

Volume Shadow Snapshot (VSS)

Analysis the Windows NT VSS format

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Summary

As of Windows Vista the Volume Shadow Snapshot (VSS) stores persistent shadow copies on the local NTFS volume.

This document is intended as a working document for the Window NT VSS format. Which should allow existing Open Source forensic tooling to be able to process this type of volume format.

Document information

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Abstract: This document contains information about the Volume Shadow Snapshot (VSS) format

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Version

Version	Author	Date	Comments
0.0.1	J.B. Metz	March 2011	Initial version, based on earlier notes.
0.0.2	J.B. Metz	March 2011 April 2011	Changes after initial feedback by B. Schatz and new findings.
0.0.3	J.B. Metz	May 2011	Changes regarding block descriptors and Windows Vista.
0.0.4	J.B. Metz	November 2011 December 2011	Updates regarding block descriptors.
0.0.5	J.B. Metz	April 2012	Additional information.
0.0.6	J.B. Metz	May 2012	Additional information about bitmaps. Updates for Windows 8 Consumer Preview.
0.0.7	J.B. Metz	August 2012	Updates and corrections.
0.0.8	J.B. Metz	August 2012	Additional findings.
0.0.9	J.B. Metz	September 2012	Updates and corrections. Additional findings regarding overlays.
0.0.10	J.B. Metz	September 2012	Additional findings regarding catalog entries and corruption scenarios with thanks to R. Lee.
0.0.11	J.B. Metz	November 2012	Additional findings regarding Windows 2003 R2 (SP2).
0.0.12	J.B. Metz	May 2013	Small changes.

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1. Overview

As of Windows Vista the Volume Shadow Snapshot (VSS) stores persistent shadow copies on the local NTFS volume.

According to [MSDN] a shadow copy is a snapshot of a volume. A shadow copy can be part of a set which contains a collection of shadow copies of various volumes, taken at the same time.

Does a set always contains a single shadow copy per volume?

VSS can use different providers to store shadow copies, this document focuses on “Microsoft Software Shadow Copy provider 1.0”, which uses the GUID: b5946137-7b9f-4925-af80-51abd60b20d5. This provider stores the copies on the local volume using 16 KiB blocks.

VSS uses the GUID 3808876b-c176-4e48-b7ae-04046e6cc752 to identify its data or metadata files. VSS provides for several metadata files in “System Volume Information”:

- VSS catalog; stored in the metadata file named {%VSSGUID%}
- VSS store; stored in the metadata file named {%GUID%}{%VSSGUID%}

Where %VSSGUID% (_VSP_DIFF_AREA_FILE_GUID) contains the VSS identifier and %GUID% contains a time/MAC based GUID/UUID.

Characteristics	Description
Byte order	little-endian
Date and time values	FILETIME in UTC
Character string	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 2003 R2 (SP2)
- Windows Vista
- Windows 2008 server
- Windows 7
- Windows 8 (Consumer Preview)

2. Volume header

The VSS volume header is part of the NTFS volume header (or \$Boot metadata file). The VSS volume header data is stored at offset 7680 (0x1e00) of the volume and is at least 100 bytes in size (but probably 512 bytes, sector size) and consists of:

offset	size	value	description
0	16		VSS identifier GUID
16	4		Version
20	4	0x01	Record type

offset	size	value	description
24	8	0x1e00	Current offset The offset is relative to the start of the volume
32	8	0x1e00	Unknown (Next offset?) The offset is relative to the start of the volume
40	8		Unknown (empty value)
48	8		Catalog offset The offset is relative to the start of the volume 0 if no catalog
56	8		Maximum size 0 if unbounded
64	16		Volume identifier Contains a GUID
80	16		Shadow copy storage volume identifier Contains a GUID
96	4		Unknown
100	412		Unknown (empty values)

2.1. Version

Value	Identifier	Description
1		Windows Vista, 7
2		Windows 8

3. Catalog

The catalog contains information about the individual stores. The catalog consists of one or more catalog blocks. Each catalog block is 16384 (0x4000) bytes of size and consists of:

- catalog block header
- an array of catalog entries

The VSS catalog metadata files contains the catalog blocks stored directly after one-and-other.

If the volume does not contain a catalog when there are no snapshots (stored) but VSS is enabled.

