

Note: is the metadata block referred to as synchronous ministore (SMS) by Microsoft?

3.1. Metadata block header

The metadata block header is 48 bytes of size and consists of:

offset	size	value	description
0	8		Block number Relative from the start of the volume
8	8		Sequence number? Previous block number ?
16	8		Unknown (empty values)
24	8		Object identifier See section: 3.1.1 Object identifiers At least this seems to be the case in level

offset	size	value	description
			3 metadata blocks
32	8	0x01	Unknown (version?, flags?) tree level?
40	8		Unknown (empty values)

It seems that the data in bytes 8 – 23 is used as an identifier. Level 3 table contains an identifier that matches the data in the corresponding level 4 block.

3.1.1. Object identifiers

Level 0 and 1

Value	Identifier	Description
0x00000000		Level 0 and level 1 metadata

Level 2

Value	Identifier	Description
0x00000001		Level 2 metadata
0x00000002		Level 2 metadata
0x00000003		Level 2 metadata
0x0000000c		Level 2 metadata
0x0000000d		Level 2 metadata
0x0000000e		Level 2 metadata

Level 3

Value	Identifier	Description
0x00000500	REFS_OBJECT_UNKNOWN_1	Volume
0x00000520	REFS_OBJECT_UNKNOWN_2	
0x00000530		
0x00000600	REFS_ROOT_DIRECTORY_ID	
0x00000700	REFS_OBJECT_UNKNOWN_3	
0x00000701		Used for first sub directory

Values 0x00000701 and above are used for sub directories.

3.2. Metadata block descriptor

The metadata block descriptor is 24 bytes of size and consists of:

offset	size	value	description
0	8		Block number
8	8		Flags?
16	8		Checksum?

4. Metadata table

The metadata table is used to store various metadata.

Note: is the metadata table referred to as object table by Microsoft?

The metadata table consists of:

- the metadata table header entry
- the metadata table allocation entry
- the metadata table value entries

Note that the metadata table value entries are not always stored consecutive and that the metadata table value entry offsets array is needed to determine the location and order of the metadata table value entries.

4.1. Metadata table entry

A metadata table entry is variable of size and consists of:

offset	size	value	description
0	4		Size Including the the size value
4	…		Entry data

4.2. Metadata table header

The first metadata table entry contains TODO.

The metadata table header is variable in size and consists of:

offset	size	value	description
0	4		Size Including the the size value
4	2	0x0028	Header data offset? Offset relative from the start of the table entry

offset	size	value	description
6	2	0x0000 0x0001	Unknown 0x0001 => has sub table flag?
If size > 8 ?			
8	4	0x00000000 0x00000001	Unknown Sometimes matches the number of values
12	4		Unknown
16	4		Unknown
20	4	0x00000002 0x00020002	Unknown
24	8	0x00000000 0x00000016	Unknown
32	8		Unknown Sometimes matches the number of values
If header data offset > 0 or if size > 40 ?			
40	...		Header data? Sometimes contains data

```
Size?

00000000: f0 00 00 00 28 00 00 00  00 00 00 00 30 e0 00 00   ....(... ....0...
00000010: 30 e0 00 00 02 00 00 00  00 00 00 00 00 00 00 00   0....... ........
00000020: 06 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000030: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........

000000e0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........

number of data records?
```

```
00000000: 38 00 00 00 28 00 10 e0  01 00 00 00 10 e0 00 00   8...(... ........
00000010: 10 e0 00 00 02 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000020: 01 00 00 00 00 00 00 00  00 f0 03 00 00 00 00 00   ........ ........
00000030: 00 c0 03 00 00 00 00 00                            ........
```

```
level: 3 entry: 00 data:
00000000: a8 00 00 00 28 00 01 00  01 00 00 00 10 01 00 00   ....(... ........
00000010: 10 01 00 00 02 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000020: 00 00 00 00 00 00 00 00  98 b8 c4 b1 87 f9 cc 01   ........ ........
00000030: 98 b8 c4 b1 87 f9 cc 01  98 b8 c4 b1 87 f9 cc 01   ........ ........
00000040: 98 b8 c4 b1 87 f9 cc 01  10 00 00 00 00 00 00 00   ........ ........
00000050: 20 05 00 00 00 00 00 00  00 00 00 00 00 00 00 00    ....... ........
00000060: ac 74 c5 c1 01 00 00 00  00 00 00 00 00 00 00 00   .t...... ........
00000070: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000080: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000090: 01 00 00 00 00 00 00 00  01 00 00 00 00 00 00 00   ........ ........
000000a0: 00 00 00 00 00 00 00 00                            ........

level: 3 entry: 00 size                     : 168
level: 3 entry: 00 unknown1a                : 0x0028
level: 3 entry: 00 unknown1b                : 0x0001
```

```
level: 3 entry: 00 unknown2                : 0x00000001
level: 3 entry: 00 unknown3                : 0x00000110
level: 3 entry: 00 unknown4                : 0x00000110
level: 3 entry: 00 unknown5                : 0x00000002
level: 3 entry: 00 unknown6                : 0x00000000
level: 3 entry: 00 number of values        : 0
```

4.3. Metadata table allocation entry

The second metadata table entry contains table allocation information.

The metadata table allocation entry is 32 bytes of size and consists of:

offset	**size**	**value**	**description**
0	4	32	Size Including the the size value
4	4		Unused table data offset Offset inside block relative from the end of the first table entry
8	4		Unused table data size
12	4	0x00000000 0x00000200 0x00000301	Unknown (flags?) 0x0200 => has unused data?
16	4		Value entry offsets array start offset Offset inside block relative from the end of the first table entry
20	4		Number of values in the metadata table
24	4		Value entry offsets array end offset Offset inside block relative from the end of the first table entry
28	4		Unknown (empty value)

4.4. Metadata table value entry

The third and later metadata table value entries contain a metadata value.

