

Transcript of the Testimony of:

**MICHAEL FRANZ**

NETSKOPE, INC.

VS.

FORTINET, INC.

April 23, 2024

Volume II



**I M A G I N E**  
R E P O R T I N G

UNITED STATES PATENT AND TRADEMARK OFFICE  
BEFORE THE PATENT TRIAL AND APPEAL BOARD

|                 |   |                             |
|-----------------|---|-----------------------------|
| NETSKOPE, INC., | ) |                             |
|                 | ) |                             |
| Petitioner,     | ) | PTAB Case No. IPR2022-01587 |
|                 | ) |                             |
| vs.             | ) | Patent No. 10,237,282 B2    |
|                 | ) |                             |
| FORTINET, INC., | ) |                             |
|                 | ) |                             |
| Patent Owner.   | ) |                             |
| _____           | ) |                             |

DEPOSITION OF MICHAEL FRANZ

VOLUME II

Sacramento, California

Tuesday, April 23, 2024

REPORTED BY: Matthew Sculatti  
CSR No. 13558

1 UNITED STATES PATENT AND TRADEMARK OFFICE  
2 BEFORE THE PATENT TRIAL AND APPEAL BOARD  
3  
4

5 NETSKOPE, INC., )  
6 Petitioner, ) PTAB Case No. IPR2022-01587  
7 vs. ) Patent No. 10,237,282 B2  
8 FORTINET, INC., )  
9 Patent Owner. )  
\_\_\_\_\_) )

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11  
12 Deposition of MICHAEL FRANZ, VOLUME II, taken before  
13 Matthew Sculatti, a Certified Shorthand Reporter for the  
14 State of California, commencing at 9:00 A.M.,  
15 Tuesday, April 23, 2024. This deposition was reported  
16 remotely.  
17  
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## I N D E X

| WITNESS       | EXAMINATION       | PAGE |
|---------------|-------------------|------|
| MICHAEL FRANZ | By Mr. Zivojnovic | 77   |

## E X H I B I T S

| EXHIBIT   | DESCRIPTION                | PAGE |
|-----------|----------------------------|------|
| Exhibit 1 | Volume Shadow Copy Service | 94   |

1           Sacramento, California; Tuesday, April 23, 2024;  
2                                           9:00 A.M.

3  
4                                           MICHAEL FRANZ,  
5       having been administered an oath, was examined and  
6       testified as follows:

7  
8                                           EXAMINATION

9       BY MR. ZIVOJNOVIC:

10       Q     All right. Good morning, Dr. Franz.  
11             You submitted a rebuttal declaration in  
12       connection with IPR2023-00456. Correct?

13       A     That is correct.

14       Q     And do you have a copy of your rebuttal  
15       declaration available to you?

16       A     Yes.

17             I have a -- right now in front of me, I have my  
18       rebuttal declaration, the patent, the institution  
19       decision, my declaration, and the patents that I am  
20       being -- that I am citing. That's Sharpe, Burdett,  
21       Kamalapuram, Seese, and Dods.

22       Q     If you could please go to paragraph 18 of  
23       your -- actually, paragraph 19 of your rebuttal  
24       declaration.

25             Let me know when you're there.

1           A     Yes.

2           Q     And in paragraph 19, you wrote: In such  
3 copy-on-write file systems, additional disc storage blocks  
4 are allocated only at the time that one of the copies is  
5 modified -- i.e., upon writing -- to store the modified  
6 bits of the affected copy, while any remaining copies  
7 continue to share divisional bits.

8                     Do you see that?

9           A     I see that.

10          Q     Now, I noticed that you put upon writing in  
11 quotation marks. Do you see that?

12          A     Yes.

13          Q     Why did you put upon writing in quotation marks?

14          A     I tried to relate that to the term  
15 "copy-on-write."

16          Q     All right. So in your view, "on write" means  
17 "upon writing"; correct?

18          A     So it is my understanding that in systems like  
19 this, you can have modifications of files that share disc  
20 blocks with earlier versions of the same file, and  
21 these -- the blocks that differ are allocated when the  
22 modified file is being modified.

23          Q     And this modification? That refers to the write  
24 operation; correct?

25          A     Excuse me? Say that again, please.

1           Q     The modification you referenced? That would be a  
2 write operation. Right?

3           A     Well, so the writing is what happens to the disc.  
4 Right? So that might be.

5                     So modifying the file would be one of the cases  
6 where this happens. Yes.

7           Q     And again, I just want to focus on the language  
8 "upon writing." Did I understand correctly that in your  
9 view, you equated the words "on write" with the language  
10 "upon writing"; right?

11          A     No, sir. I tried to relate what happens to the  
12 familiar term "copy-on-write."

13          Q     Okay. So the familiar term "copy-on-write"  
14 is -- does that mean generally the same as "copy upon  
15 writing"?

16                     MS. SCHUNTER: Objection. Form.

17                     THE WITNESS: I tried to give an -- I tried to  
18 give an example of what copy-on-write -- you know, give an  
19 example of how that -- what that term comes from.

20                     And so the -- in such systems, the point is that  
21 you don't -- do not modify data in place. You actually  
22 allocate a new block, make the modification, and then  
23 after the fact, change pointers so that the modified file  
24 might include disc blocks that are -- earlier disc blocks  
25 that have not been modified and the newly allocated blocks

1 that are inserted in the right places where the  
2 modifications have occurred.

3 BY MR. ZIVOJNOVIC:

4 Q So when you wrote upon writing in quotation  
5 marks, what were you referring to?

6 A Again, I -- I -- the term that is known is the  
7 copy-on-write functionality, and in the example in  
8 paragraph 19, I tried to give an example of this  
9 functionality and relate it to the term that the POSITA  
10 would be familiar with.

11 That's why I put the quotes.

12 Q Sorry. I'm not -- when you say with a term that  
13 POSITA would be familiar with, is that the term "upon  
14 writing"?

15 A No.

16 Q I'm sorry. Go ahead.

17 A "Copy-on-write" is the term that is the widely  
18 used term for a specific property of file systems.

19 Q So I guess I'm just trying to understand what  
20 your reason was for putting upon writing in quotation  
21 marks.

22 MS. SCHUNTER: Objection. Form.

23 THE WITNESS: I believe I already said that.

24 I tried to relate a functionality that is present  
25 to the term that is known in the art.

1 BY MR. ZIVOJNOVIC:

2 Q So in the term "copy-on-write," would it also  
3 have been fair to characterize that term using the words  
4 "upon writing"?

5 MS. SCHUNTER: Objection. Form.

6 THE WITNESS: I believe copy-on-write is the term  
7 that everybody uses. And I -- in paragraph 18, I am  
8 stating that a POSITA would be familiar with not only the  
9 term but also the functionality, and in paragraph 19, I am  
10 trying to elaborate what that actually means, and I'm  
11 using quotes to relate that to the term that is known in  
12 the art.

13 And that's why I'm putting it in quotes.

14 BY MR. ZIVOJNOVIC:

15 Q So you are relating the words "upon writing" with  
16 the term "copy-on-write"? Is that what I am to  
17 understand?

18 A No.

19 (Overlapping speakers.)

20 THE REPORTER: I'm sorry, guys. I'm sorry. I'm  
21 sorry.

22 Kristen, could I get that objection?

23 MS. SCHUNTER: It was asked and answered, was my  
24 objection.

25 THE REPORTER: Thank you.

1           Go ahead, Mr. Franz.

2           THE WITNESS: I'm sorry for being -- yeah. It's  
3 early morning.

4           So, again, I'm explaining that functionality.  
5 That means that in addition the storage blocks are  
6 allocated only at the time that one of the copies is  
7 modified, and I put "upon writing" because that obviously  
8 relates to the familiar term "copy-on-write  
9 (unintelligible)."

10          So, again, what it means is that you do not  
11 modify existing blocks on discs in such systems. Like,  
12 you actually -- when a modification of a file occurs, you  
13 allocate new blocks for the places where modifications  
14 occur, and then in the end, you create a version of the  
15 file that includes the existing blocks that have not been  
16 modified and the new blocks that have been modified,  
17 strung together. And you may still have old versions of  
18 the file that are contained on the -- old blocks that are  
19 still, for example, used as -- in a shadow copy for backup  
20 purposes when you have a snapshot of the file system, for  
21 example.

22 BY MR. ZIVOJNOVIC:

23       Q     Okay. Just want to make sure I understand this.  
24 In this system, the new storage blocks are only allocated  
25 on write. Is that correct?

1           A     I didn't say that.

2                     I said that -- I said, in particular, I was  
3 referring to modifying an existing file, and when you  
4 modify an existing file, even when it's on the same  
5 volume, you do not directly modify storage blocks that  
6 make up the file, but you actually allocate new blocks,  
7 apply the modifications to the new blocks, and then string  
8 together the file, possibly by combining the old blocks  
9 that don't have modifications and the new blocks that  
10 contain the places where you make modifications.

11                    So that, if something goes wrong, for example,  
12 you still have the old data totally unperturbed, and if  
13 you took a snapshot, you still have the old file as it was  
14 before the modification in its original form.

15           Q     So when you modify the file, new storage blocks  
16 are allocated on write. Is that correct?

17           A     When you modify the file, you obviously need to  
18 put those modifications somewhere. Right. And the idea  
19 is that you put those modifications into new storage  
20 blocks, rather than the storage blocks that already have  
21 parts of the file in it, so that the original data is not  
22 directly overwritten but still accessible, in case you  
23 have a copy of the file or a snapshot of the file.

24           Q     I just want to kind of simplify it even further.  
25 What I'm getting at is, in this particular example, you

1 are allocating additional storage blocks on write.

2 Correct?

3 A I do not know when those disc storage blocks  
4 specifically are allocated, but my statement is that you  
5 make those write operations to new disc storage blocks, or  
6 to disc storage blocks that are separate from the disc  
7 storage blocks that already comprise the file.

8 Q So in paragraph 19, you wrote: Additional disc  
9 storage blocks are allocated only at the time that one of  
10 the copies is modified. Correct?

11 A Correct.

12 That would be the -- yes. I wrote that.  
13 So -- so I meant additional disc storage blocks for this  
14 file.

15 Q Would it, then, also be fair to say that  
16 additional disc storage blocks for this file are allocated  
17 upon writing?

