



FlexCache volumes management

ONTAP 9

NetApp
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FlexCache volumes management

FlexCache overview

NetApp FlexCache technology accelerates data access, reduces WAN latency and lowers WAN bandwidth costs for read-intensive workloads, especially where clients need to access the same data repeatedly. When you create a FlexCache volume, you create a remote cache of an already existing (origin) volume that contains only the actively accessed data (hot data) of the origin volume.

When a FlexCache volume receives a read request of the hot data it contains, it can respond faster than the origin volume because the data does not need to travel as far to reach the client. If a FlexCache volume receives a read request for infrequently read data (cold data), it retrieves the needed data from the origin volume and then stores the data before serving the client request. Subsequent read requests for that data are then served directly from the FlexCache volume. After the first request, the data no longer needs to travel across the network, or be served from a heavily loaded system. For example, suppose you are experiencing bottlenecks within your cluster at a singular access point for frequently requested data. You can use FlexCache volumes within the cluster to provide multiple mount points to the hot data, thereby reducing the bottlenecks and increasing performance. As another example, suppose you need to decrease network traffic to a volume that is accessed from multiple clusters. You can use FlexCache volumes to distribute hot data from the origin volume across the clusters within your network. This reduces WAN traffic by giving users closer access points.

You can also use FlexCache technology to improve performance in cloud and hybrid cloud environments. A FlexCache volume can help you transition workloads to the hybrid cloud by caching data from an on-premises data center to cloud. You can also use FlexCache volumes to remove cloud silos by caching data from one cloud provider to another or between two regions of the same cloud provider.

Beginning with ONTAP 9.10.1, you can [enable global file locking](#) across all FlexCache volumes. Global file locking prevents a user from accessing a file that is already opened by another user. Updates to the origin volume are then distributed to all FlexCache volumes simultaneously.

Beginning with ONTAP 9.9.1, FlexCache volumes maintain a list of files not found. This helps reduce network traffic by removing the need to send multiple calls to the origin when clients search for non-existent files.

A list of additional [features supported for FlexCache volumes and their origin volumes](#), including a list of supported protocols by ONTAP version, is also available.

You can learn more about the architecture of ONTAP FlexCache technology in [TR-4743: FlexCache in ONTAP](#).

Videos

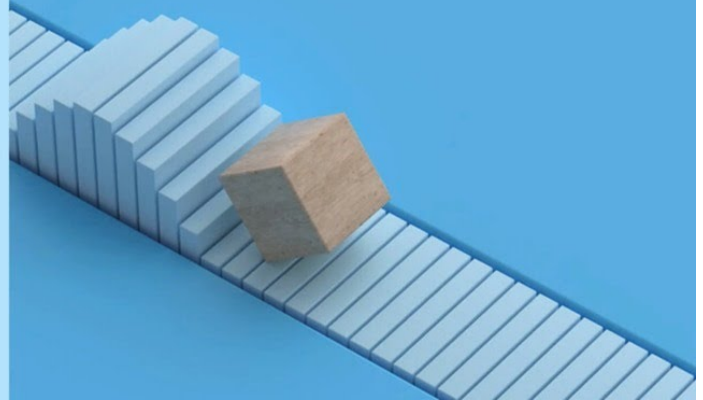
How FlexCache can reduce WAN latency and read times for global data

ONTAP FlexCache

Data Access Where You Need It

Use Case

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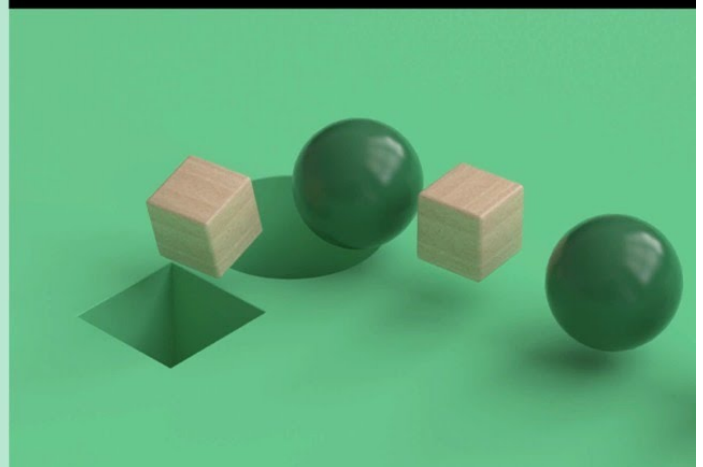
Learn about the performance benefits of ONTAP FlexCache!