A metadata table value entry is variable of size and consists of:

offset	**size**	**value**	**description**
0	4		Size Including the the size value
4	2		Identifier offset Offset relative from the start of the table entry
6	2		Identifier size
8	2		Value flags See section: 4.4.1 Metadata table value

offset	size	value	description
10	2		Value offset Offset relative from the start of the table entry
12	4		Value size

Note that the identifier seems to be used as the key within a B-tree.

4.4.1. Metadata table value entry flags

Value	Identifier	Description
0x0002		Has not identifier Only used for the last value in a B-tree node?
0x0004		missing checksum?
0x0008		value data contains a table?

4.5. Metadata table unused data

The metadata table allocation entry contains the location of the metadata table unused data.

Note that the metadata table unused data can contain remnant data.

4.6. Metadata table value entry offsets array

The metadata table allocation entry contains the location of the metadata table value entry offsets array (or value entry offsets array).

The value entry offsets array entry is 4 bytes of size and contains:

offset	size	value	description
0	4		Value entry offset Offset inside block relative from the end of the first table entry

The value entry offsets array depict the location and order of the table values.

4.7. Metadata table trailing data

Note that there seems to sometimes be remnant data stored after the value offsets array. These look like previous versions of the value offsets array data.

5. Level 0 metadata block data

The level 0 metadata block consists of:

- metadata block header
- level 0 metadata block data header
- level 0 metadata block data value 1
- level 0 metadata block data value 2

Note always block number 0x1e? 2 backups at the end of the volume?

5.1. Level 0 metadata block data header

The level 0 metadata block data header is 112 bytes of size and consists of:

offset	size	value	description
48	16		Identifier Contains a GUID
64	8		Unknown (empty values)
72	4	0x01	Unknown (Number of values? Primary metadata level 1 block number?)
76	4		Unknown (Value offset?)
80	4	0xa0	Value offset 1 Relative from the start of the block
84	4	0x02	Unknown (number of value 1 ?)
88	4	0xb0	Value offset 2 Relative from the start of the block
92	4	0x18	Value 2 size
96	64		Unknown (empty values)

```
02178030  1f 1e a3 0c 55 36 4d 46  b1 f1 ae cf 0f c9 be e8  |....U6MF........|
02178040  00 00 00 00 00 00 00 00  01 00 00 00 00 00 00 00  |................|
02178050  a0 00 00 00 02 00 00 00  b0 00 00 00 18 00 00 00  |................|
02178060  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|

offset
size
```

```
00078030  84 18 cf 97 80 0f a1 45  97 0c 4f 48 24 86 91 d7  |.......E..OH$...|
00078040  00 00 00 00 00 00 00 00  01 00 00 00 00 00 00 00  |................|
00078050  a0 00 00 00 02 00 00 00  b0 00 00 00 18 00 00 00  |................|
00078060  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
```

5.2. Level 0 metadata block data value 1

Value 1

offset	size	value	description
160	8		Primary metadata level 1 block number

offset	size	value	description
			Relative from the start of the volume
168	8		Secondary metadata level 1 block number Relative from the start of the volume

```
021780a0   34 0a 00 00 00 00 00 00   15 79 00 00 00 00 00 00   |4.......y......|
```

```
000780a0   67 01 00 00 00 00 00 00   7c 0f 00 00 00 00 00 00   |g.......|.......|
```

Primary and secondary are back-ups from one and other. Should be the same on a non-dirty volume.

5.3. Level 0 metadata block data value 2

Value 2 (self extent? Object identifier)

offset	size	value	description
176	8		Block number
184	8		Flags?
192	8		Checksum?

```
021780b0   1e 00 00 00 00 00 00 00   00 00 02 08 08 00 00 00   |................|
021780c0   33 df cc 4f 6a dd 5c 13   00 00 00 00 00 00 00 00   |3..Oj.\.........|
```

```
000780b0   1e 00 00 00 00 00 00 00   00 00 02 08 08 00 00 00   |................|
000780c0   f8 b4 ea e4 5e fe 12 93   00 00 00 00 00 00 00 00   |....^...........|
```

Copies at end of volume ?

```
fe0f4000   fd ef 03 00 00 00 00 00   00 00 00 00 00 00 00 00   |................|
fe0f4010   00 00 00 00 00 00 00 00   00 00 00 00 00 00 00 00   |................|
fe0f4020   01 00 00 00 00 00 00 00   00 00 00 00 00 00 00 00   |................|
fe0f4030   1f 1e a3 0c 55 36 4d 46   b1 f1 ae cf 0f c9 be e8   |....U6MF........|
fe0f4040   00 00 00 00 00 00 00 00   01 00 00 00 00 00 00 00   |................|
fe0f4050   a0 00 00 00 02 00 00 00   b0 00 00 00 18 00 00 00   |................|
fe0f4060   00 00 00 00 00 00 00 00   00 00 00 00 00 00 00 00   |................|
*
fe0f40a0   34 0a 00 00 00 00 00 00   15 79 00 00 00 00 00 00   |4.......y......|

fe0f40b0   fd ef 03 00 00 00 00 00   00 00 02 08 08 00 00 00   |................|
fe0f40c0   f4 44 39 bc d6 f2 4d 7d   00 00 00 00 00 00 00 00   |.D9...M}........|
fe0f40d0   00 00 00 00 00 00 00 00   00 00 00 00 00 00 00 00   |................|
```

```
fe0f8000   fe ef 03 00 00 00 00 00   00 00 00 00 00 00 00 00   |................|
fe0f8010   00 00 00 00 00 00 00 00   00 00 00 00 00 00 00 00   |................|
fe0f8020   01 00 00 00 00 00 00 00   00 00 00 00 00 00 00 00   |................|
fe0f8030   1f 1e a3 0c 55 36 4d 46   b1 f1 ae cf 0f c9 be e8   |....U6MF........|
fe0f8040   00 00 00 00 00 00 00 00   01 00 00 00 00 00 00 00   |................|
fe0f8050   a0 00 00 00 02 00 00 00   b0 00 00 00 18 00 00 00   |................|
fe0f8060  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
*
fe0f80a0  34 0a 00 00 00 00 00 00  15 79 00 00 00 00 00 00  |4.......y.......|
fe0f80b0  fe ef 03 00 00 00 00 00  00 00 02 08 08 00 00 00  |................|
fe0f80c0  aa 96 43 c4 64 29 67 4e  00 00 00 00 00 00 00 00  |..C.d)gN........|
fe0f80d0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
```