18 A So the new version of the file has  
19 disc -- obviously, you need to -- you need additional  
20 blocks for a file if you're writing to a file and  
21 the -- you want to preserve the original contents so  
22 you're not overwriting any existing data.

23 So in the functional idea of how this works, you  
24 would typically do this allocation exactly at the time  
25 that you know that you're writing to the file. So if you

1 are asking this -- you know, does this happen in every  
2 possible situation? There might be some smart ways of  
3 pre-allocating who knows what, but in the functional  
4 operation, the fact is that, as you're writing the file,  
5 you allocate new blocks to the file because you want to  
6 preserve the blocks that are already there.

7 Q Let me maybe ask a simpler question.

8 The relevant term here is "copy-on-write"; right?

9 A That is the term that has been familiar to most  
10 people since that's what people use, yes.

11 Q Okay. And so part of it is the words "on write."  
12 You see that; correct?

13 A I did not invent this term.

14 Q Well, but you see the words "on write" as part of  
15 that term? It's there. Isn't it?

16 A That happens to be the term that -- yeah. That's  
17 the term of the art.

18 Q And then, in paragraph 19, you also reference the  
19 term "upon writing"; correct?

20 A Again, I'm trying to relate the example that I'm  
21 giving to the technical term.

22 Q In your mind, are the words "upon writing"  
23 synonymous with the words "on write" in the context of  
24 copy-on-write?

25 MS. SCHUNTER: Objection. Asked and answered.

1 THE WITNESS: I don't think they're necessarily  
2 synonymous. I'm relating the example of what happens to  
3 the term upon copy-on-write.

4 BY MR. ZIVOJNOVIC:

5 Q I'm asking -- and that's not my question.

6 I'm asking you, in your view, are the terms "on  
7 write" and "upon write" -- do they mean the same thing?

8 MS. SCHUNTER: Objection. Form.

9 THE WITNESS: I believe I'm giving an example,  
10 and I am relating it, in quotes, to the technical term  
11 "copy-on-write."

12 BY MR. ZIVOJNOVIC:

13 Q So in this example, would you agree that the  
14 terms "on write" and "upon writing" are, in your mind,  
15 synonymous?

16 MS. SCHUNTER: Objection. Asked and answered.

17 THE WITNESS: Again, I'm simply presenting an  
18 example, and I'm relating it to -- you know, so I'm saying  
19 at the time that one of the copies is modified; and that  
20 means, obviously, on -- you know, upon writing. Right?

21 So I'm -- I'm relating that example that I'm  
22 giving to the term that a POSITA would become comfortable  
23 with.

24 BY MR. ZIVOJNOVIC:

25 Q Is it fair to say that you're relating the words

1 "upon writing" to the words "on write"?

2 MS. SCHUNTER: Objection. Asked and answered.

3 THE WITNESS: Yes. I'm giving an example, and  
4 I'm saying, see. Look, this is upon writing, and that  
5 sounds very similar to the known term "copy-on-write."

6 BY MR. ZIVOJNOVIC:

7 Q I'm going to drop in the chat -- let me start  
8 actually over.

9 In your rebuttal report, if you could please go  
10 to paragraph 20.

11 A Yes.

12 Q And in the second sentence -- the second sentence  
13 starts with "For example, the copy-on-write feature is  
14 supported in Microsoft's Windows Server 2012 operating  
15 system released in August 2012."

16 Do you see that?

17 A I see that.

18 Q And so is it fair to say that, in your view, how  
19 copy-on-write is implemented in  
20 Microsoft Windows Server 2012 is consistent with how a  
21 POSITA at that time would understand the term  
22 "copy-on-write"?

23 A So -- so I believe that the copy-on-write  
24 functionality came out of -- it came out of research.

25 So there was -- and then there was a file system;

1 I believe that was called ZFS. And so different file  
2 systems implemented copy-on-write following this.  
3 So -- and I believe that one of the reasons that people do  
4 this is, again, to prevent -- to prevent damage to your  
5 file system if something goes wrong. For example, if the  
6 power goes off, and so on.

7 And so one of the ideas is that you do the  
8 operations that are destructive, such as directory  
9 operations, and so on, without, you know, changing the  
10 blocks of the original structure, or doing this, you  
11 know -- creating new blocks and then changing pointers.

12 And so I believe that Microsoft's server  
13 operating system -- and I will have to look at the  
14 reference again -- did have a copy-on-write feature for  
15 redundancy. And I know, for sure, that in Apple's  
16 implementation, this idea of even being able to clone  
17 files at the user level is present. So if you make a  
18 copy, even in the finder, you get essentially a new  
19 directory entrance that points to the exact same disc  
20 blocks, even at the user level.

21 Q I just want to know -- and so you've referenced  
22 Microsoft Windows Server 2012 in your declaration;  
23 correct?

24 A That's correct.

25 Q And Microsoft's Windows Server 2012 included an

1 implementation of copy-on-write; correct?

2 A That is correct. That is what the  
3 implementation -- that's what the document that I  
4 referenced states.

5 Q And you wouldn't have cited Microsoft Windows  
6 implementation of copy-on-write if you did not think it  
7 was representative of how a POSITA would understand that  
8 term. Correct?

9 A I cited the -- can you say it again, please?

10 Q Yes.

11 You would not have cited Microsoft Windows Server  
12 2012 implementation of copy-on-write if you did not  
13 believe it was representative of how a POSITA understood  
14 the term of copy-on-write in 2012. Correct?

15 MS. SCHUNTER: Objection.

16 THE WITNESS: I was citing it to illustrate that  
17 copy-on-write feature was present in major operating  
18 systems at that time.

19 BY MR. ZIVOJNOVIC:

20 Q Has your understanding of the concept of  
21 copy-on-write changed since 2012?

22 MS. SCHUNTER: Objection. Form.

23 THE WITNESS: I believe copy-on-write is a pretty  
24 common technology. So it encompasses, you  
25 know -- there's -- it means you do not do destructive

1 updates, but you actually, you know, create -- you may  
2 have shared -- shared data, and you might -- and only if  
3 you make a modification to one of the shared items do you  
4 actually peel off what's shared and create a unique copy  
5 for that -- for that version of the data.

6 That's a pretty common idea that is used in many  
7 different implementations and many different contexts.

8 Q And one of the issues of this IPR is, what does  
9 the word "copy" mean; right?

10 A I understand that you are questioning that. Yes.

11 Q And the 856 patent that we're talking about?  
12 That has a priority date of 2018; correct?

13 A I believe that is so, yes.

14 Q Do you have any reason to believe that a POSITA's  
15 understanding of the term "copying" would have been  
16 different in 2012, versus 2018, versus today?

17 MS. SCHUNTER: Objection. Form.

18 THE WITNESS: Of copying what?

19 MR. ZIVOJNOVIC: I'm asking about the word  
20 "copy."

21 BY MR. ZIVOJNOVIC:

22 Q Do you have an understanding of what the word  
23 "copy" means?

24 MS. SCHUNTER: Objection, again.

25 THE WITNESS: I think, generally, copying has a

1 meaning that is pretty much, you know, consistent.

2 But I earlier said -- we have been -- the last  
3 time we spoke, I believe we talked about copying happening  
4 at different levels having a slightly different effect and  
5 meaning.

6 So the meaning of copy may be the same, but it  
7 depends on what level in the stack you are applying it to.

8 BY MR. ZIVOJNOVIC:

9 Q I'm not asking about differences in stack. I'm  
10 asking about differences in time. Let me start over.

11 Did you qualify as a POSITA for purposes of the  
12 856 patent in 2018?

13 A At least, yes.

14 Q Okay. And were you at least a POSITA for  
15 purposes of the 856 patent back in 2012?

16 A I believe so.

17 Q Okay. Has your understanding as a POSITA, or at  
18 least a POSITA, of the term "copying" changed since 2012?

19 MS. SCHUNTER: Objection to form.

20 THE WITNESS: I believe in 2012 and in 2018 and  
21 now, I would give you the same answer that, depending on  
22 what level you are asking the copy, you know -- what you  
23 are asking about. So whether I'm doing a -- copying the  
24 bits and bytes underneath or whether I'm copying a whole  
25 file, my answer would be, you know, my understanding would

1 be similar.

2 BY MR. ZIVOJNOVIC:

3 Q And now we're talking about the term  
4 "copy-on-write." Correct?

5 A You would like to talk about that. Yes.

6 Q And has your understanding of what  
7 "copy-on-write" means changed since 2012?

8 MS. SCHUNTER: Objection to form.

9 THE WITNESS: So the term "copy-on-write" is also  
10 quite old. So I believe we -- we also use it, you know,  
11 in memory management, and I believe there we've used it  
12 even longer.

13 When you have shared memory pages, similar idea.  
14 You have different processes that share the same memory  
15 page. Initially, you map them onto the same memory page.  
16 If one of them modifies it, you disambiguate them. You  
17 create a copy of the memory page, and now they are using  
18 different memory pages. So the concept of copy-on-write  
19 is probably much older.

20 And the interesting idea here is that so -- so a  
21 POSITA would have known what copy-on-write means, even  
22 outside of file systems, and the important new idea is  
23 that you can actually now also implement that in file  
24 systems because it gives you these extra capabilities.  
25 And in particular, there was a need for it in the security

1 space because of this problem of ransomware that was  
2 becoming quite apparent.

3 And so the idea of taking snapshots, which  
4 is -- and the idea of being able to deal with, you know,  
5 corruption of the file system. So having  
6 additional -- having an easy way of having a copy, you  
7 know, is -- and not actually making updates of data that  
8 is relevant is -- is very powerful.

9 MR. ZIVOJNOVIC: Dr. Franz, I would please ask  
10 you to listen to my question. This deposition would go  
11 much faster if you could, please.

12 BY MR. ZIVOJNOVIC:

13 Q I'm asking -- my question is very different and  
14 very simple. I'm just asking, since 2012, has your  
15 understanding of the term -- since 2012, just since then,  
16 has your understanding of the term "copy-on-write"  
17 changed?

18 MS. SCHUNTER: Objection to form, again, and  
19 asked and answered.

20 THE WITNESS: Okay. So the term "copy-on-write"  
21 is a term that is a fixed term that is well-known to  
22 people, and it has -- that is a -- the whole thing,  
23 copy-on-write, is a -- if you put that in quotes, you will  
24 find that that is a term in the art that has -- that has a  
25 meaning.