3.1. Catalog block header

The catalog block header is 128 bytes of size and consists of:

offset	size	value	description
0	16		VSS identifier GUID

offset	size	value	description
16	4	0x01	Version
20	4	0x02	Record type
24	8		Relative (catalog block) offset The offset is relative to the start of the first catalog block
32	8		Current (catalog block) offset The offset is relative to the start of the volume
40	8		Next (catalog block) offset The offset is relative to the start of the volume. Contains 0 if this is the last block.
48	80		Unknown (empty values)

3.2. Catalog entry

Each catalog entry consists of a catalog entry type 0x02. A corresponding type 0x03 is required if the shadow copy is stored in a store, which is the case as of Windows Vista.

Note how does Windows 2003 R2 volumes store the snapshot data?

The type 0x02 and type 0x03 entries are not necessarily stored directly after one-and-other and can be scattered over the catalog. For now it is assumed that entry type 0x02 must be defined before entry type 0x03.

Also these entries are not necessarily stored in order of age.

There can be unused catalog entries (of type 0x01) as well. Empty catalog entries seem to consist entirely of 0-bytes.

3.2.1. Unused catalog entry (type 0x01)

An unused catalog entry (type 0x01) is 128 bytes of size and consists of:

offset	size	value	description
0	8	0x01	Catalog entry type
8	120		Unknown (empty values)

3.2.2. Catalog entry type 0x02

A catalog entry type 0x02 is 128 bytes of size and consists of:

Offset	size	value	description
0	8	0x02	Catalog entry type
8	8		Volume size

Offset	size	value	description
16	16		Store identifier GUID This GUID is used in the store filename
32	8		Unknown (Sequence number)
40	8		Unknown (Flags?) 0x40 => windows in vista and 7 0x440 => in windows 8 (file backup?)
48	8		Shadow copy creation time Contains a filetime
56	72		Unknown (empty values)

3.2.3. Catalog entry type 0x03

A catalog entry type 0x03 is 128 bytes of size and consists of:

offset	size	value	description
0	8	0x03	Catalog entry type
8	8		Store block list offset The offset is relative to the start of the volume
16	16		Store identifier GUID This GUID is used in the store filename
32	8		Store header offset The offset is relative to the start of the volume
40	8		Store block range list offset The offset is relative to the start of the volume
48	8		Store (current) bitmap offset The offset is relative to the start of the volume
56	8		NTFS (metadata) file reference
64	8		Allocated size
72	8		Store previous bitmap offset The offset is relative to the start of the volume or 0 if not used
80	8		Unknown Looks like store index but assumption does not hold
88	40		Unknown (empty)

4. Store

The store contains information about the shadow volume; it actually contains copies of previous versions of data blocks on the volume.

The stores must be applied starting with the most recent on top of the current volume. E.g. if there are 3 stores and we want to access the state of the oldest (number 1) we must first apply the changes in store 3 over the current volume, the changes in store 2 over the resulting volume, and finally the changes in store 1 over the resulting volume.

The store consists of;

- store header
- store block list
- store block range list
- store bitmaps
- data blocks

4.1. Store block header

The store block header is 128 bytes of size and consists of:

offset	size	value	description
0	16		VSS identifier GUID
16	4	0x01	Version
20	4		Record type
24	8		Relative (block) offset The offset is relative to the start of the store
32	8		Current (block) offset The offset is relative to the start of the volume
40	8		Next (block) offset The offset is relative to the start of the volume Contains 0 if this is the last block.
48	8		Size of store information Only used in first block header Should be 0 in other block headers
56	72		Unknown (empty value)

4.1.1. Store block record types

Value	Identifier	Description
0x0000		Unknown
0x0001		Volume header

Value	Identifier	Description
0x0002		Catalog block header
0x0003		Block descriptor list (Diff area table)
0x0004		Store header
0x0005		Store block ranges list
0x0006		Store bitmap

4.1.1.1. Notes

TODO: Are these values related to VSS_MGMT_OBJECT_TYPE?

0x0000	VSS_MGMT_OBJECT_UNKNOWN
0x0001	VSS_MGMT_OBJECT_VOLUME
0x0002	VSS_MGMT_OBJECT_DIFF_VOLUME
0x0003	VSS_MGMT_OBJECT_DIFF_AREA

4.2. Store information

The store information is stored directly after the store header.