6. Level 1 metadata block data

The level 1 metadata block data is X bytes of size and consists of:

offset	size	value	description
48	4		Unknown (empty values)
52	2		Unknown
54	2		Unknown
56	4		Table header offset?
60	4		Table entry size
64	8		Sequence number?
72	16		Unknown (empty values)
88	4		Number of block descriptors
92	4 x number		Array of 32-bit block descriptor offsets
...	...		Unknown (empty values)

The self block descriptor is defined before the first block descriptor defined by the offset in the array.

offset	size	value	description
128	8		Block number
132	8		Unknown
140	8		Checksum

```
049d0000  34 0a 00 00 00 00 00 00  05 00 00 00 00 00 00 00  |4...............|
049d0010  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
049d0020  01 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|

offset
size
049d0030  00 00 00 00 01 00 01 00  80 00 00 00 18 00 00 00  |................|
049d0040  05 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|

number of values
value offset
049d0050  00 00 00 00 00 00 00 00  06 00 00 00 98 00 00 00  |................|
049d0060  b0 00 00 00 c8 00 00 00  e0 00 00 00 f8 00 00 00  |................|
049d0070  10 01 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|

extent for self ?
* block number
* unknown (flags)
* checksum ?
049d0080  34 0a 00 00 00 00 00 00  00 00 02 08 08 00 00 00  |4...............|
049d0090  d7 c6 d6 69 fb 7e 10 cb                           |...i.~..:.......|

extent for ?
* block number
* unknown
* checksum ?
049d0090                           3a 01 00 00 00 00 00 00  |...i.~..:.......|
049d00a0  00 00 02 08 08 00 00 00  18 4d ee 6a 9e 50 e3 b9  |.........M.j.P..|

049d00b0  22 00 00 00 00 00 00 00  00 00 02 08 08 00 00 00  |"...............|
049d00c0  ac 6a f4 2f c9 25 ce 5a                           |.j./.%.Z(.......|

049d00c0                           28 00 00 00 00 00 00 00  |.j./.%.Z(.......|
049d00d0  00 00 02 08 08 00 00 00  1a c7 03 03 4d d3 59 e2  |...........M.Y.|

049d00e0  29 00 00 00 00 00 00 00  00 00 02 08 08 00 00 00  |)...............|
049d00f0  ec 4d 1f 93 16 0f 0c 67                           |.M.....g@.......|

049d00f0                           40 01 00 00 00 00 00 00  |.M.....g@.......|
049d0100  00 00 02 08 08 00 00 00  df 73 3a 0c 1c f7 9a e3  |.........s:.....|

049d0110  3c 01 00 00 00 00 00 00  00 00 02 08 08 00 00 00  |<...............|
049d0120  43 f9 75 45 e1 b9 98 e0                           |C.uE............|

049d0120                           00 00 00 00 00 00 00 00  |C.uE............|
049d0130  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
```

Block numbers not always the same between primary and secondary level 2 block? At least runtime.

7. Level 2 metadata block data

Different types of metadata for different object identifiers?

Every level 2 metadata block contains a metadata table.

7.1. Table value of size 0x50

Seen in level 2 metadata with object identifier 0x000c

```
level: 2 value size                         : 80
level: 2 identifier data offset             : 0x0010
level: 2 identifier data size               : 16
level: 2 flags                              : 0x0000
level: 2 data offset                        : 0x0010
level: 2 data size                          : 64
level: 2 identifier data:
00000000: 00 00 00 00 00 00 00 00  28 00 00 00 00 00 00 00   ........ (.......

level: 2 data:
00000000: 00 00 00 00 00 00 00 00  28 00 00 00 00 00 00 00   ........ (.......
00000010: 40 00 00 00 28 00 00 00  00 00 00 00 02 00 00 00   @...(... ........
00000020: 20 00 00 00 02 00 00 00  00 00 00 00 00 00 00 00    ....... ........
00000030: 38 00 00 00 08 00 00 00  ff ff ff ff fc 00 00 00   8....... ........
```

Seen in level 2 metadata with object identifier 0x000e

```
level: 2 value size                         : 80
level: 2 identifier data offset             : 0x0010
level: 2 identifier data size               : 16
level: 2 flags                              : 0x0000
level: 2 data offset                        : 0x0010
level: 2 data size                          : 64
level: 2 identifier data:
00000000: 00 00 00 00 00 00 00 00  00 80 00 00 00 00 00 00   ........ ........

level: 2 data:
00000000: 00 00 00 00 00 00 00 00  00 80 00 00 00 00 00 00   ........ ........
00000010: 40 00 00 00 08 00 00 00  0c 00 00 00 06 00 00 00   @....... ........
00000020: 01 00 00 00 06 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000030: 38 00 00 00 08 00 00 00  81 00 00 00 00 00 00 00   8....... ........
```

7.2. Table value of size 0x68

Seen in level 2 metadata with object identifier 0x0001

```
level: 2 value size                         : 104
level: 2 identifier data offset             : 0x0010
level: 2 identifier data size               : 4
level: 2 flags                              : 0x0000
level: 2 data offset                        : 0x0018
level: 2 data size                          : 80
level: 2 identifier data:
00000000: 04 00 00 00                                        ....

level: 2 data:
00000000: 50 00 00 00 18 00 00 00  00 00 00 00 00 00 00 00   P....... ........
00000010: 00 00 00 00 00 00 00 00  38 00 00 00 01 00 00 00   ........ 8.......
00000020: 00 00 00 00 04 00 00 00  04 00 00 00 ff ff ff ff   ........ ........
00000030: 00 00 00 00 00 00 00 00  00 00 00 00 00 40 00 00   ........ .....@..
00000040: ff ff ff ff 00 00 00 00  01 00 00 00 4b 00 00 00   ........ ....K...
```