1           And it simply means that, you know, you -- you  
2   share common data and you disambiguate at the time when  
3   you need to disambiguate between different versions,  
4   because -- and that is precisely when one of the copies is  
5   actually modified.

6           So that is an old term, and what was new is that  
7   people have actually built file systems that implement  
8   that.

9   BY MR. ZIVOJNOVIC:

10       Q     I'm just asking, has that term, which I believe  
11   you said has an understood meaning -- has that meaning  
12   changed since 2012?

13       MS. SCHUNTER:  Objection, again.

14       THE WITNESS:  The general concept copy-on-write  
15   is, you know, is -- has not changed.  What has changed is  
16   the scope.

17       MR. ZIVOJNOVIC:  Okay.  I'm now going to drop in  
18   an exhibit.  Let's just mark it Exhibit 1, and it's an  
19   article titled "Volume Shadow Copy Service."

20                   (Exhibit 1 was marked for  
21                   identification.)

22       MS. SCHUNTER:  I'm going to object to the new  
23   exhibit.

24       MR. ZIVOJNOVIC:  Dr. Franz, please let me know  
25   when you've had a chance to download and review this

1 document.

2 THE WITNESS: Well, I -- I have got the exhibit,  
3 but it's fairly long. I mean, obviously, I will not be  
4 able to review the whole thing in useful time.

5 What is your question?

6 MS. SCHUNTER: I'm going to jump in and reserve  
7 our right to exclude this evidence.

8 MR. ZIVOJNOVIC: Yeah. I'm still allowed to ask  
9 him questions, and I disagree that there's a basis to  
10 exclude. I'm still entitled to proceed with the  
11 deposition.

12 MR. KLEIN: Ogi, what's your basis for  
13 introducing new evidence at this point?

14 MR. ZIVOJNOVIC: I'm allowed to do this  
15 deposition. Deposition itself is new evidence, as well as  
16 I do believe there are patent PTAB decisions that allow  
17 the inclusion of these -- of deposition exhibits with  
18 sur-reply. But either way, I don't think that's relevant  
19 to something you need to decide right now. I just want to  
20 finish my deposition and use this exhibit and ask  
21 Dr. Franz questions.

22 MR. KLEIN: Well, I know what you want to do, but  
23 we've got to do what's appropriate. So I would like to  
24 know what CFR case law you have that says it's appropriate  
25 to add new evidence during a deposition as a way to get

1 around the exclusion of submitting new evidence with a  
2 sur-reply.

3 You can, of course, submit the deposition  
4 transcript, but you can't separately introduce a new  
5 exhibit with your sur-reply. And if you have authority  
6 for that, we'd like to see it.

7 MR. ZIVOJNOVIC: Well, do you have a case that  
8 says I can't use an exhibit -- a new exhibit in a  
9 deposition?

10 (Overlapping speakers.)

11 MR. ZIVOJNOVIC: I'm entitled to my deposition.  
12 So you're the one that's trying to limit -- excuse me.

13 I'm entitled to this deposition. You're the ones  
14 that are trying to limit the scope of -- trying to limit  
15 this deposition by excluding a -- by preventing me from  
16 using a deposition exhibit. So what's your authority for  
17 doing so?

18 MR. KLEIN: It's in the CFRs. You know it's in  
19 the CFRs where it says you cannot submit new evidence with  
20 a sur-reply, other than a deposition transcript. It's  
21 plain as day in the CFRs.

22 MR. ZIVOJNOVIC: And I'm not submitting. I'm not  
23 filing a sur-reply right now. I'm sitting in a  
24 deposition.

25 (Overlapping speakers.)

1 MR. KLEIN: Are you representing you're not going  
2 to submit this new evidence with your sur-reply?

3 MR. ZIVOJNOVIC: I am not representing that  
4 either. It depends on the deposition. I know you can  
5 use -- I mean, I reserve my rights. If the case law  
6 allows me to submit the evidence, I will. If it doesn't,  
7 I will not.

8 (Overlapping speakers.)

9 MR. ZIVOJNOVIC: Excuse me.

10 We also reserve the right to seek leave to submit  
11 the new evidence, which we are entitled to seek leave to.  
12 But either way, none of that, I believe, is at issue. The  
13 issue here is that you are stopping me from using a  
14 deposition exhibit in a deposition that I'm entitled to  
15 take.

16 MR. KLEIN: I don't agree with that last  
17 characterization. Of course, you can proceed with your  
18 deposition, but you cannot introduce new evidence, as I  
19 have stated.

20 And if you want to seek leave, that's one thing.  
21 But you weren't saying you were going to seek leave. You  
22 were saying you were going to submit it with your  
23 sur-reply, or might submit it with your sur-reply, and you  
24 said you believed you had authority to do that. And I was  
25 asking, if you have authority, I would like to see what

1 authority that is.

2 MR. ZIVOJNOVIC: I'm saying I'm not  
3 taking a -- I'm not saying -- right now I'm not taking a  
4 position whether or not we would be submitting this with  
5 the sur-reply, whether or not we'd be seeking leave to  
6 submit it with the sur-reply, or if we have to. I think  
7 that's a separate -- those are all separate issues.

8 Right now I'm just using an exhibit in a  
9 deposition, and I'm entitled to take that deposition.

10 MR. KLEIN: All right. Well, our objection is  
11 noted on the record. So you can proceed.

12 MR. ZIVOJNOVIC: Thank you.

13 BY MR. ZIVOJNOVIC:

14 Q Dr. Franz, have you had an opportunity to  
15 download Exhibit 1 to this deposition?

16 A Yes.

17 Q All right. And do you see at the bottom left  
18 that the URL from which Exhibit 1 is downloaded is from  
19 learn.microsoft.com?

20 A I see that.

21 Q And Microsoft is the manufacturer of  
22 Windows Server 2012; right?

23 A I believe it is, yes.

24 Q And then below the title of the section of  
25 the -- of this document, it says

1 "Applies to: Windows Server," and then it lists a number  
2 of different versions, including Windows Server 2012.

3 Do you see that?

4 A I do see that.

5 Q If you could please go to page 5 of Exhibit 1.

6 And do you see under the section title

7 "How the Provider Creates" -- do you see the section  
8 titled "How the Provider Creates a Shadow Copy"?

9 A Apparently, this refers to a specific service  
10 which is called Volume Shadow Copy Service. That's a  
11 service that apparently Microsoft offers. So -- and it  
12 talks about -- the provider appears to be this  
13 Volume Shadow Copy Service.

14 Q Now, in your testimony earlier you referenced  
15 shadow copies as one of the use cases for copy-on-write.  
16 Correct?

17 A I referenced ransomware and snapshots.

18 Q Are you familiar with the concept of shadow copy?

19 A So I -- so the term "shadow copy" is something  
20 that colloquially people use, you know, for certain things  
21 which are related to what I've called snapshot.

22 But what you're talking about here is one very  
23 specific implementation that Microsoft uses for one very  
24 specific service: Volume Shadow Copy Service. So, you  
25 know, I -- you know, it's -- it's one specific

1 implementation of something. I would have to study this  
2 in detail, you know.

3 It's easier to use -- to use a term. You know,  
4 you only have so many terms. This is apparently a service  
5 that uses the term "shadow copy" in its name, yes, but I  
6 would have to go and study this.

7 Q Do you see one of the items listed on page 5 is  
8 copy-on-write? Do you see that?

9 A I see that.

10 So it starts off by saying "A hardware or  
11 software shadow copy provider uses one of the following  
12 methods," and then it uses to copy-on-write -- as I said,  
13 copy-on-write is a very well-understood term, and it would  
14 have been to a POSITA.

15 So, you know, they are -- they are referring to  
16 this term here, but you're talking about a specific  
17 service of a specific manufacturer, you know, that I  
18 haven't studied in detail.

19 Q Do you see where it says "Copy-on-write: This  
20 method does not copy the original volume. Instead, it  
21 makes a differential copy by copying all changes  
22 (completed write I/O requests) that are made to the volume  
23 after a given point in time"?

24 Do you see that?

25 A I see that.

1           This is not talking about the file system itself.  
2   This is talking about a service, and the service  
3   apparently creates a shadow copy. Right? So --

4       Q     Sir, I'm just asking if you see the words on the  
5   page. That's all I asked.

6           Do you see those words? Yes or no?

7       A     But this is talking about the service doing a  
8   copy-on-write, which doesn't tell us anything about what  
9   this -- okay.

10           This is telling you that there is a service,  
11   which is a separate service, which is a hardware or  
12   software shadow copy provider, and that service uses,  
13   also, a copy-on-write method, apparently, or uses one of  
14   three different methods for creating a shadow copy.

15       Q     All I asked you was, did I read that sentence  
16   correctly? Can you please answer my question?

17       A     You read something to me that's in this article.

18       Q     That's all I asked.

19       A     Yes.

20       Q     Okay. I read it correctly? Can we agree?

21       A     Yes.

22       Q     Thank you. All right.

23           Now, you've said many times, I believe, that in  
24   your view, copy-on-write is a well-understood term.  
25   Right?

1           A     Yes.

2           Q     And you've said that copy-on-write has a  
3 well-understood meaning; right?

4           A     And that -- yes.

5           Q     All right. Is in this article the description of  
6 copy-on-write as a method that does not copy the original  
7 volume? Instead, it makes a differential copy by copying  
8 all changes completed by I/O requests that are made to the  
9 volume after a given point in time?

10                   Is that an accurate reflection of what the term  
11 "copy-on-write" can mean?

12                   MS. SCHUNTER: Objection. Form.

13                   THE WITNESS: So they are making a distinction  
14 between three different methods, and they're using the  
15 term "copy-on-write" to say that they are not -- they are  
16 not making it -- copying the changes.

17                   So this is -- that is not my intuitive  
18 understanding of, you know, what copy-on-write means in  
19 a -- in a memory system or in -- directly in a file  
20 system, but they are using this to make a distinction  
21 between these three different things, and they have  
22 decided to use that term for it. It's in a service that  
23 creates a volume shadow copy.

24 BY MR. ZIVOJNOVIC:

25           Q     So you're not disputing that that is an accurate

1 characterization of the term "copy-on-write" in the  
2 context of a service?