ONTAP FlexCache

Data Access Where You Need It

Tech Clip

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Supported and unsupported features for FlexCache volumes

Beginning in ONTAP 9.5, you can configure FlexCache volumes. FlexVol volumes are

supported as origin volumes and FlexGroup volumes are supported as FlexCache volumes. Beginning in ONTAP 9.7 both FlexVol volumes and FlexGroup volumes are supported as origin volumes. The supported features and protocols for the origin volume and the FlexCache volume vary.

Cache volumes and origin volumes can interoperate as long as both are running on a supported version of ONTAP. Keep in mind that features are supported only when both the cache and the origin are running at least the ONTAP version where support was introduced or a later ONTAP version.

Supported protocols



Protocol	Supported at the origin volume?	Supported at the FlexCache volume?
NFSv3	Yes	Yes
NFSv4	Yes To access cache volumes using NFSv4.x protocol, both the origin and cache clusters must be using ONTAP 9.10.1 or later. The origin cluster and FlexCache cluster can have different ONTAP versions, but both should be ONTAP 9.10.1 and later versions, for example, the origin can have ONTAP 9.10.1, and the cache can have ONTAP 9.11.1.	Yes Supported beginning with ONTAP 9.10.1. To access cache volumes using NFSv4.x protocol, both the origin and cache clusters must be using ONTAP 9.10.1 or later. The origin cluster and FlexCache cluster can have different ONTAP versions, but both should be ONTAP 9.10.1 and later versions, for example, the origin can have ONTAP 9.10.1, and the cache can have ONTAP 9.11.1.
NFSv4.2	Yes	No
SMB	Yes	Yes Supported beginning with ONTAP 9.8.

Supported features

Feature	Supported at the origin volume?	Supported at the FlexCache volume?
---------	---------------------------------	------------------------------------

Autonomous ransomware protection	<p>Yes</p> <p>Supported for FlexVol origin volumes beginning with ONTAP 9.10.1, and supported for FlexGroup origin volumes beginning with ONTAP 9.13.1. See Autonomous Ransomware Protection use cases and considerations.</p>	No
Antivirus	<p>Yes</p> <p>Supported beginning with ONTAP 9.7.</p>	<p>Not applicable</p> <p>If you configure antivirus scanning at the origin, it is not required on the cache. The origin antivirus scanning detects files infected with viruses before writes are committed, regardless of the write source. For more information about using antivirus scanning with FlexCache, see the FlexCache with ONTAP technical report.</p>
Auditing	<p>Yes</p> <p>Supported beginning with ONTAP 9.7. You can audit NFS file access events in FlexCache relationships using native ONTAP auditing. For more information, see Considerations for auditing FlexCache volumes</p>	<p>Yes</p> <p>Supported beginning with ONTAP 9.7. You can audit NFS file access events in FlexCache relationships using native ONTAP auditing. For more information, see Considerations for auditing FlexCache volumes</p>
Cloud Volumes ONTAP	<p>Yes</p> <p>Supported beginning with ONTAP 9.6</p>	<p>Yes</p> <p>Supported beginning with ONTAP 9.6</p>
Compaction	<p>Yes</p> <p>Supported beginning with ONTAP 9.6</p>	<p>Yes</p> <p>Supported beginning with ONTAP 9.7</p>
Compression	<p>Yes</p> <p>Supported beginning with ONTAP 9.6</p>	<p>Yes</p> <p>Supported beginning with ONTAP 9.6</p>