The store information is variable of size and consists of:

offset	size	value	description
0	16		Unknown (identifier?) Contains a GUID
16	16		Shadow copy identifier Contains a GUID
32	16		Shadow copy set identifier Contains a GUID
48	4		Type
52	4		Provider
56	4		Attribute flags See section: 4.2.2 Store attribute flags
60	4		Unknown (empty values)
64	2		Operating machine string size Contains the number of bytes
66	(size)		Operating machine string Contains Unicode string without end-of-string character
...	2		Service machine string size Contains the number of bytes
...	(size)		Service machine string

offset	size	value	description
			Contains Unicode string without end-of-string character
...	...		Unknown (empty value)

Note the difference between the operating machine and the service machine is currently unknown.

4.2.1. Store types

Value	Identifier	Description
0x00000009	ApplicationRollback	Application rollback
0x0000000d	ClientAccessibleWriters	Client accessible writers

4.2.1.1. Notes

Or is the type inferred based on the flags?

Value	Identifier	Description
0x00000000	Backup	
0x00420009	ApplicationRollback	
	ClientAccessibleWriters	

4.2.2. Store attribute flags

[MSDN] refers to the store attribute flags as `_VSS_VOLUME_SNAPSHOT_ATTRIBUTES`.

Value	Identifier	Description
0x00000001	VSS_VOLSNAP_ATTR_PERSISTENT	Is persistent The shadow copy is persistent across reboots
0x00000002	VSS_VOLSNAP_ATTR_NO_AUTORECOVERY	Auto-recovery is disabled (Previously named: VSS_VOLSNAP_ATTR_READ_WRITE) Not shown by vssadmin
0x00000004	VSS_VOLSNAP_ATTR_CLIENT_ACCESSIBLE	Is client-accessible The specified shadow copy is a client-accessible.
0x00000008	VSS_VOLSNAP_ATTR_NO_AUTO_RELEASE	No auto release The shadow copy is not automatically deleted when the shadow copy requester process ends.
0x00000010	VSS_VOLSNAP_ATTR_NO_WRITERS	Has no writers No writers are involved in creating the shadow copy.
0x00000020	VSS_VOLSNAP_ATTR_TRANSPORTABLE	Is transportable The shadow copy is to be transported and therefore

Value	Identifier	Description
		should not be exposed locally.
0x00000040	VSS_VOLSNAP_ATTR_NOT_SURFACED	Not surfaced (not exposed) The shadow copy is not currently exposed.
0x00000080	VSS_VOLSNAP_ATTR_NOT_TRANSACTED	Not transacted The shadow copy is not transacted. Not shown by vssadmin
0x00010000	VSS_VOLSNAP_ATTR_HARDWARE_ASSISTED	(Provider) is hardware assisted Indicates that a given provider is a hardware provider.
0x00020000	VSS_VOLSNAP_ATTR_DIFFERENTIAL	(Provider) is differential Indicates that a given provider uses differential data or a copy-on-write mechanism to implement shadow copies.
0x00040000	VSS_VOLSNAP_ATTR_PLEX	(Provider) is PLEX Indicates that a given provider uses a PLEX or mirrored split mechanism to implement shadow copies.
0x00080000	VSS_VOLSNAP_ATTR_IMPORTED	Is imported The shadow copy of the volume was imported onto this machine.
0x00100000	VSS_VOLSNAP_ATTR_EXPOSED_LOCALLY	Is exposed locally The shadow copy is locally exposed.
0x00200000	VSS_VOLSNAP_ATTR_EXPOSED_REMOTELY	Is exposed remotely The shadow copy is remotely exposed.
0x00400000	VSS_VOLSNAP_ATTR_AUTORECOVER	Auto recovered Indicates that the writer will need to auto-recover the on post snapshot .
0x00800000	VSS_VOLSNAP_ATTR_ROLLBACK_RECOVERY	For rollback recovery Indicates that the writer will need to auto-recover the on post snapshot if the snapshot is used for rollback.
0x01000000	VSS_VOLSNAP_ATTR_DELAYED_POSTSNAPSHOT	Delayed post snapshot Reserved for system use Not shown by vssadmin
0x02000000	VSS_VOLSNAP_ATTR_TRANSACTIONAL_RECOVERY	Transactional NTFS (TxF) recovery required Indicates that Transactional NTFS (TxF) recovery should be enforced during shadow copy creation. Not shown by vssadmin

4.3. Store block list

The store block list contains information about the data block ranges used by the snapshot.