3 MS. SCHUNTER: Objection. Form.

4 THE WITNESS: Again, I would not -- I would not  
5 have thought of this -- of this application using the  
6 term. I -- I believe this is, you know -- the authors of  
7 this document, you know, had three different methods that  
8 they have implemented, and they give them names, and they  
9 decided to call this -- this method "copy-on-write."

10 But this is talking not about the file system.  
11 This is talking about the Volume Shadow Copy Service.

12 BY MR. ZIVOJNOVIC:

13 Q Does the phrase "copy-on-write" have different  
14 meanings, depending on whether it's implemented in -- for  
15 memory allocation, file system, or as a part of a service?

16 MS. SCHUNTER: Objection. Form.

17 THE WITNESS: As I said, the term "copy-on-write"  
18 tells a POSITA that you are not making a destructive  
19 update of shared information, but, rather, that you  
20 disambiguate between the different versions at the time  
21 where you need to keep them separate. So at that point,  
22 you take whatever has changed, and you make the modified  
23 version point to it, and the existing data does not get  
24 modified.

25 So -- so -- you know, so what -- what the service

1 does is, it makes a differential copy by copying all the  
2 changes. So that is the spirit of copy-on-write.

3 BY MR. ZIVOJNOVIC:

4 Q If you could now please go to page 6 of this  
5 document. Do you see the section that's with the header  
6 "Copy-on-write method"?

7 A I do.

8 Q And do you see it says: In the copy-on-write  
9 method, when a change to the original volume occurs (but  
10 before the write I/O request is completed), each block to  
11 be modified is read and then written to the volume's  
12 shadow copy area (also called its "diff area")?

13 Do you see that?

14 A I see that.

15 Q And then it goes on to say "The shadow copy  
16 storage area can be on the same volume or a different  
17 volume. This preserves a copy of the data block on the  
18 original volume before the change overwrites it."

19 Do you see that?

20 A I see that.

21 Q Sorry. I don't think I caught an answer to my  
22 question. I apologize if I missed it.

23 A I don't think you asked a question. You asked if  
24 I see that, and I said, yes, I see that. What you read to  
25 me.

1           Q     Okay. Sorry. My internet must have been spotty  
2     for a second then. No worries.

3                     And below that text, do you see that there's a  
4     table with three columns and four rows? Table 1?

5           A     Yes.

6           Q     And so the -- the first column is time. The  
7     second column is source data (status and data). And the  
8     third column is shadow copy (status and data).

9                     Do you see that?

10          A     I see what it says. Yes.

11          Q     And then the first time, 0. It says there's  
12     original data: 1, 2, 3, 4, 5. And then, under shadow  
13     copy, it says "No copy."

14                     Do you see that?

15          A     So this table explains the copy-on-write method  
16     of creating shadow copies.

17                     I still don't understand why -- why we are  
18     talking about the shadow -- the copy-on-write method of  
19     creating shadow copies. This is about creating shadow  
20     copies.

21          Q     Okay. I'm just -- right now I'm just trying to  
22     get us on the same page.

23                     Did I characterize T0 correctly?

24          A     You said something to me, you know.

25                     In order to deeply understand what's there, I

1     probably need a little more time. But I'm still not  
2     exactly sure where you're going with this.

3           Q     Well, let's just keep going down. The next row,  
4     T1. Data changed in cache: 3 to 3 prime. Shadow copy  
5     created (differences only): 3.

6                     Do you see that?

7           A     I see that's what you're reading to me. Yes.

8           Q     And then the final row says T2. Original data  
9     overwritten: 1, 2, 3 prime, 4, 5. And on the shadow  
10    copy, it says "Differences and index stored on shadow  
11    copy: 3."

12                    Do you see that?

13          A     I see that.

14          Q     Now, is it fair to say that T1 and T2 is when the  
15    on-write occurs?

16                   MS. SCHUNTER: Objection to the form.

17                   THE WITNESS: You're talking about a method of  
18    creating shadow copies, and I explained copy-on-write is  
19    a -- is a generally understood method to disambiguate  
20    shared data at the moment where one of the copies needs to  
21    be updated and the other one is not.

22                   And so here, you know, 3 has been changed to  
23    3-dash and -- but this is using, you know -- this is  
24    creating copies of the original data when -- you know,  
25    this is a slightly different way of -- this is -- this is

1 creating a very specific kind of copy. Of a shadow copy.

2 It's using the idea of copy-on-write to create a  
3 very specific data item that has the -- apparently, the  
4 originals when you -- the original data when you change  
5 the original file. It's applying the idea, but it's doing  
6 it in a slightly different way. Right.

7 It's a very specific implementation of something  
8 here. It's what they called a copy-on-write method of  
9 creating shadow copies.

10 BY MR. ZIVOJNOVIC:

11 Q Is it fair to say that this article, then,  
12 describes a single, specific use of a copy-on-write  
13 method?

14 MS. SCHUNTER: Objection. Form.

15 THE WITNESS: This article describes a service  
16 that Microsoft uses, and they are using the term  
17 "copy-on-write" for one of the three ways in which they do  
18 this creation of a shadow copy.

19 BY MR. ZIVOJNOVIC:

20 Q Is Microsoft in this article accurately using the  
21 term "copy-on-write"?

22 MS. SCHUNTER: Objection. Form.

23 THE WITNESS: So they are creating, you know,  
24 when it -- they are doing the copying at the time that a  
25 modification is happening. So they are using a version of

1 the idea.

2 And the important thing is, of course, that, you  
3 know, a person of skill in the art would have understood  
4 that there are, you know, lots of other implementations,  
5 including for file systems, where a much more  
6 straightforward way of applying this idea is being used.

7 BY MR. ZIVOJNOVIC:

8 Q So is this Microsoft article misusing the  
9 phrase -- let me start over.

10 Now, we've established that copy-on-write has a  
11 well-understood meaning. Right?

12 A Disambiguate at the time of where they start  
13 differing. Yes.

14 Q I didn't catch that first part of your answer.

15 A Yes. The well-understood meaning is disambiguate  
16 the different versions at the time where differences  
17 occur.

18 Q And is this Microsoft article using the phrase  
19 "copy-on-write" consistent with that well-understood  
20 meaning?

21 MS. SCHUNTER: Objection. Asked and answered.

22 THE WITNESS: So we're getting very far away from  
23 the original -- from my original argument, you know.

24 My original argument was that there are file  
25 systems in which, you know -- in which copying a file

1 might actually not duplicate all the blocks of the  
2 original file, and I -- I am very confident that that is  
3 correct. And now you are going off on a tangent and  
4 finding a use of the term that is the -- the term that  
5 will be known for a POSITA that characterizes this  
6 particular file system function, that a POSITA would have  
7 been aware of.

8           And now you're finding something that -- that,  
9 you know, where Microsoft has a service, and they are  
10 talking about, you know, three different methods for  
11 creating a shadow copy, and they are characterizing them  
12 by three different names that -- and one is called  
13 complete copy. The other one is called copy-on-write, and  
14 the third is called redirect-on-write.

15           And obviously, they are trying to make this  
16 understandable to someone who has to configure the system,  
17 and so "copy-on-write" is probably not a bad term in the  
18 context of Volume Shadow Copy Services to relate what it  
19 does to someone, because they understand that  
20 copy-on-write means you do the disambiguation at that  
21 point.

22           But we were talking earlier about file systems  
23 and, in particular, you know, what it means to copy a file  
24 or move a file, and now you're talking about a specific  
25 service that creates volume shadow copies. That's

1 different.

2 BY MR. ZIVOJNOVIC:

3 Q Sir, my question is very simple. Are you saying  
4 that this Microsoft article is misusing the word  
5 "copy-on-write"? Yes or no? That's all I'm asking.

6 MS. SCHUNTER: Objection. Asked and answered.

7 THE WITNESS: Again, they have a very specific  
8 service, and they are using three catchy terms to describe  
9 the different methods, and copy-on-write is probably not  
10 an inappropriate term to relate to a person using this  
11 service of what it does.

12 MS. SCHUNTER: Ogi, do you want to go ahead and  
13 take a break right now? We're at about the top of the  
14 hour.

15 MR. ZIVOJNOVIC: I actually think, if you just  
16 give me a couple more minutes, we might be done.

17 MS. SCHUNTER: Okay.

18 BY MR. ZIVOJNOVIC:

19 Q Do you see this Microsoft article, in the third  
20 column, that it says no copy prior to the subsequent write  
21 operation?

22 A On what?

23 Oh. Okay. You mean, on page -- on page 6?

24 Q I'm still on page 6. Yes.

25 A Okay.

1           Q     All right. Do you see on page 6 in this  
2     Microsoft article, in the third column, that it  
3     says -- quote -- no copy -- end quote -- prior to the  
4     subsequent write operation?

5           A     This is the table that says the copy-on-write  
6     method of creating shadow copies?

7                     It says that. Yes.

8           MR. ZIVOJNOVIC: Okay. No further questions.

9           THE REPORTER: Kristen, did you have any  
10    questions?

11           MS. SCHUNTER: Maybe a ten-minute break to review  
12    on our end, and we can regroup after that.

13           MR. ZIVOJNOVIC: Okay.

14                     (A brief recess was taken.)

15           MS. SCHUNTER: We just have a brief redirect.

16

17                                 EXAMINATION

18    BY MS. SCHUNTER:

19           Q     Dr. Franz, do you recall --

20                     MR. ZIVOJNOVIC: Kristen, you're on mute.

21                     MR. KLEIN: I can hear her.

22                     MR. ZIVOJNOVIC: Okay. Sorry. I guess it was on  
23    my end.

24                     MS. SCHUNTER: Can you hear me?

25                     THE WITNESS: I can hear you. Thank you.

1 BY MS. SCHUNTER:

2 Q You can hear me. Okay?

3 MS. SCHUNTER: Matthew, can you hear me?

4 THE REPORTER: I can hear you just fine.

5 MS. SCHUNTER: Okay. Perfect.

6 All right. I'll start over.

7 BY MS. SCHUNTER:

8 Q Dr. Franz, do you recall Counsel asking you  
9 questions about this document that was labeled Exhibit 1,  
10 entitled "Volume Shadow Copy Service"?