Deduplication	Yes	Yes Inline deduplication is supported on FlexCache volumes beginning with ONTAP 9.6. Cross-volume deduplication is supported on FlexCache volumes beginning with ONTAP 9.7.
FabricPool	Yes	Yes Supported beginning with ONTAP 9.7
FlexCache DR	Yes	Yes Supported beginning with ONTAP 9.9.1, with NFSv3 protocol, only. FlexCache volumes must be in separate SVMs or in separate clusters.
FlexGroup volume	Yes Supported beginning with ONTAP 9.7	Yes
FlexVol volume	Yes	No
FPolicy	Yes Supported beginning with ONTAP 9.7	Yes Supported for NFS beginning with ONTAP 9.7. Supported for SMB beginning with ONTAP 9.14.1.
MetroCluster configuration	Yes Supported beginning with ONTAP 9.7	Yes Supported beginning with ONTAP 9.7
Microsoft Offloaded Data Transfer (ODX)	Yes	No
NetApp Aggregate Encryption (NAE)	Yes Supported beginning with ONTAP 9.6	Yes Supported beginning with ONTAP 9.6

NetApp Volume Encryption (NVE)	<p>Yes</p> <p>Supported beginning with ONTAP 9.6</p>	<p>Yes</p> <p>Supported beginning with ONTAP 9.6</p>
ONTAP S3 NAS bucket	<p>Yes</p> <p>Supported beginning with ONTAP 9.12.1</p>	No
QoS	Yes	<p>Yes</p> <div>  <p>File-level QoS is not supported for FlexCache volumes.</p> </div>
Qtrees	<p>Yes</p> <p>Beginning with ONTAP 9.6, you can create and modify qtrees. Qtrees created on the source can be accessed on the cache.</p>	No
Quotas	<p>Yes</p> <p>Beginning with ONTAP 9.6, quota enforcement on FlexCache origin volumes is supported for users, groups, and qtrees.</p>	<p>No</p> <p>With FlexCache writearound mode (the default mode), writes on the cache are forwarded to the origin volume. Quotas are enforced at the origin.</p> <div>  <p>Beginning with ONTAP 9.6, remote quota (rquota) is supported at FlexCache volumes.</p> </div>
SMB Change Notify	Yes	<p>Yes</p> <p>Beginning with ONTAP 9.14.1, SMB Change Notify is supported at the cache.</p>
SnapLock volumes	No	No
SnapMirror asynchronous relationships*	Yes	No

	<p>*FlexCache origins:</p> <ul style="list-style-type: none"> • You can have a FlexCache volume from an origin FlexVol • You can have a FlexCache volume from an origin FlexGroup • You can have a FlexCache volume from an origin primary volume in SnapMirror relationship. • Beginning with ONTAP 9.8, a SnapMirror secondary volume can be a FlexCache origin volume. The SnapMirror secondary volume must be idle with no active SnapMirror updates; otherwise, FlexCache creation fails. 	
SnapMirror synchronous relationships	No	No
SnapRestore	Yes	No
Snapshot copies	Yes	No
SVM DR configuration	<p>Yes</p> <p>Supported beginning with ONTAP 9.5. The primary SVM of an SVM DR relationship can have the origin volume; however, if the SVM DR relationship is broken, the FlexCache relationship must be re-created with a new origin volume.</p>	<p>No</p> <p>You can have FlexCache volumes in primary SVMs, but not in secondary SVMs. Any FlexCache volume in the primary SVM is not replicated as part of the SVM DR relationship.</p>
Storage-level Access Guard (SLAG)	No	No
Thin provisioning	Yes	<p>Yes</p> <p>Supported beginning with ONTAP 9.7</p>
Volume cloning	<p>Yes</p> <p>Cloning of an origin volume and the files in the origin volume is supported beginning with ONTAP 9.6.</p>	No
Volume move	Yes	<p>Yes (only for volume constituents)</p> <p>Moving volume constituents of a FlexCache volume is supported with ONTAP 9.6 and later.</p>

Volume rehost	No	No
vStorage API for Array Integration (VAAI)	Yes	No



In ONTAP 9 releases earlier than 9.5, origin FlexVol volumes can only serve data to FlexCache volumes created on systems running Data ONTAP 8.2.x operating in 7-Mode. Beginning with ONTAP 9.5, origin FlexVol volumes can also serve data to FlexCache volumes on ONTAP 9 systems. For information about migrating from 7-mode FlexCache to ONTAP 9 FlexCache see [NetApp Technical Report 4743: FlexCache in ONTAP](#).

Guidelines for sizing a FlexCache volume

You must be aware of the limits for FlexCache volumes before you start provisioning the volumes.