The store block list is stored in blocks of 16384 (0x4000) bytes. Each store block list block consists of:

- a store block header of type 3
- an array of store block descriptors

4.3.1. Block descriptor

The block descriptor is 32 bytes of size and consists of:

offset	size	value	description
0	8		Original data block offset The offset is relative to the start of the volume
8	8		Relative store data block offset The offset is relative to the start of the store lower bits used for different purpose?
16	8		Store data block offset The offset is relative to the start of the volume
24	4		Flags
28	4		Allocation bitmap Used if flag 0x02 is set, otherwise is should contain a value of 0

4.3.2. Store block descriptor flags

Value	Identifier	Description
0x00000001		Is forwarder The absolute offset is set to 0 and the relative offset maps to the original offset of the next block.
0x00000002		Overlay The block descriptor is an overlay. The allocation bitmap value contains information about the block fill.
0x00000004		Not used If set block is ignored.
0x00000008		Unknown
0x00000010		Unknown
0x00000020		Unknown
0x00000040		Unknown
0x00000080		Unknown

4.3.2.1. Notes

Note max flags 0xff?

If flags 0x01 not allowed 0x1a

If flags 0x02 not allowed 0x19

If flags 0x08 not allowed 0x03, allowed 0x10, 0x20, 0x40, 0x80

If flags 0x18

If flags 0x28 not allowed 0x10, 0xc0

If flags 0x48 not allowed 0x10, 0xa0

If flags 0x88 not allowed 0x60

0x00 => mode 0 ?

0x08 => mode 1

0x28 => mode 2

0x48 => mode 3

0x88 => mode 4

0x18 => mode 10 ?

0x88 related to journal RCRD ?

4.3.3. Successive block descriptors

Note that this section is not complete yet, since the meaning of several flags is unknown.

Successive block descriptors with the same original offset are handled differently based on their flags and position in the block list. The block list is scanned front to back.

For the new block descriptor

- If the not used flag is set (0x04):
 - Ignore the new block descriptor

- If the overlay flag (0x02) is not set:
 - If there is a corresponding block descriptor in the reverse block list:
Meaning that the original offset (of the new block descriptor) matches the relative offset of a forwarder block descriptor in the reverse block list.
 - Replace the original offset with that of the forwarder block descriptor in the reverse block list.
 - Remove the forwarder block descriptor from the reverse block list.
 - If the forwarder flag (0x01) (of the new block descriptor) is set:
 - If the original offset (of the new block descriptor) is the same as the relative offset:
 - Ignore the new block descriptor

- If no previous block descriptor was found:
 - Add the new block descriptor to the block list.
- Else:
 - If the overlay flag (0x02) is set:
The new block descriptor contains an overlay. The allocation bitmap contains information about which part of the block is used. Every bit in the allocation bitmap signifies a block of 512 bytes. The LSB in the allocation bitmap represent the first 512 bytes in the block.

Normally the relative offset is should not be 1, but this seems to be ignored if it is.

- If an existing overlay block descriptor was defined:
 - Extended the existing overlay.
Normally the relative offset should be 1 and the original offset should match that of the existing overlay block descriptor. If not these values seem to be ignored and the existing overlay is extended with the allocation bitmap in the new block descriptor.
- Else:
 - Replace the existing block descriptor. Existing overlay block descriptors are applied to the new block descriptor.
- If the forwarder flag (0x01) is set:
 - If no previous reverse block descriptor was found:
 - Add the new block descriptor to the reverse block list.
 - Else:
 - Replace the existing reverse block descriptor.

4.4. Store block range list

The store block range list contains information about the data block ranges used by the store itself. It is probably used to maintain these ranges on the volume layer, since the corresponding NTFS file entry data runs are applied on the file system layer.

The store block range list is stored in blocks of 16384 (0x4000) bytes. Each store block range list block consists of:

- a store block header of type 5
- an array of store block range list entries

4.4.1. Store block range entry

The store block range entry is 24 bytes of size and consists of:

offset	size	value	description
0	8		Store (block range start) offset The offset is relative to the start of the volume
8	8		Relative (block range start) offset The offset is relative to the start of the store
16	8		Block range size

4.5. Store bitmap

The store bitmap contains information about the allocation of blocks.