11 A Correct. Yes.

12 Q After your brief review of this document, does  
13 that change any of your opinion?

14 A No, it does not.

15 Q Can you explain why not?

16 A The whole discussion, you know, that is in my  
17 rebuttal declaration and, also, my other declaration is,  
18 you know -- first of all, the main point was that the  
19 patent itself uses copy and -- copying and moving  
20 interchangeably in many places. And the real point is  
21 about making the -- making a file accessible to the users  
22 only after it's been determined to be safe, and we're  
23 getting very far away from that.

24 And then the discussion where copy-on-write came  
25 in was, you know, about a POSITA knowing that, in

1 actuality, whether bits and bytes are being copied,  
2 physically copied, or not depends more on the  
3 configuration of the file system, rather than on the  
4 high-level file operation that is being invoked.

5 And so what we talked about today is, you know, a  
6 service by Microsoft that uses the term "copy-on-write" to  
7 explain one of three different modes that it uses to  
8 create volume shadow copies; and that is, indeed, very far  
9 away from the matter that we have been discussing and does  
10 not change my opinion.

11 Q Thank you.

12 MS. SCHUNTER: No further questions.

13 THE REPORTER: Okay, guys. Can we go off the  
14 record?

15 MR. ZIVOJNOVIC: Let me just think for one  
16 second.

17 I have no further questions.

18 THE REPORTER: Ms. Schunter, would you like to  
19 order a certified transcript?

20 MS. SCHUNTER: Yes, please.

21 THE REPORTER: And then, Ogi, I got the expedite  
22 order.

23 Do either of you guys need a rough on this one?

24 MR. ZIVOJNOVIC: Yes. Can you send me the rough,  
25 like, today as soon as it's available?

And then on the expedite order, I can't recall if we said Friday or Thursday, but given that it's a short depo, I'm hoping you can get it to me by Thursday, end of day.

THE REPORTER: You got it.

(Whereupon, the deposition concluded at 10:12 A.M.)

(DECLARATION UNDER PENALTY OF PERJURY ON THE FOLLOWING  
PAGE HEREOF.)

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I, MICHAEL FRANZ, do solemnly declare under penalty of perjury that the foregoing is my deposition under oath; that these are the questions asked of me and my answers thereto; that I have read same and have made the necessary corrections, additions, or changes to my answers that I deem necessary.

In witness thereof, I hereby subscribe my name this day of \_\_\_\_\_, 2024.

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WITNESS SIGNATURE

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CERTIFICATION  
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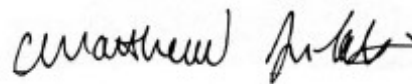
I, the undersigned, a Certified Shorthand  
Reporter of the State of California do hereby certify:

That the foregoing proceedings were taken before  
me at the time and place herein set forth; that any  
witnesses in the foregoing proceedings, prior to  
testifying, were placed under oath; that a verbatim record  
of the proceedings was made by me using machine shorthand  
which was thereafter transcribed under my direction;  
further, that the foregoing is an accurate transcription  
thereof.

I further certify that I am neither financially  
interested in the action nor a relative or employee of any  
attorney of any of the parties.

IN WITNESS WHEREOF, I have this date

subscribed my name



Matthew Sculatti, CSR No. 13558

Dated: April 23, 2024

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Deposition of: Michael Franz  
Proceedings Date: April 23, 2024

PAGE      LINE      CHANGE TESTIMONY TO READ AS FOLLOWS:

[illegible]

\_\_\_\_\_Date\_\_\_\_\_

Michael Franz

|                                                                                                               |                                                              |                                                                                    |                                                                                                                                                   |                                                 |
|---------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|
| <b>Exhibits</b>                                                                                               | <b>5</b>                                                     | <b>allocating</b> 84:1                                                             | <b>bits</b> 78:6,7 91:24<br>113:1                                                                                                                 | 91:18 92:7 93:17<br>94:12,15 103:22<br>106:4,22 |
| <b>Ex 0001 Michael Franz 042324</b><br>76:8 94:18,20<br>98:15,18 99:5<br>112:9                                | <b>5</b> 99:5 100:7<br>105:12 106:9                          | <b>allocation</b> 84:24<br>103:15                                                  | <b>block</b> 79:22<br>104:10,17                                                                                                                   | <b>changing</b> 88:9,<br>11                     |
| <b>1</b>                                                                                                      | <b>6</b>                                                     | <b>allowed</b> 95:8,14                                                             | <b>blocks</b> 78:3,20,<br>21 79:24,25 82:5,<br>11,13,15,16,18,24<br>83:5,6,7,8,9,15,20<br>84:1,3,5,6,7,9,13,<br>16,20 85:5,6<br>88:10,11,20 109:1 | <b>characterization</b><br>97:17 103:1          |
| <b>1</b> 94:18,20 98:15,<br>18 99:5 105:4,12<br>106:9 112:9                                                   | <b>6</b> 104:4 110:23,24<br>111:1                            | <b>apologize</b> 104:22                                                            | <b>bottom</b> 98:17                                                                                                                               | <b>characterize</b><br>81:3 105:23              |
| <b>10:12</b> 114:7                                                                                            | <b>8</b>                                                     | <b>apparent</b> 93:2                                                               | <b>break</b> 110:13<br>111:11                                                                                                                     | <b>characterizes</b><br>109:5                   |
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# Exhibit 1

# Volume Shadow Copy Service

Article • 12/07/2022

Applies to: Windows Server 2022, Windows Server 2019, Windows Server 2016, Windows Server 2012 R2, Windows Server 2012, and Windows Server 2008 R2, Windows Server 2008, Windows 10, Windows 8.1, Windows 8, Windows 7

Backing up and restoring critical business data can be very complex due to the following issues:

- The data usually needs to be backed up while the applications that produce the data are still running. This means that some of the data files might be open or they might be in an inconsistent state.
- If the data set is large, it can be difficult to back up all of it at one time.

Correctly performing backup and restore operations requires close coordination between the backup applications, the line-of-business applications that are being backed up, and the storage management hardware and software. The Volume Shadow Copy Service (VSS), which was introduced in Windows Server® 2003, facilitates the conversation between these components to allow them to work better together. When all the components support VSS, you can use them to back up your application data without taking the applications offline.

VSS coordinates the actions that are required to create a consistent shadow copy (also known as a snapshot or a point-in-time copy) of the data that is to be backed up. The shadow copy can be used as-is, or it can be used in scenarios such as the following:

- You want to back up application data and system state information, including archiving data to another hard disk drive, to tape, or to other removable media.
- You are data mining.
- You are performing disk-to-disk backups.
- You need a fast recovery from data loss by restoring data to the original Logical Unit Number (LUN) or to an entirely new LUN that replaces an original LUN that failed.

Windows features and applications that use VSS include the following:

- [Windows Server Backup](https://go.microsoft.com/fwlink/?LinkId=180891) (<https://go.microsoft.com/fwlink/?LinkId=180891>)

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- [Shadow Copies of Shared Folders](https://go.microsoft.com/fwlink/?LinkId=142874) (<https://go.microsoft.com/fwlink/?LinkId=142874>)
- [System Center Data Protection Manager](https://go.microsoft.com/fwlink/?LinkId=180892) (<https://go.microsoft.com/fwlink/?LinkId=180892>)
- [System Restore](https://support.microsoft.com/windows/use-system-restore-a5ae3ed9-07c4-fd56-45ee-096777ecd14e) (<https://support.microsoft.com/windows/use-system-restore-a5ae3ed9-07c4-fd56-45ee-096777ecd14e>)

## How Volume Shadow Copy Service Works

A complete VSS solution requires all of the following basic parts:

**VSS service** Part of the Windows operating system that ensures the other components can communicate with each other properly and work together.

**VSS requester** The software that requests the actual creation of shadow copies (or other high-level operations like importing or deleting them). Typically, this is the backup application. The Windows Server Backup utility and the System Center Data Protection Manager application are VSS requesters. Non-Microsoft® VSS requesters include nearly all backup software that runs on Windows.

**VSS writer** The component that guarantees we have a consistent data set to back up. This is typically provided as part of a line-of-business application, such as SQL Server® or Exchange Server. VSS writers for various Windows components, such as the registry, are included with the Windows operating system. Non-Microsoft VSS writers are included with many applications for Windows that need to guarantee data consistency during back up.

**VSS provider** The component that creates and maintains the shadow copies. This can occur in the software or in the hardware. The Windows operating system includes a VSS provider that uses copy-on-write. If you use a storage area network (SAN), it is important that you install the VSS hardware provider for the SAN, if one is provided. A hardware provider offloads the task of creating and maintaining a shadow copy from the host operating system.

The following diagram illustrates how the VSS service coordinates with requesters, writers, and providers to create a shadow copy of a volume.

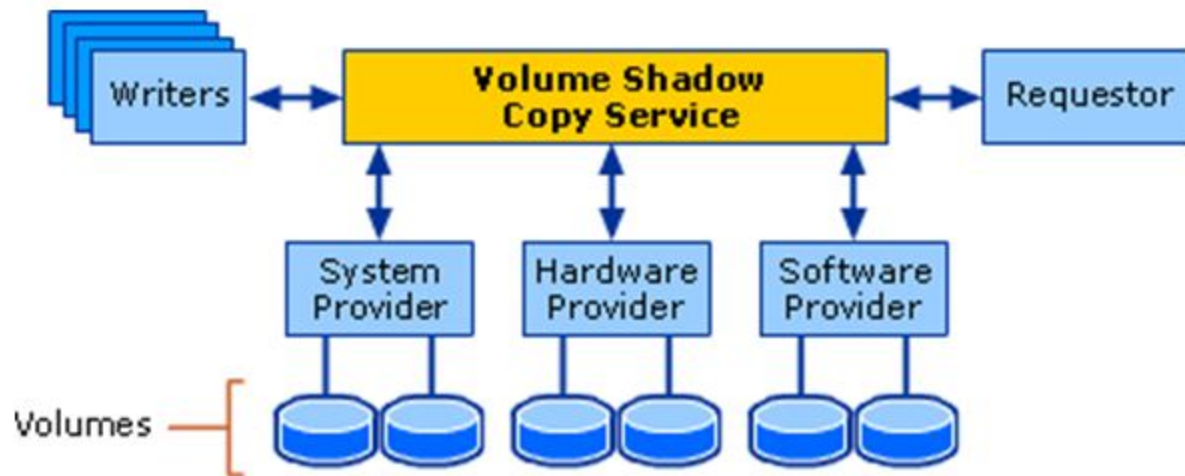


Figure 1 Architectural diagram of Volume Shadow Copy Service

## How a Shadow Copy Is Created

This section puts the various roles of the requester, writer, and provider into context by listing the steps that need to be taken to create a shadow copy. The following diagram shows how the Volume Shadow Copy Service controls the overall coordination of the requester, writer, and provider.