7.3. Table value of size 0xc8

Seen in level 2 metadata with object identifier 0x000d

```
level: 2 value size                         : 200
level: 2 identifier data offset             : 0x0010
level: 2 identifier data size               : 16
level: 2 flags                              : 0x0000
level: 2 data offset                        : 0x0010
level: 2 data size                          : 184
level: 2 identifier data:
00000000: 00 00 00 00 00 00 00 00  00 10 00 00 00 00 00 00   ........ ........

level: 2 data:
00000000: 00 00 00 00 00 00 00 00  00 10 00 00 00 00 00 00   ........ ........
00000010: b8 00 00 00 00 04 00 00  02 00 00 00 dc 03 00 00   ........ ........
00000020: 5a 00 00 00 85 03 00 00  00 00 00 00 00 00 00 00   Z....... ........
```

```
00000030: 38 00 00 00 80 00 00 00  ff ff ff ff 03 00 00 00   8....... ........
00000040: 00 00 00 02 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000050: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000060: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000070: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000080: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000090: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
000000a0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
000000b0: 00 00 00 80 00 00 00 00                            ........
```

```
level: 2 value size                               : 200
level: 2 identifier data offset                   : 0x0010
level: 2 identifier data size                     : 16
level: 2 flags                                    : 0x0000
level: 2 data offset                              : 0x0010
level: 2 data size                                : 184
level: 2 identifier data:
00000000: 00 70 00 00 00 00 00 00  00 10 00 00 00 00 00 00   .p...... ........

level: 2 data:
00000000: 00 70 00 00 00 00 00 00  00 10 00 00 00 00 00 00   .p...... ........
00000010: b8 00 00 00 00 04 00 00  02 00 00 00 ff 03 00 00   ........ ........
00000020: 00 00 00 00 ff 03 00 00  00 00 00 00 00 00 00 00   ........ ........
00000030: 38 00 00 00 80 00 00 00  00 00 00 00 00 00 00 00   8....... ........
00000040: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000050: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000060: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000070: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000080: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000090: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
000000a0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
000000b0: 00 00 00 00 00 00 00 80                            ........
```

8. Block descriptors

TODO

8.1. Block descriptor metadata table entry

The block descriptor metadata table entry is variable of size and consists of:

offset	**size**	**value**	**description**
0	4		Size Including the the size value
4	2	0x0010	Identifier offset
6	2		Identifier size
8	2	0x0000	Value flags
10	2		Value offset
12	4		Value size
Identifier			
16	...		Object identifier?

offset	size	value	description
			See section: 3.1.1 Object identifiers
Value data			
…	...		Block descriptor data

8.2. Block descriptor

The block descriptor is variable of size and consists of:

offset	size	value	description
0	8		Block number
8	8	0x808020000	Unknown (flags?)
16	8		Checksum
If value data size == 48			
24	8		Unknown (empty values)
32	4	0x00000008	Unknown
36	4	0x00000008	Unknown
40	8	0x00000000 0x00000001 0x00000500	Unknown (parent object identifier?)

9. Level 3 metadata block data

Uses table based approach as in level 2

TODO

10. Level 3 metadata - volume

Value	Identifier	Description
0x00000510		Volume name
0x00000520		Volume information
0x00000530		Volume object identifier
0x00000540		Volume metadata data ranges?

10.1. Volume name

offset	size	value	description
0	4	...	Size Including the the size value
4	2	0x0010	Identifier offset

offset	size	value	description
6	2	8	Identifier size
8	2	0x0000	Value flags
10	2	0x0018	Value offset
12	4	...	Value size
Identifier			
16	8	0x00000510	Object identifier See section: 3.1.1 Object identifiers
Value data			
24	…		Volume name Contains an UTF-16 little-endian string without an end-of-string character

10.2. Volume information

offset	size	value	description
0	4	488	Size Including the the size value
4	2	0x0010	Identifier offset
6	2	8	Identifier size
8	2	0x0000	Value flags
10	2	0x0018	Value offset
12	4	464	Value size
Identifier			
16	8	0x00000520	Object identifier See section: 3.1.1 Object identifiers
Value data			
24	128		Unknown (empty values)
152	4	0x01010101 0x02010201	Unknown Same value as in volume header?
156	12		Unknown (empty values)
168	8		Unknown time Contains a FILETIME
176	8		Unknown (empty values)
184	8		Unknown time Contains a FILETIME
192	8		Unknown (empty values)
200	8	0x2000	Unknown
208	8	0x0050 0x0140	Unknown

offset	size	value	description
216	272		Unknown (empty values)

10.3. Volume object identifier

offset	size	value	description
0	4	376	Size Including the the size value
4	2	0x0010	Identifier offset
6	2	8	Identifier size
8	2	0x0000	Value flags
10	2	0x0018	Value offset
12	4	352	Value size
Identifier			
16	8	0x00000530	Object identifier See section: 3.1.1 Object identifiers
Value data			
24	328		Sub table with 1 value?

10.3.1. Volume object identifier – sub table value

offset	size	value	description
0	4	112	Size Including the the size value
4	2	0x0010	Identifier offset
6	2	16	Identifier size
8	2	0x0000	Value flags
10	2	0x0010	Value offset
12	4	97	Value size
Identifier / Value data			
16	8	0x00000000	Unknown (empty values)
24	8	0x00000008	Unknown
32	8	0x0064	Unknown
40	2	0x0001	Unknown (version?)
42	2	0x0802 0x0804	Unknown (flags?)
44	4	64	Data size Contains the size of the data that follows
48	16		Droid file identifier

offset	size	value	description
			Contains a GUID
64	16		Birth droid volume identifier Contains a GUID
80	16		Birth droid file identifier Contains a GUID
96	16		Birth droid domain identifier Contains a GUID

10.4. Volume object 0x0540

offset	size	value	description
0	4	376	Size Including the the size value
4	2	0x0010	Identifier offset
6	2	8	Identifier size
8	2	0x0000	Value flags
10	2	0x0018	Value offset
12	4	352	Value size
Identifier			
16	8	0x00000540	Object identifier See section: 3.1.1 Object identifiers
Value data			
24	352		Sub table with 1 value?