The size limit of a FlexVol volume is applicable to an origin volume. The size of a FlexCache volume can be less than or equal to the origin volume. The best practice for the size of a FlexCache volume is to be at least 10 percent of the size of the origin volume.

You must also be aware of the following additional limits on FlexCache volumes:

Limit	ONTAP 9.5-9.6	ONTAP 9.7	ONTAP 9.8 and later
Maximum number of FlexCache volumes that you can create from an origin volume	10	10	100
Recommended maximum number of origin volumes per node	10	100	100
Recommended maximum number of FlexCache volumes per node	10	100	100
Recommended maximum number of FlexGroup constituents in a FlexCache volume per node	40	800	800
Maximum number of constituents per FlexCache volume per node	32	32	32

Related information

[NetApp Interoperability](#)

Create a FlexCache volume

You can create a FlexCache volume in the same cluster for improving performance when accessing a hot object. If you have data centers in different locations, you can create FlexCache volumes on remote clusters for accelerating data access.

About this task

- Beginning with ONTAP 9.5, FlexCache supports FlexVol volumes as origin volumes and FlexGroup

volumes as FlexCache volumes.

- Beginning in ONTAP 9.7 both FlexVol volume and FlexGroup volumes are supported as origin volumes.
- Beginning with ONTAP 9.14.0, you can create an unencrypted FlexCache volume from an encrypted source.

Before you begin

- You must be running ONTAP 9.5 or later.
- If you are running ONTAP 9.6 or earlier, you must [add a FlexCache license](#).

A FlexCache license is not required for ONTAP 9.7 or later. Beginning with ONTAP 9.7, FlexCache functionality is included with ONTAP and no longer requires a license or activation.




If an HA pair is using [encrypting SAS or NVMe drives \(SED, NSE, FIPS\)](#), you must follow the instructions in the topic [Returning a FIPS drive or SED to unprotected mode](#) for all drives within the HA pair prior to initializing the system (boot options 4 or 9). Failure to do this may result in future data loss if the drives are repurposed.


Example 1. Steps

System Manager

1. If the FlexCache volume is on a different cluster than the origin volume, create a cluster peer relationship:
 - a. In the local cluster, click **Protection > Overview**.
 - b. Expand **Intercluster Settings**, click **Add Network Interfaces** and add intercluster network interfaces for the cluster.

Repeat this step on the remote cluster.

 - c. In the remote cluster, click **Protection > Overview**. Click  in the Cluster Peers section and click **Generate Passphrase**.
 - d. Copy the generated passphrase and paste it in the local cluster.
 - e. In the local cluster, under Cluster Peers, click **Peer Clusters** and peer the local and remote clusters.
2. Create an SVM peer relationship:

Under Storage VM Peers, click  and then **Peer Storage VMs** to peer the storage VMs.
3. Select **Storage > Volumes**.
4. Select **Add**.
5. Select **More Options** and then select **Add as cache for a remote volume**.



If you are running ONTAP 9.8 or later and you want to disable QoS or choose a custom QoS policy, click **More Options**, and then under **Storage and Optimization**, select **Performance Service Level**.

CLI

1. If the FlexCache volume to be created is in a different cluster, create a cluster peer relationship:
 - a. On the destination cluster, create a peer relationship with the data protection source cluster:

```
cluster peer create -generate-passphrase -offer-expiration
MM/DD/YYYY HH:MM:SS|1...7days|1...168hours -peer-addr
<peer_LIF_IPs> -initial-allowed-vserver-peers <svm_name>,...|*
-ipospace <ipospace_name>
```

Beginning with ONTAP 9.6, TLS encryption is enabled by default when creating a cluster peer relationship. TLS encryption is supported for the intercluster communication between the origin and FlexCache volumes. You can also disable TLS encryption for the cluster peer relationship, if required.

```
cluster02::> cluster peer create -generate-passphrase -offer
-expiration 2days -initial-allowed-vserver-peers *
```

Passphrase: UCa+6lRVICXeL/gq1WrK7ShR
Expiration Time: 6/7/2017 08:16:10 EST
Initial Allowed Vserver Peers: *
Intercluster LIF IP: 192.140.112.101
Peer Cluster Name: Clus_7ShR (temporary generated)

Warning: make a note of the passphrase - it cannot be displayed again.