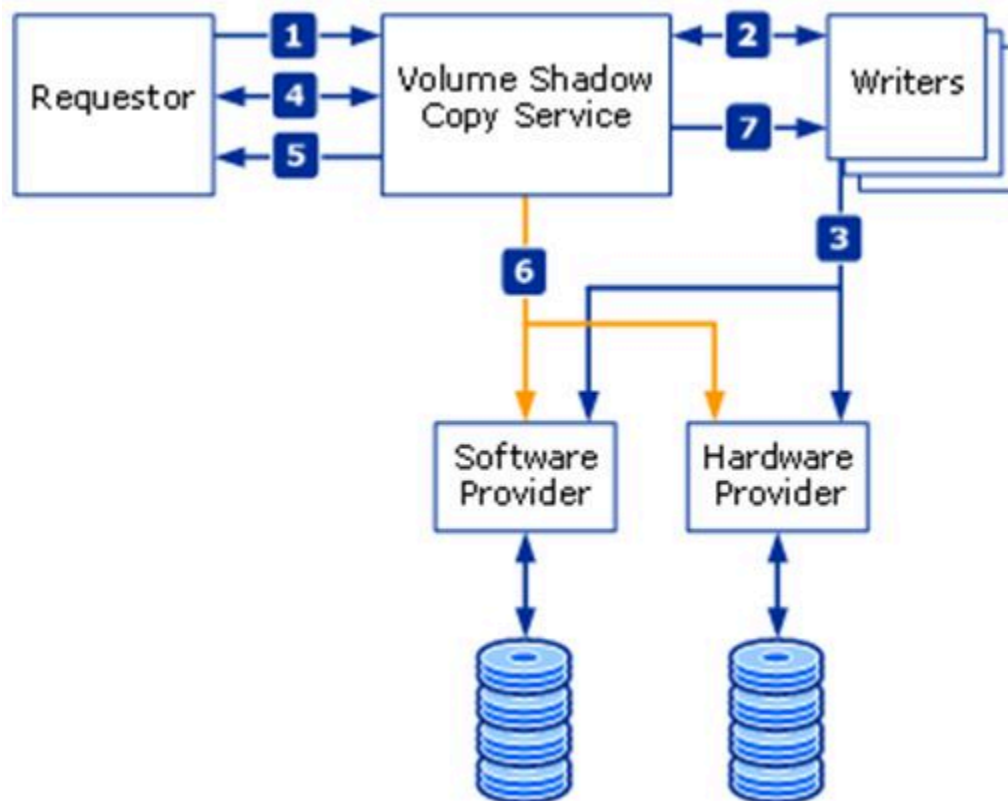


Figure 2 Shadow copy creation process

To create a shadow copy, the requester, writer, and provider perform the following actions:

1. The requester asks the Volume Shadow Copy Service to enumerate the writers, gather the writer metadata, and prepare for shadow copy creation.
2. Each writer creates an XML description of the components and data stores that need to be backed up and provides it to the Volume Shadow Copy Service. The writer also defines a restore method, which is used for all components. The Volume Shadow Copy Service provides the writer's description to the requester, which selects the components that will be backed up.
3. The Volume Shadow Copy Service notifies all the writers to prepare their data for making a shadow copy.
4. Each writer prepares the data as appropriate, such as completing all open transactions, rolling transaction logs, and flushing caches. When the data is ready to be shadow-copied, the writer notifies the Volume Shadow Copy Service.
5. The Volume Shadow Copy Service tells the writers to temporarily freeze application write I/O requests (read I/O requests are still possible) for the few seconds that are required to create the shadow copy of the volume or volumes. The application freeze is not allowed to take longer than 60 seconds. The Volume Shadow Copy Service flushes the file system buffers and then freezes the file system, which ensures that the file system metadata is recorded correctly and the data to be shadow-copied is written in a consistent order.
6. The Volume Shadow Copy Service tells the provider to create the shadow copy. The shadow copy creation period lasts no more than 10 seconds, during which all write I/O requests to the file system remain frozen.
7. The Volume Shadow Copy Service releases file system write I/O requests.
8. VSS tells the writers to thaw application write I/O requests. At this point applications are free to resume writing data to the disk that is being shadow-copied.

#### Note

The shadow copy creation can be aborted if the writers are kept in the freeze state for longer than 60 seconds or if the providers take longer than 10 seconds to commit the shadow copy.

9. The requester can retry the process (go back to step 1) or notify the administrator to retry at a later time.
10. If the shadow copy is successfully created, the Volume Shadow Copy Service returns the location information for the shadow copy to the requester. In some cases, the shadow copy can be temporarily made available as a read-write volume so that VSS and one or more applications can alter the contents of the shadow copy before the shadow copy is finished. After VSS and the applications make their alterations, the shadow copy is made read-only. This phase is called Auto-recovery, and it is used to undo any file-system or application transactions on the shadow copy volume that were not completed before the shadow copy was created.

## How the Provider Creates a Shadow Copy

A hardware or software shadow copy provider uses one of the following methods for creating a shadow copy:

**Complete copy** This method makes a complete copy (called a "full copy" or "clone") of the original volume at a given point in time. This copy is read-only.

**Copy-on-write** This method does not copy the original volume. Instead, it makes a differential copy by copying all changes (completed write I/O requests) that are made to the volume after a given point in time.

**Redirect-on-write** This method does not copy the original volume, and it does not make any changes to the original volume after a given point in time. Instead, it makes a differential copy by redirecting all changes to a different volume.

## Complete copy

A complete copy is usually created by making a "split mirror" as follows:

1. The original volume and the shadow copy volume are a mirrored volume set.
2. The shadow copy volume is separated from the original volume. This breaks the mirror connection.

After the mirror connection is broken, the original volume and the shadow copy volume are independent. The original volume continues to accept all changes (write I/O requests),

while the shadow copy volume remains an exact read-only copy of the original data at the time of the break.

## Copy-on-write method

In the copy-on-write method, when a change to the original volume occurs (but before the write I/O request is completed), each block to be modified is read and then written to the volume's shadow copy storage area (also called its "diff area"). The shadow copy storage area can be on the same volume or a different volume. This preserves a copy of the data block on the original volume before the change overwrites it.

 Expand table

| Time | Source data (status and data)         | Shadow copy (status and data)                  |
|------|---------------------------------------|------------------------------------------------|
| T0   | Original data: 1 2 3 4 5              | No copy: —                                     |
| T1   | Data changed in cache: 3 to 3'        | Shadow copy created (differences only): 3      |
| T2   | Original data overwritten: 1 2 3' 4 5 | Differences and index stored on shadow copy: 3 |

**Table 1** The copy-on-write method of creating shadow copies

The copy-on-write method is a quick method for creating a shadow copy, because it copies only data that is changed. The copied blocks in the diff area can be combined with the changed data on the original volume to restore the volume to its state before any of the changes were made. If there are many changes, the copy-on-write method can become expensive.

## Redirect-on-write method

In the redirect-on-write method, whenever the original volume receives a change (write I/O request), the change is not applied to the original volume. Instead, the change is written to another volume's shadow copy storage area.

 Expand table

| Time | Source data (status and data) | Shadow copy (status and data) |
|------|-------------------------------|-------------------------------|
| T0   | Original data: 1 2 3 4 5      | No copy: —                    |

| Time | Source data (status and data)      | Shadow copy (status and data)                   |
|------|------------------------------------|-------------------------------------------------|
| T1   | Data changed in cache: 3 to 3'     | Shadow copy created (differences only): 3'      |
| T2   | Original data unchanged: 1 2 3 4 5 | Differences and index stored on shadow copy: 3' |

**Table 2** The redirect-on-write method of creating shadow copies

Like the copy-on-write method, the redirect-on-write method is a quick method for creating a shadow copy, because it copies only changes to the data. The copied blocks in the diff area can be combined with the unchanged data on the original volume to create a complete, up-to-date copy of the data. If there are many read I/O requests, the redirect-on-write method can become expensive.

## Shadow Copy Providers

There are two types of shadow copy providers: hardware-based providers and software-based providers. There is also a system provider, which is a software provider that is built in to the Windows operating system.

### Hardware-based providers

Hardware-based shadow copy providers act as an interface between the Volume Shadow Copy Service and the hardware level by working in conjunction with a hardware storage adapter or controller. The work of creating and maintaining the shadow copy is performed by the storage array.

Hardware providers always take the shadow copy of an entire LUN, but the Volume Shadow Copy Service only exposes the shadow copy of the volume or volumes that were requested.

A hardware-based shadow copy provider makes use of the Volume Shadow Copy Service functionality that defines the point in time, allows data synchronization, manages the shadow copy, and provides a common interface with backup applications. However, the Volume Shadow Copy Service does not specify the underlying mechanism by which the hardware-based provider produces and maintains shadow copies.

### Software-based providers

Software-based shadow copy providers typically intercept and process read and write I/O requests in a software layer between the file system and the volume manager software.

These providers are implemented as a user-mode DLL component and at least one kernel-mode device driver, typically a storage filter driver. Unlike hardware-based providers, software-based providers create shadow copies at the software level, not the hardware level.

A software-based shadow copy provider must maintain a "point-in-time" view of a volume by having access to a data set that can be used to re-create volume status before the shadow copy creation time. An example is the copy-on-write technique of the system provider. However, the Volume Shadow Copy Service places no restrictions on what technique the software-based providers use to create and maintain shadow copies.

A software provider is applicable to a wider range of storage platforms than a hardware-based provider, and it should work with basic disks or logical volumes equally well. (A logical volume is a volume that is created by combining free space from two or more disks.) In contrast to hardware shadow copies, software providers consume operating system resources to maintain the shadow copy.

For more information about basic disks, see [What Are Basic Disks and Volumes?](#).