10.4.1. Volume object 0x0540 – sub table value

offset	size	value	description
0	4	80	Size Including the the size value
4	2	0x0010	Identifier offset
6	2	16	Identifier size
8	2	0x0000	Value flags
10	2	0x0010	Value offset
12	4	84	Value size
Identifier / Value data			
16	8	0x00000000	Unknown (empty values)
24	8	0x00000004	Unknown
32	8	0x006c	Unknown

offset	size	value	description
		0x0150	
40	2	0x0001	Unknown (version?)
42	2	0x8002	Unknown (flags?)
44	4	32	Data size Contains the size of the data that follows
48	32		Unknown (data runs?)

```
00000000: 00 00 00 00 00 00 00 00  04 00 00 00 00 00 00 00   ........ ........
00000010: 6c 00 00 00 00 00 00 00  01 00 02 08 20 00 00 00   l....... .... ...
00000020: 62 d8 97 f6 9c bc de 4d  41 26 9e 95 d2 76 f1 3b   b......M A&...v.;
00000030: 41 26 9e 95 d2 76 f1 3b  41 26 9e 95 d2 76 f1 3b   A&...v.; A&...v.;
```

11. Level 3 metadata – root directory

Value	Identifier	Description
0x00000010		Directory

Root directory table

- Table entry: 0
- Table entry: 1
- Table entry: 2 (Directory)
  - Sub table: $I30
- Table entry: 3 – # (Directory entry)

11.1. Directory

offset	size	value	description
0	4		Size Including the the size value
4	2	0x0010	Identifier offset
6	2	4	Identifier size
8	2	0x0008	Value flags
10	2	0x0018	Value offset
12	4		Value size
Identifier			
16	4	0x00000010	Object identifier See section: 3.1.1 Object identifiers
20	4	0x00000000	Alignment padding (empty values)
Value data			
24	328		Sub table

Sub table entry 2 (1st value entry)

- table entry 2 ($I30)
- table entry 3

11.1.1. Directory index ($I30)

offset	size	value	description
0	4	192	Size Including the the size value
4	2	0x0010	Identifier offset
6	2	20	Identifier size
8	2	0x0000	Value flags
10	2	0x0028	Value offset
12	4	148	Value size
Identifier			
16	8	0x00000094	Unknown
24	4	0x00000090	Unknown
28	8	“$I30”	Unknown
36	4	0x00000000	Alignment padding (empty values)
Value data			
40	4	0x00000000	Unknown
44	4	0x00000080	Unknown
48	4	0x0000000c	Unknown
52	4	0x00000030	Unknown
56	4	0x00010240	Unknown
60	4	0x00000016	Unknown
64	4	0x00000010	Unknown
68	4	0x00000070	Unknown
72	4	0x00000070	Unknown
76	72		Unknown (empty values)

11.1.2. Unknown

offset	size	value	description
0	4		Size Including the the size value
4	2	0x0010	Identifier offset

offset	size	value	description
6	2	14	Identifier size
8	2	0x0000	Value flags
10	2	0x0020	Value offset
12	4		Value size
Identifier			
16	8		Size of value data
24	6	0x000038	Unknown
30	2	0x0000	Alignment padding (empty values)
Value data			
32	4		Unknown (empty values)
36	4		Size
40	2	0x000c	Unknown
42	2	0x0001	Unknown
44	4	0x00000600	Unknown
48	12		Unknown (empty values)
60	...		

```
level: 5 data:
00000000: 00 00 00 00 7a 00 00 00  0c 00 01 00 00 06 00 00   ....z... ........
00000010: 00 00 00 00 00 00 00 00  00 00 00 00 14 00 00 00   ........ ........
00000020: 02 00 6c 00 04 00 00 00  00 00 14 00 00 00 00 20   ..l..... .......
00000030: 01 01 00 00 00 00 00 01  00 00 00 00 00 00 14 00   ........ ........
00000040: 00 00 00 10 01 01 00 00  00 00 00 05 12 00 00 00   ........ ........
00000050: 00 00 18 00 14 00 00 10  01 02 30 00 00 00 46 00   ........ ..0...F.
00000060: 69 00 6c 00 65 00 20 00  53 00 79 00 73 00 74 00   i.l.e. . S.y.s.t.
00000070: 65 00 6d 00 20 00 4d 00  65 00 74 00 61 00 64 00   e.m. .M. e.t.a.d.
00000080: 61 00 74 00 61 00 00 00  00 00 00 00               a.t.a... ....
```

```
level: 5 data:
00000000: 00 00 00 00 54 00 00 00  0c 00 01 00 00 06 00 00   ....T... ........
00000010: 00 00 00 00 00 00 00 00  00 00 00 00 02 01 00 00   ........ ........
00000020: 00 00 00 00 00 00 00 00  00 00 00 00 10 99 58 07   ........ ......X.
00000030: 80 fa ff ff 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000040: 00 00 00 00 38 de 2f 01  a0 f8 ff ff 58 2e ca 01   ....8./. ....X...
00000050: a0 f8 ff ff 01 00 00 07  a0 f8 30 00 00 00 2e 00   ........ ..0.....
00000060: 00 00 00 00                                        ....
```

11.2. Directory entry

11.2.1. Directory entry – types

Value	Identifier	Description
0x0000		File system metadata file
0x0001		File
0x0002		Directory