The store bitmap is stored in blocks of 16384 (0x4000) bytes. Each store bitmap block consists of:

- a store block header of type 6
- a bitmap

4.5.1. Store (current) bitmap data

Every bit in the store (current) bitmap represents a block of 16384 (0x4000) bytes, where the LSB is the first bit in a byte.

If a bit is set, the corresponding block is considered not in-use (or not allocated) by the store.

The use of this bitmap is described in section: 4.7 Reading snapshot data.

4.5.2. Store previous bitmap data

Every bit in the store previous bitmap represents a block of 16384 (0x4000) bytes, where the LSB is the first bit in a byte.

If a bit is set, the corresponding block is not in-use (or not allocated) by the previous store.

Note that the first store can also contain a previous bitmap if an older store before it was removed.

The use of this bitmap is described in section: 4.7 Reading snapshot data.

4.6. Store data block

The store data is stored in blocks of 16384 (0x4000) bytes.

4.7. Reading snapshot data

For the size of the data that will fit in the buffer:

- If the block offset has a corresponding block descriptor:
 - The data is defined by block descriptor and has a maximum size accordingly
 - If this is the active store and the block has an overlay:
 - If the overlay applies:
 - use the overlay block descriptor
 - If the forwarder flag (0x01) is set and there is a next store:
 - read the block from the next store using the relative store offset
 - Else:
 - read the block from the current volume using the store offset
- Else:
 - If there is a next store:
 - read the block from the next store
 - Else if the block offset has a corresponding reverse block descriptor:
 - read the block from the current volume
 - Else if the active store is the most recent (last) store and the block is flagged in the current bitmap and (the store has no previous bitmap or the block is flagged in the previous bitmap):
 - zero-fill the block
 - Else:
 - read the block from the current volume
- Increment the block offset with the size of the block data that was read

Note that on Windows the actual behavior of unused block is undefined. A read of a corresponding block will return successful but will not alter the buffer passed to the read. For sanitation purposes libvshadow will zero-fill the block.

5. Corruption scenarios

This chapter contains several corruption scenarios that have been encountered “in the wild”.

5.1. Catalog volume size out of bounds

Note that this currently considered a corruption scenario future findings may or may not prove otherwise.

The volume size of one of the catalog entries exceeds the size of the underlying volume and does not corresponds with the volume size defined by the rest of the catalog entries.

Libvshadow as of 20120915 detects this scenario it will return the corrupt value as store size but the volume size will be detected based on the NTFS volume headers if possible.

6. Notes

If the VSS_VOLSNAP_ATTR_NO_AUTORECOVERY flag is set in the shadow copy context, this means that auto-recovery is disabled, and no files can be excluded from the shadow copy.

The specified shadow copy is a client-accessible shadow copy that supports Shadow Copies for Shared Folders and should not be exposed.

The device files behave like the CreateFile() FILE_FLAG_NO_BUFFERING flags is set and can only be read in multitudes of the sector size.

Appendix A. References

[WHITFIELD10]

Title: Into The Shadows
Author(s): Lee Whitfield
Date: April 19, 2010
URL: <http://www.forensic4cast.com/2010/04/into-the-shadows/>

[MSDN]

Title: Shadow Copies and Shadow Copy Sets
URL: <http://msdn.microsoft.com/en-us/library/aa384612%28v=vs.85%29.aspx>

Title: `_VSS_VOLUME_SNAPSHOT_ATTRIBUTES` Enumeration
URL: <http://msdn.microsoft.com/en-us/library/aa385012%28v=vs.85%29.aspx>

[MSDN-VSS]

Title: Volume Shadow Copy Service Overview
URL: [http://msdn.microsoft.com/en-us/library/windows/desktop/aa384649\(v=vs.85\).aspx](http://msdn.microsoft.com/en-us/library/windows/desktop/aa384649(v=vs.85).aspx)

Title: Excluding Files from Shadow Copies
URL: [http://msdn.microsoft.com/en-us/library/windows/desktop/aa819132\(v=vs.85\).aspx](http://msdn.microsoft.com/en-us/library/windows/desktop/aa819132(v=vs.85).aspx)

[WIKIPEDIA]

Title: Shadow Copy
URL: http://en.wikipedia.org/wiki/Volume_Shadow_Copy_Service

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Version 1.3, 3 November 2008

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