## System provider

One shadow copy provider, the system provider, is supplied in the Windows operating system. Although a default provider is supplied in Windows, other vendors are free to supply implementations that are optimized for their storage hardware and software applications.

To maintain the "point-in-time" view of a volume that is contained in a shadow copy, the system provider uses a copy-on-write technique. Copies of the blocks on volume that have been modified since the beginning of the shadow copy creation are stored in a shadow copy storage area.

The system provider can expose the production volume, which can be written to and read from normally. When the shadow copy is needed, it logically applies the differences to data on the production volume to expose the complete shadow copy.

For the system provider, the shadow copy storage area must be on an NTFS volume. The volume to be shadow copied does not need to be an NTFS volume, but at least one

volume mounted on the system must be an NTFS volume.

The component files that make up the system provider are swprv.dll and volsnap.sys.

## In-Box VSS Writers

The Windows operating system includes a set of VSS writers that are responsible for enumerating the data that is required by various Windows features.

For more information about these writers, see [In-Box VSS Writers](#).

## How Shadow Copies Are Used

In addition to backing up application data and system state information, shadow copies can be used for a number of purposes, including the following:

- Restoring LUNs (LUN resynchronization and LUN swapping)
- Restoring individual files (Shadow Copies for Shared Folders)
- Data mining by using transportable shadow copies

## Restoring LUNs (LUN resynchronization and LUN swapping)

In Windows Server 2008 R2 and Windows 7, VSS requesters can use a hardware shadow copy provider feature called LUN resynchronization (or "LUN resync"). This is a fast-recovery scheme that allows an application administrator to restore data from a shadow copy to the original LUN or to a new LUN.

The shadow copy can be a full clone or a differential shadow copy. In either case, at the end of the resync operation, the destination LUN will have the same contents as the shadow copy LUN. During the resync operation, the array performs a block-level copy from the shadow copy to the destination LUN.

### ⓘ Note

The shadow copy must be a transportable hardware shadow copy.

Most arrays allow production I/O operations to resume shortly after the resync operation begins. While the resync operation is in progress, read requests are redirected to the shadow copy LUN, and write requests to the destination LUN. This allows arrays to recover very large data sets and resume normal operations in several seconds.

LUN resynchronization is different from LUN swapping. A LUN swap is a fast recovery scenario that VSS has supported since Windows Server 2003 SP1. In a LUN swap, the shadow copy is imported and then converted into a read-write volume. The conversion is an irreversible operation, and the volume and underlying LUN cannot be controlled with the VSS APIs after that. The following list describes how LUN resynchronization compares with LUN swapping:

- In LUN resynchronization, the shadow copy is not altered, so it can be used several times. In LUN swapping, the shadow copy can be used only once for a recovery. For the most safety-conscious administrators, this is important. When LUN resynchronization is used, the requester can retry the entire restore operation if something goes wrong the first time.
- At the end of a LUN swap, the shadow copy LUN is used for production I/O requests. For this reason, the shadow copy LUN must use the same quality of storage as the original production LUN to ensure that performance is not impacted after the recovery operation. If LUN resynchronization is used instead, the hardware provider can maintain the shadow copy on storage that is less expensive than production-quality storage.
- If the destination LUN is unusable and needs to be recreated, LUN swapping may be more economical because it doesn't require a destination LUN.

#### **Warning**

All of the operations listed are LUN-level operations. If you attempt to recover a specific volume by using LUN resynchronization, you are unwittingly going to revert all the other volumes that are sharing the LUN.

## Restoring individual files (Shadow Copies for Shared Folders)

Shadow Copies for Shared Folders uses the Volume Shadow Copy Service to provide point-in-time copies of files that are located on a shared network resource, such as a file server. With Shadow Copies for Shared Folders, users can quickly recover deleted or changed files that are stored on the network. Because they can do so without administrator assistance, Shadow Copies for Shared Folders can increase productivity and reduce administrative costs.

For more information about Shadow Copies for Shared Folders, see [Shadow Copies for Shared Folders](https://go.microsoft.com/fwlink/?LinkId=180898) (<https://go.microsoft.com/fwlink/?LinkId=180898>) on TechNet.

## Data mining by using transportable shadow copies

With a hardware provider that is designed for use with the Volume Shadow Copy Service, you can create transportable shadow copies that can be imported onto servers within the same subsystem (for example, a SAN). These shadow copies can be used to seed a production or test installation with read-only data for data mining.

With the Volume Shadow Copy Service and a storage array with a hardware provider that is designed for use with the Volume Shadow Copy Service, it is possible to create a shadow copy of the source data volume on one server, and then import the shadow copy onto another server (or back to the same server). This process is accomplished in a few minutes, regardless of the size of the data. The transport process is accomplished through a series of steps that use a shadow copy requester (a storage-management application) that supports transportable shadow copies.

## To transport a shadow copy

1. Create a transportable shadow copy of the source data on a server.
2. Import the shadow copy to a server that is connected to the SAN (you can import to a different server or the same server).
3. The data is now ready to be used.

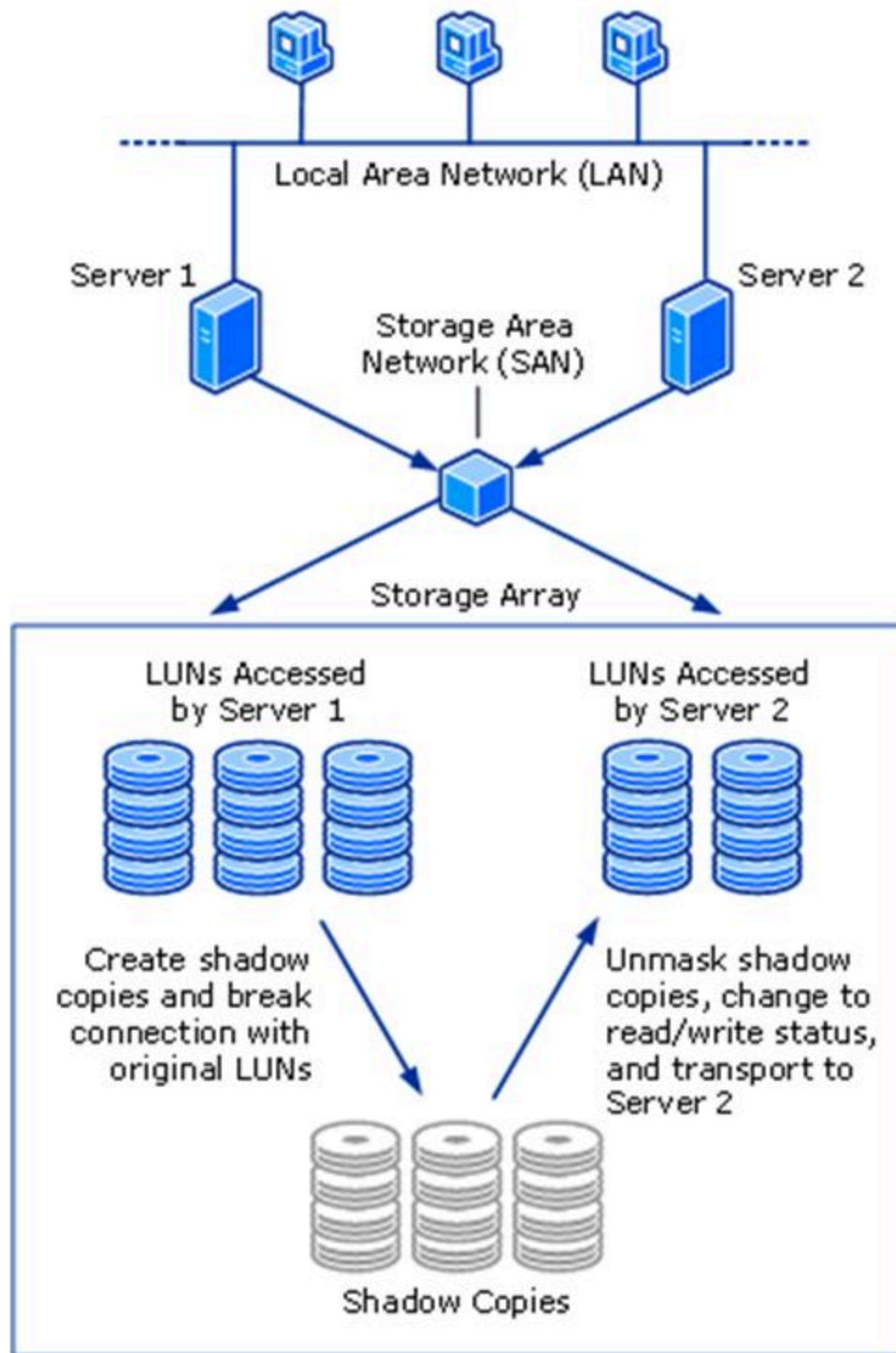


**Figure 3** Shadow copy creation and transport between two servers

#### ⓘ Note

A transportable shadow copy that is created on Windows Server 2003 cannot be imported onto a server that is running Windows Server 2008 or Windows Server 2008 R2. A transportable shadow copy that was created on Windows Server 2008 or Windows Server 2008 R2 cannot be imported onto a server that is running Windows

Server 2003. However, a shadow copy that is created on Windows Server 2008 can be imported onto a server that is running Windows Server 2008 R2 and vice versa.

Shadow copies are read-only. If you want to convert a shadow copy to a read/write LUN, you can use a Virtual Disk Service-based storage-management application (including some requesters) in addition to the Volume Shadow Copy Service. By using this application, you can remove the shadow copy from Volume Shadow Copy Service management and convert it to a read/write LUN.

Volume Shadow Copy Service transport is an advanced solution on computers running Windows Server 2003 Enterprise Edition, Windows Server 2003 Datacenter Edition, Windows Server 2008, or Windows Server 2008 R2. It works only if there is a hardware provider on the storage array. Shadow copy transport can be used for a number of purposes, including tape backups, data mining, and testing.

## Frequently Asked Questions

This FAQ answers questions about Volume Shadow Copy Service (VSS) for system administrators. For information about VSS application programming interfaces, see [Volume Shadow Copy Service](https://go.microsoft.com/fwlink/?LinkId=180899) (<https://go.microsoft.com/fwlink/?LinkId=180899>) in the Windows Developer Center Library.