11.2.2. Directory entry – sub directory

offset	size	value	description
0	4		Size Including the the size value
4	2	0x0010	Identifier offset
6	2		Identifier size
8	2	0x0000	Value flags
10	2		Value offset
12	4	72	Value size
Identifier			
16	2	0x0030	Directory entry indicator
18	2	0x0002	Directory entry type
20	…		Directory entry name
Value data			
…	8		Object identifier
…	8		Unknown (empty values)
…	8		Creation date and time Contains a FILETIME
…	8		Last modification date and time (Also referred to as last written date and time) Contains a FILETIME
…	8		MFT entry last modification date and time Contains a FILETIME
…	8		Last access date and time Contains a FILETIME
…	8		Unknown (empty value)
…	8		Unknown (empty value)
…	4		File attribute flags

offset	size	value	description
…	4		Unknown (empty value)

11.2.3. Directory entry – file

offset	size	value	description
0	4		Size Including the the size value
4	2	0x0010	Identifier offset
6	2		Identifier size
8	2	0x0000	Value flags
10	2		Value offset
12	4	1040	Value size
Identifier			
16	2	0x0030	Directory entry indicator
18	2	0x0001	Directory entry type
20	…		Directory entry name
Value data			
…	8		

```
value size                                       : 1088
identifier data offset                           : 0x0010
identifier data size                             : 32
flags                                            : 0x0000
data offset                                      : 0x0030
data size                                        : 1040
identifier data:
00000000: 30 00 01 00 4d 00 79 00  46 00 69 00 6c 00 65 00   0...M.y. F.i.l.e.
00000010: 2e 00 74 00 78 00 74 00  2e 00 74 00 78 00 74 00   ..t.x.t. ..t.x.t.

Attribute type?
file entry

level: 0 entry: 00 data:
00000000: a8 00 00 00 28 00 01 00  00 00 00 00 10 01 00 00   ....(... ........
00000010: 10 01 00 00 02 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000020: 00 00 00 00 00 00 00 00                            ........ c7[..;..

time stamps
file attribute flags?

00000020:                          63 37 5b a9 c5 3b cd 01   ........ c7[..;..
00000030: d5 ee 2f b8 c5 3b cd 01  d5 ee 2f b8 c5 3b cd 01   ../..;.. ../..;..
00000040: 63 37 5b a9 c5 3b cd 01  20 00 00 00 00 00 00 00   c7[..;..  .......
00000050: 00 06 00 00 00 00 00 00  01 00 00 00 00 00 00 00   ........ ........
00000060: 2d 30 22 8b 01 00 00 00  18 00 00 00 00 00 00 00   -0"..... ........
```

```
00000070: 00 00 01 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000080: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000090: 00 00 00 00 00 00 00 00  01 00 00 00 00 00 00 00   ........ ........
000000a0: 00 00 00 00 00 00 00 00                            ........

file size

level: 0 entry: 00 size                           : 168
level: 0 entry: 00 unknown1a                      : 0x0028
level: 0 entry: 00 unknown1b                      : 0x0001
level: 0 entry: 00 unknown2                       : 0x00000000
level: 0 entry: 00 unknown3                       : 0x00000110
level: 0 entry: 00 unknown4                       : 0x00000110
level: 0 entry: 00 unknown5                       : 0x00000002
level: 0 entry: 00 number of values               : 0

level: 0 entry: 01 data:
00000000: 20 00 00 00 a0 01 00 00  d4 00 00 00 00 02 00 00    ....... ........
00000010: 74 02 00 00 01 00 00 00  78 02 00 00 00 00 00 00   t....... x.......

level: 0 entry: 01 size                           : 32
level: 0 entry: 01 unknown1                       : 0x000001a0
level: 0 entry: 01 unknown2                       : 0x000000d4
level: 0 entry: 01 unknown3                       : 0x00000200
level: 0 entry: 01 unknown4                       : 0x00000274
level: 0 entry: 01 unknown5                       : 0x00000001
level: 0 entry: 01 unknown6                       : 0x00000278
level: 0 entry: 01 unknown7                       : 0x00000000

level: 0 entry: 02 size                           : 384

level: 0 value size                               : 384
level: 0 identifier data offset                   : 0x0010
level: 0 identifier data size                     : 14
level: 0 flags                                    : 0x0008
level: 0 data offset                              : 0x0020
level: 0 data size                                : 352
level: 0 identifier data:
00000000: 60 01 00 00 00 00 00 00  80 00 00 00 00 00         `....... ......

level: 0 data:
...

level: 1 entry: 00 size                  : 136
level: 1 entry: 00 unknown1a             : 0x0028
level: 1 entry: 00 unknown1b             : 0x0001
level: 1 entry: 00 unknown2              : 0x00000001
level: 1 entry: 00 unknown3              : 0x00000120
level: 1 entry: 00 unknown4              : 0x00000120
level: 1 entry: 00 unknown5              : 0x00000002
level: 1 entry: 00 number of values      : 0

level: 1 entry: 01 data:
00000000: 20 00 00 00 50 00 00 00  84 00 00 00 00 02 00 00    ...P... ........
00000010: d4 00 00 00 01 00 00 00  d8 00 00 00 00 00 00 00   ........ ........

level: 1 entry: 01 size                  : 32
level: 1 entry: 01 unknown1              : 0x00000050
level: 1 entry: 01 unknown2              : 0x00000084
level: 1 entry: 01 unknown3              : 0x00000200
```

```
level: 1 entry: 01 unknown4                : 0x000000d4
level: 1 entry: 01 unknown5                : 0x00000001
level: 1 entry: 01 unknown6                : 0x000000d8
level: 1 entry: 01 unknown7                : 0x00000000

level: 1 entry: 02 size                    : 48
value data:
00000000: 30 00 00 00 10 00 10 00  00 00 10 00 20 00 00 00   0....... .... ...
00000010: 00 00 00 00 00 00 00 00  04 00 00 00 00 00 00 00   ........ ........
00000020: 6c 01 00 00 00 00 00 00  00 00 00 08 00 00 00 00   l....... ........

level: 1 value size                        : 48
level: 1 identifier data offset            : 0x0010
level: 1 identifier data size              : 16
level: 1 flags                             : 0x0000