- b. On the source cluster, authenticate the source cluster to the destination cluster:

```
cluster peer create -peer-addr <peer_LIF_IPs> -ip-space <ip-space>
```

```
cluster01::> cluster peer create -peer-addr
192.140.112.101,192.140.112.102
```

Notice: Use a generated passphrase or choose a passphrase of 8 or more characters.

To ensure the authenticity of the peering relationship, use a phrase or sequence of characters that would be hard to guess.

Enter the passphrase:
Confirm the passphrase:

Clusters cluster02 and cluster01 are peered.

2. If the FlexCache volume is in a different SVM than that of the origin volume, create an SVM peer relationship with flexcache as the application:

- a. If the SVM is in a different cluster, create an SVM permission for the peering SVMs:

```
vserver peer permission create -peer-cluster <cluster_name>
-vserver <svm-name> -applications flexcache
```

The following example illustrates how to create an SVM peer permission that applies for all of the local SVMs:

```
cluster1::> vsserver peer permission create -peer-cluster cluster2
-vserver "*" -applications flexcache
```

Warning: This Vserver peer permission applies to all local Vservers. After that no explicit "vsserver peer accept" command required for Vserver peer relationship creation request from peer cluster "cluster2" with any of the local Vservers. Do you want to continue? {y|n}: y

b. Create the SVM peer relationship:

```
vsserver peer create -vserver <local_SVM> -peer-vserver
<remote_SVM> -peer-cluster <cluster_name> -applications flexcache
```

3. Create a FlexCache volume:

```
volume flexcache create -vserver <cache_svm> -volume
<cache_vol_name> -auto-provision-as flexgroup -size <vol_size>
-origin-vserver <origin_svm> -origin-volume <origin_vol_name>
```

The following example creates a FlexCache volume and automatically selects existing aggregates for provisioning:

```
cluster1::> volume flexcache create -vserver vs_1 -volume fc1 -auto
-provision-as flexgroup -origin-volume vol_1 -size 160MB -origin
-vserver vs_1
[Job 443] Job succeeded: Successful
```

The following example creates a FlexCache volume and sets the junction path:

```
cluster1::> flexcache create -vserver vs34 -volume fc4 -aggr-list
aggr34,aggr43 -origin-volume origin1 -size 400m -junction-path /fc4
[Job 903] Job succeeded: Successful
```

4. Verify the FlexCache relationship from the FlexCache volume and the origin volume.

a. View the FlexCache relationship in the cluster:

```
volume flexcache show
```

```
cluster1::> volume flexcache show
Vserver Volume      Size      Origin-Vserver Origin-Volume
Origin-Cluster
-----
vs_1      fc1        160MB     vs_1          vol_1
cluster1
```

- b. View all of the FlexCache relationships in the origin cluster:

```
volume flexcache origin show-caches
```

```
cluster::> volume flexcache origin show-caches
Origin-Vserver Origin-Volume  Cache-Vserver  Cache-Volume
Cache-Cluster
-----
vs0            ovol1        vs1            cfg1
clusA
vs0            ovol1        vs2            cfg2
clusB
vs_1           vol_1        vs_1           fc1
cluster1
```

Result

The FlexCache volume is successfully created. Clients can mount the volume by using the junction path of the FlexCache volume.

Related information

[Cluster and SVM peering](#)

FlexCache writeback

FlexCache write-back overview

Introduced in ONTAP 9.15.1, FlexCache write-back is an alternate mode of operation for writing at a cache. Writeback allows the write to be committed to stable storage at the cache and acknowledged to the client without waiting for the data to make it to the origin. The data is asynchronously flushed back to the origin. The result is a globally distributed file system that enables writes to perform at near-local speeds for specific workloads and environments, offering significant performance benefits.



ONTAP 9.12.1 introduced a write-back feature as a public preview. This is referred to as write-back version 1 (wbv1) and shouldn't be thought of as the same as write-back in ONTAP 9.15.1, which is referred to as write-back version 2 (wbv2).