### When was Volume Shadow Copy Service introduced? On which Windows operating system versions is it available?

VSS was introduced in Windows XP. It is available on Windows XP, Windows Server 2003, Windows Vista®, Windows Server 2008, Windows 7, and Windows Server 2008 R2.

### What is the difference between a shadow copy and a backup?

In the case of a hard disk drive backup, the shadow copy created is also the backup. Data can be copied off the shadow copy for a restore or the shadow copy can be used for a fast recovery scenario—for example, LUN resynchronization or LUN swapping.

When data is copied from the shadow copy to tape or other removable media, the content that is stored on the media constitutes the backup. The shadow copy itself can be deleted

after the data is copied from it.

## What is the largest size volume that Volume Shadow Copy Service supports?

Volume Shadow Copy Service supports a volume size of up to 64 TB.

## I made a backup on Windows Server 2008. Can I restore it on Windows Server 2008 R2?

It depends on the backup software that you used. Most backup programs support this scenario for data but not for system state backups.

Shadow copies that are created on either of these versions of Windows can be used on the other.

## I made a backup on Windows Server 2003. Can I restore it on Windows Server 2008?

It depends on the backup software you used. If you create a shadow copy on Windows Server 2003, you cannot use it on Windows Server 2008. Also, if you create a shadow copy on Windows Server 2008, you cannot restore it on Windows Server 2003.

## How can I disable VSS?

It is possible to disable the Volume Shadow Copy Service by using the Microsoft Management Console. However, you should not do this. Disabling VSS adversely affects any software you use that depends on it, such as System Restore and Windows Server Backup.

For more information, see the following Microsoft TechNet Web sites:

- [System Restore \(https://go.microsoft.com/fwlink/?LinkID=157113\)](https://go.microsoft.com/fwlink/?LinkID=157113)
- [Windows Server Backup \(https://go.microsoft.com/fwlink/?LinkID=180891\)](https://go.microsoft.com/fwlink/?LinkID=180891)

## Can I exclude files from a shadow copy to save space?

VSS is designed to create shadow copies of entire volumes. Temporary files, such as paging files, are automatically omitted from shadow copies to save space.

To exclude specific files from shadow copies, use the following registry key:

**FilesNotToSnapshot.**

#### ⓘ Note

The **FilesNotToSnapshot** registry key is intended to be used only by applications. Users who attempt to use it will encounter limitations such as the following:

- It cannot delete files from a shadow copy that was created on a Windows Server by using the Previous Versions feature.
- It cannot delete files from shadow copies for shared folders.
- It can delete files from a shadow copy that was created by using the [Diskshadow](#) utility, but it cannot delete files from a shadow copy that was created by using the [Vssadmin](#) utility.
- Files are deleted from a shadow copy on a best-effort basis. This means that they are not guaranteed to be deleted.

For more information, see [Excluding Files from Shadow Copies](#) (<https://go.microsoft.com/fwlink/?LinkId=180904>) on MSDN.

## My non-Microsoft backup program failed with a VSS error. What can I do?

Check the product support section of the Web site of the company that created the backup program. There may be a product update that you can download and install to fix the problem. If not, contact the company's product support department.

System administrators can use the VSS troubleshooting information on the following Microsoft TechNet Library Web site to gather diagnostic information about VSS-related issues.

For more information, see [Volume Shadow Copy Service \(https://go.microsoft.com/fwlink/?LinkId=180905\)](https://go.microsoft.com/fwlink/?LinkId=180905) on TechNet.

## What is the "diff area"?

The shadow copy storage area (or "diff area") is the location where the data for the shadow copy that is created by the system software provider is stored.

## Where is the diff area located?

The diff area can be located on any local volume. However, it must be located on an NTFS volume that has enough space to store it.

## How is the diff area location determined?

The following criteria are evaluated, in this order, to determine the diff area location:

- If a volume already has an existing shadow copy, that location is used.
- If there is a preconfigured manual association between the original volume and the shadow copy volume location, then that location is used.
- If the previous two criteria do not provide a location, the shadow copy service chooses a location based on available free space. If more than one volume is being shadow copied, the shadow copy service creates a list of possible snapshot locations based on the size of free space, in descending order. The number of locations provided is equal to the number of volumes being shadow copied.
- If the volume being shadow copied is one of the possible locations, then a local association is created. Otherwise an association with the volume with the most available space is created.

## Can VSS create shadow copies of non-NTFS volumes?

Yes. However, persistent shadow copies can be made only for NTFS volumes. In addition, at least one volume mounted on the system must be an NTFS volume.

## What's the maximum number of shadow copies I can create at one time?

The maximum number of shadow copied volumes in a single shadow copy set is 64. Note that this is not the same as the number of shadow copies.

## What's the maximum number of software shadow copies created by the system provider that I can maintain for a volume?

The max number is of software shadow copies for each volume is 512. However, by default you can only maintain 64 shadow copies that are used by the Shadow Copies of Shared Folders feature. To change the limit for the Shadow Copies of Shared Folders feature, use the following registry key: **MaxShadowCopies**.

## How can I control the space that is used for shadow copy storage space?

Type the **vssadmin resize shadowstorage** command.

For more information, see [Vssadmin resize shadowstorage](https://go.microsoft.com/fwlink/?LinkId=180906) (<https://go.microsoft.com/fwlink/?LinkId=180906>) on TechNet.

## What happens when I run out of space?

Shadow copies for the volume are deleted, beginning with the oldest shadow copy.

# Volume Shadow Copy Service Tools

The Windows operating system provides the following tools for working with VSS:

- **DiskShadow** (<https://go.microsoft.com/fwlink/?LinkId=180907>)
- **VssAdmin** (<https://go.microsoft.com/fwlink/?LinkId=84008>)

## DiskShadow

DiskShadow is a VSS requester that you can use to manage all the hardware and software snapshots that you can have on a system. DiskShadow includes commands such as the following:

- **list**: Lists VSS writers, VSS providers, and shadow copies
- **create**: Creates a new shadow copy
- **import**: Imports a transportable shadow copy
- **expose**: Exposes a persistent shadow copy (as a drive letter, for example)
- **revert**: Reverts a volume back to a specified shadow copy

This tool is intended for use by IT professionals, but developers might also find it useful when testing a VSS writer or VSS provider.

DiskShadow is available only on Windows Server operating systems. It is not available on Windows client operating systems.

## VssAdmin

VssAdmin is used to create, delete, and list information about shadow copies. It can also be used to resize the shadow copy storage area ("diff area").

VssAdmin includes commands such as the following:

- **create shadow**: Creates a new shadow copy
- **delete shadows**: Deletes shadow copies
- **list providers**: Lists all registered VSS providers
- **list writers**: Lists all subscribed VSS writers
- **resize shadowstorage**: Changes the maximum size of the shadow copy storage area

VssAdmin can only be used to administer shadow copies that are created by the system software provider.

VssAdmin is available on Windows client and Windows Server operating system versions.

## Volume Shadow Copy Service Registry Keys

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The following registry keys are available for use with VSS:

- **VssAccessControl**
- **MaxShadowCopies**
- **MinDiffAreaFileSize**

## VssAccessControl

This key is used to specify which users have access to shadow copies.

For more information, see the following entries on the MSDN Web site:

- [Security Considerations for Writers](https://go.microsoft.com/fwlink/?LinkId=157739) (<https://go.microsoft.com/fwlink/?LinkId=157739>)
- [Security Considerations for Requesters](https://go.microsoft.com/fwlink/?LinkId=180908) (<https://go.microsoft.com/fwlink/?LinkId=180908>)

## MaxShadowCopies

This key specifies the maximum number of client-accessible shadow copies that can be stored on each volume of the computer. Client-accessible shadow copies are used by Shadow Copies for Shared Folders.

For more information, see the following entry on the MSDN Web site:

**MaxShadowCopies** under [Registry Keys for Backup and Restore](https://go.microsoft.com/fwlink/?LinkId=180909) (<https://go.microsoft.com/fwlink/?LinkId=180909>)

## MinDiffAreaFileSize

This key specifies the minimum initial size, in MB, of the shadow copy storage area.

For more information, see the following entry on the MSDN Web site:

**MinDiffAreaFileSize** under [Registry Keys for Backup and Restore](https://go.microsoft.com/fwlink/?LinkId=180910) (<https://go.microsoft.com/fwlink/?LinkId=180910>)

## Supported Operating System Versions

**Ex. 2006**

The following table lists the minimum supported operating system versions for VSS features.

 Expand table

| VSS feature                                                                                                                                                                                                                                                                  | Minimum supported client | Minimum supported server     |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|------------------------------|
| LUN resynchronization                                                                                                                                                                                                                                                        | None supported           | Windows Server 2008 R2       |
| FilesNotToSnapshot registry key                                                                                                                                                                                                                                              | Windows Vista            | Windows Server 2008          |
| Transportable shadow copies                                                                                                                                                                                                                                                  | None supported           | Windows Server 2003 with SP1 |
| Hardware shadow copies                                                                                                                                                                                                                                                       | None supported           | Windows Server 2003          |
| Previous versions of Windows Server                                                                                                                                                                                                                                          | Windows Vista            | Windows Server 2003          |
| Fast recovery using LUN swap                                                                                                                                                                                                                                                 | None supported           | Windows Server 2003 with SP1 |
| Multiple imports of hardware shadow copies                                                                                                                                                                                                                                   | None supported           | Windows Server 2008          |
| <div><div> Expand table</div><div><div>Note</div><div>This is the ability to import a shadow copy more than once. Only one import operation can be performed at a time.</div></div></div> |                          |                              |
| Shadow Copies for Shared Folders                                                                                                                                                                                                                                             | None supported           | Windows Server 2003          |
| Transportable auto-recovered shadow copies                                                                                                                                                                                                                                   | None supported           | Windows Server 2008          |

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| VSS feature                                      | Minimum supported client | Minimum supported server     |
|--------------------------------------------------|--------------------------|------------------------------|
| Concurrent backup sessions (up to 64)            | Windows XP               | Windows Server 2003          |
| Single restore session concurrent with backups   | Windows Vista            | Windows Server 2003 with SP2 |
| Up to 8 restore sessions concurrent with backups | Windows 7                | Windows Server 2003 R2       |

## Additional References

[Volume Shadow Copy Service in Windows Developer Center](#)