level: 1 data offset                       : 0x0010
level: 1 data size                         : 32
level: 1 identifier data:
00000000: 00 00 00 00 00 00 00 00  04 00 00 00 00 00 00 00   ........ ........

level: 1 data:
00000000: 00 00 00 00 00 00 00 00  04 00 00 00 00 00 00 00   ........ ........
00000010: 6c 01 00 00 00 00 00 00  00 00 00 08 00 00 00 00   l....... ........

data block number

level: 1 entry: 03 size                    : 0

level: 0 entry: 03 size                    : 0
```

```
level: 3 value size                        : 1104
level: 3 identifier data offset            : 0x0010
level: 3 identifier data size              : 46
level: 3 flags                             : 0x000c
level: 3 data offset                       : 0x0040
level: 3 data size                         : 1040
level: 3 identifier data:
00000000: 30 00 01 00 4e 00 65 00  77 00 20 00 54 00 65 00   0...N.e. w. .T.e.
00000010: 78 00 74 00 20 00 44 00  6f 00 63 00 75 00 6d 00   x.t. .D. o.c.u.m.
00000020: 65 00 6e 00 74 00 2e 00  74 00 78 00 74 00         e.n.t... t.x.t.

level: 3 data:
00000000: a8 00 00 00 28 00 01 00  00 00 00 00 10 01 00 00   ....(... ........
00000010: 10 01 00 00 02 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000020: 00 00 00 00 00 00 00 00  85 b3 2b be 3c e3 ce 01   ........ ..+.<...
00000030: 85 b3 2b be 3c e3 ce 01  85 b3 2b be 3c e3 ce 01   ..+.<... ..+.<...
00000040: 85 b3 2b be 3c e3 ce 01  20 00 00 00 00 00 00 00   ..+.<...  .......
00000050: 00 06 00 00 00 00 00 00  01 00 00 00 00 00 00 00   ........ ........
00000060: f1 0f 05 76 01 00 00 00  00 00 00 00 00 00 00 00   ...v.... ........
00000070: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000080: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000090: 00 00 00 00 00 00 00 00  01 00 00 00 00 00 00 00   ........ ........
000000a0: 00 00 00 00 00 00 00 00  20 00 00 00 a0 01 00 00   ........  .......
000000b0: d4 00 00 00 00 02 00 00  74 02 00 00 01 00 00 00   ........ t.......
000000c0: 78 02 00 00 00 00 00 00  80 01 00 00 10 00 0e 00   x....... ........
000000d0: 08 00 20 00 60 01 00 00  60 01 00 00 00 00 00 00   .. .`... `.......
000000e0: 80 00 00 00 00 00 00 00  88 00 00 00 28 00 01 00   ........ ....(...
000000f0: 01 00 00 00 20 01 00 00  20 01 00 00 02 00 00 00   .... ...  .......
00000100: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
```

```
00000110: 01 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000120: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
...
00000160: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000170: 20 00 00 00 20 00 00 00  b8 00 00 00 00 02 00 00    ... ... ........
00000180: d8 00 00 00 00 00 00 00  d8 00 00 00 00 00 00 00   ........ ........
00000190: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
...
00000300: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000310: 00 00 00 00 00 00 00 00  00 00 00 00 20 00 00 00   ........ .... ...
00000320: 38 00 00 00 28 00 20 e0  01 00 00 00 06 00 00 00   8...(. . ........
00000330: 06 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000340: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000350: 00 00 00 00 00 00 00 00  20 00 00 00 20 00 00 00   ........  ... ...
00000360: 98 00 00 00 00 02 00 00  b8 00 00 00 00 00 00 00   ........ ........
00000370: b8 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000380: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
...
00000400: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........

level: 3 data:
00000000: a8 00 00 00 28 00 01 00  00 00 00 00 10 01 00 00   ....(... ........
00000010: 10 01 00 00 02 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000020: 00 00 00 00 00 00 00 00  85 b3 2b be 3c e3 ce 01   ........ ..+.<...
00000030: 85 b3 2b be 3c e3 ce 01  d8 eb 91 c1 3c e3 ce 01   ..+.<... ....<...
00000040: 85 b3 2b be 3c e3 ce 01  20 00 00 00 00 00 00 00   ..+.<...  .......
00000050: 00 06 00 00 00 00 00 00  01 00 00 00 00 00 00 00   ........ ........
00000060: f1 0f 05 76 01 00 00 00  00 00 00 00 00 00 00 00   ...v.... ........
00000070: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000080: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000090: 00 00 00 00 00 00 00 00  01 00 00 00 00 00 00 00   ........ ........
000000a0: 00 00 00 00 00 00 00 00  20 00 00 00 a0 01 00 00   ........  .......
000000b0: d4 00 00 00 00 02 00 00  74 02 00 00 01 00 00 00   ........ t.......
000000c0: 78 02 00 00 00 00 00 00  80 01 00 00 10 00 0e 00   x....... ........
000000d0: 08 00 20 00 60 01 00 00  60 01 00 00 00 00 00 00   .. .`... `.......
000000e0: 80 00 00 00 00 00 00 00  88 00 00 00 28 00 01 00   ........ ....(...
000000f0: 01 00 00 00 20 01 00 00  20 01 00 00 02 00 00 00   .... ...  .......
00000100: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000110: 01 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000120: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
...
00000160: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000170: 20 00 00 00 20 00 00 00  b8 00 00 00 00 02 00 00    ... ... ........
00000180: d8 00 00 00 00 00 00 00  d8 00 00 00 00 00 00 00   ........ ........
00000190: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
...
00000300: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000310: 00 00 00 00 00 00 00 00  00 00 00 00 20 00 00 00   ........ .... ...
00000320: 38 00 00 00 28 00 20 e0  01 00 00 00 06 00 00 00   8...(. . ........
00000330: 06 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000340: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000350: 00 00 00 00 00 00 00 00  20 00 00 00 20 00 00 00   ........  ... ...
00000360: 98 00 00 00 00 02 00 00  b8 00 00 00 00 00 00 00   ........ ........
00000370: b8 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000380: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
...
00000400: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
```

11.2.4. Notes

```
value size                                : 112
identifier data offset                    : 0x0010
identifier data size                      : 18
flags                                     : 0x0000
data offset                               : 0x0028
data size                                 : 72
identifier data:
00000000: 30 00 02 00 43 00 75 00  72 00 73 00 6f 00 72 00   0...C.u. r.s.o.r.
00000010: 73 00                                              s.

Attribute type?
directory entry

data:
00000000: 03 07 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000010: bb 3c a9 d2 4a 3d cd 01  cd 49 cf d2 4a 3d cd 01   .<..J=.. .I..J=..
00000020: cd 49 cf d2 4a 3d cd 01  cd 49 cf d2 4a 3d cd 01   .I..J=.. .I..J=..
00000030: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ........ ........
00000040: 00 00 00 10 00 00 00 00                            ........
```

12. Level 3 metadata – sub directory

Value	Identifier	Description

Sub directory table

- Table entry: 0
- Table entry: 1
- Table entry: 2 – #
    - identifier starting with 0x20 – sub metadata blocks
    - identifier starting with 0x30 – block descriptor

```
libfsrefs_block_descriptors_initialize: level: 4 value: 00 identifier data:
00000000: 20 00 00 80 00 00 00 00  01 07 00 00 00 00 00 00    ....... ........
00000010: 51 00 00 00 00 00 00 00                            Q.......
```

13. Notes

```
level: 3 value size                       : 256
level: 3 identifier data offset           : 0x0010
level: 3 identifier data size             : 16
level: 3 flags                            : 0x0000
level: 3 data offset                      : 0x0020
level: 3 data size                        : 220
level: 3 identifier data:
00000000: dc 00 00 00 00 00 00 00  01 00 00 00 f1 0f 05 76   ........ .......v

level: 3 data:
00000000: f1 0f 05 76 01 00 00 00  dc 00 00 00 01 00 04 80   ...v.... ........
00000010: a4 00 00 00 b4 00 00 00  00 00 00 00 14 00 00 00   ........ ........
```

```
00000020: 02 00 90 00 06 00 00 00  00 00 18 00 ff 01 1f 00   ........ ........
00000030: 01 02 00 00 00 00 00 05  20 00 00 00 20 02 00 00   ........  ... ...
00000040: 00 00 14 00 ff 01 1f 00  01 01 00 00 00 00 00 05   ........ ........
00000050: 12 00 00 00 00 00 18 00  ff 01 1f 00 01 02 00 00   ........ ........
00000060: 00 00 00 05 20 00 00 00  20 02 00 00 00 00 18 00   .... ...  .......
00000070: a9 00 12 00 01 02 00 00  00 00 00 05 20 00 00 00   ........ .... ...
00000080: 21 02 00 00 00 00 18 00  02 00 00 00 01 02 00 00   !....... ........
00000090: 00 00 00 05 20 00 00 00  21 02 00 00 00 00 14 00   .... ... !.......
000000a0: a9 00 12 00 01 01 00 00  00 00 00 01 00 00 00 00   ........ ........
000000b0: 01 02 00 00 00 00 00 05  20 00 00 00 20 02 00 00   ........  ... ...
000000c0: 01 05 00 00 00 00 00 05  15 00 00 00 21 95 53 70   ........ ....!.Sp
000000d0: 1f 60 9d 5a 0a d1 cb 40  01 02 00 00                .`.Z...@ ....
```

13.0.1. X

```
value size                                       : 144
identifier data offset                           : 0x0010
identifier data size                             : 14
flags                                            : 0x0000
data offset                                      : 0x0020
data size                                        : 108
identifier data:
00000000: 6c 00 00 00 00 00 00 00  38 00 00 00 00 00         l....... 8.....

data:
00000000: 00 00 00 00 60 00 00 00  0c 00 01 00 00 06 00 00   ....`... ........
00000010: 00 00 00 00 00 00 00 00  00 00 00 00 bb 3c a9 d2   ........ .....<..
00000020: 4a 3d cd 01 bb 3c a9 d2  4a 3d cd 01 bb 3c a9 d2   J=...<.. J=...<..
00000030: 4a 3d cd 01 bb 3c a9 d2  4a 3d cd 01 00 00 00 00   J=...<.. J=......
00000040: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 10   ........ ........
00000050: 00 00 00 00 07 00 00 00  00 00 30 00 02 00 43 00   ........ ..0...C.
00000060: 75 00 72 00 73 00 6f 00  72 00 73 00               u.r.s.o. r.s.
```

14. Notes

Layers:

- object table
- directory
- file metadata
- file extent

ministore, B+ tables
checkpoints

sparse “allocators”

allocators instead of bitmaps

embedded tables

table schema, relationships

multiple file tables

Protogon object table
Protogon attribute
Protogon index
Protogon files
Protogon file id
Protogon security

Ministore
Ministore volume

- LA
- MA
- SA
- ObjT (object table)
- SchT
- PaCh
- VC

thin provisioning

sms (synchronous ministore) page

Change journal

Global table
checkpoint

logic cluster number (LCN)

Crc32 Castagnoli   0x82F63B78
Crc64 ECMA-182   0x9A6C9329AC4BC9B5

WBU ?

Appendix A. References

[BALLENTHIN12]
Title: The Microsoft ReFS On-Disk Layout
Author(s): Willi Ballenthin
Date: 2012
URL: http://www.williballenthin.com/forensics/refs/index.html

[MSDN]
Title: Building the next generation file system for Windows: ReFS
URL: http://blogs.msdn.com/b/b8/archive/2012/01/16/building-the-next-generation-file-system-for-windows-refs.aspx

[GREEN13]
Title: Resilient File System (ReFS)
Sub title: Analysis of the File System found on Windows Server 2012 and Windows 8.1
Author(s): Paul K. Green
Version: 0.6
Date: September 2013
URL: https://docs.google.com/uc?export=download&id=0B7_P1Njdyx3hdnNtYlpVZ2taaU0

Appendix B. GNU Free Documentation License

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