Writeback vs write-around

Since FlexCache was introduced in ONTAP 9.5, it has been a read-writable cache; however, it operated in write-around mode. Writes at the cache were shipped to the origin to be committed to stable storage. After the origin successfully committed the write to stable storage, it acknowledged the write to the cache. The cache would then acknowledge the write to the client. This made every write incur the penalty of traversing the network between the cache and origin. FlexCache write-back changes this.



After upgrading to ONTAP 9.15.1, you can convert a traditional write-around cache to a write-back cache, and, if necessary, back to write-around. This can, however, make reading diagnostic logs harder should a problem arise.

	Write-around	Write-back
ONTAP Version	9.6+	9.15.1+
Use case	Read-heavy workload	Write-heavy workload
Data committed at	Origin	Cache
Client experience	WAN-like	LAN-like
Limits	100 per origin	10 per origin
CAP Theorem	Available and tolerant to partition	Available and consistent

FlexCache write-back terminology

Understand key concepts and terms working with FlexCache write-back.

Term	Definition
Dirty data	Data that has been committed to stable storage at the cache, but has not been flushed to the origin.
Exclusive Lock Delegation (XLD)	A protocol-level lock authority granted on a per-file basis to a cache. This authority allows the cache to hand out exclusive write locks to clients without contacting the origin.
Shared Lock Delegation (SLD)	A protocol-level lock authority granted on a per-file basis to a cache. This authority allows the cache to hand out shared read locks to clients without contacting the origin.
Writeback	A mode of FlexCache operation where writes to a cache are committed to stable storage at that cache and immediately acknowledged to the client. Data is asynchronously written back to the origin.
Write-around	A mode of FlexCache operation where writes to a cache are forwarded to the origin to be committed to stable storage. Once committed, the origin will acknowledge the write to the cache, and the cache will acknowledge the write to the client.

Term	Definition
Dirty Data Record System (DDRS)	A proprietary mechanism that keeps track of the dirty data in a write-back-enabled cache on a per-file basis.
Origin	A FlexGroup or FlexVol that contains the source data for all FlexCache cache volumes. It is the single source of truth, orchestrates locking, and ensures 100% data consistency, currency, and coherency.
Cache	A FlexGroup that is a sparse cache volume of the FlexCache origin.

Consistent, current, and coherent

FlexCache is NetApp's solution to having the right data, everywhere, every time. FlexCache is 100% consistent, current, and coherent 100% of the time:

- **Consistent:** The data is the same wherever it is accessed.
- **Current:** The data is always up-to-date.
- **Coherent:** The data is correct/uncorrupted.

FlexCache write-back architecture

FlexCache was designed with strong consistency in mind, including both modes of write operation: write-back and write-around. Both the traditional write-around mode of operation and the new write-back mode of operation introduced in ONTAP 9.15.1 guarantee that the data accessed will always be 100% consistent, current, and coherent.

The following concepts detail how FlexCache write-back operates.

Delegations

Lock delegations and data delegations helps FlexCache keep both write-back and write-around caches data consistent, coherent, and current. The origin orchestrates both delegations.

Lock delegations

A lock delegation is a protocol-level lock authority the origin grants on a per-file basis to a cache to issue protocol locks to clients as needed. These include [exclusive lock delegations \(XLD\)](#) and [shared lock delegations \(SLD\)](#).

XLD and write-back

To ensure ONTAP never has to reconcile a conflicting write, an XLD is granted to a cache where a client requests to write to a file. Importantly, only one XLD can exist for any file at any time, meaning there never will be more than one writer to a file at a time.

When the request to write to a file comes into a write-back enabled cache, the following steps take place:

1. The cache checks if it already has an XLD for the requested file. If so, it will grant the write lock to the client as long as another client isn't writing to the file at the cache. If the cache doesn't have an XLD for the requested file, it will request one from the origin. This is a proprietary call that traverses the intercluster network.

2. Upon receiving the XLD request from the cache, the origin will check if there is an outstanding XLD for the file at another cache. If so, it will recall that file's XLD, which triggers a flush of any [dirty data](#) from that cache back to the origin.
3. Once the dirty data from that cache is flushed back and committed to stable storage at the origin, the origin will grant the XLD for the file to the requesting cache.
4. Once the file's XLD is received, the cache grants the lock to the client, and the write commences.

A high-level sequence diagram covering some of these steps is covered in the [Write-back](#) sequence diagram.

From a client perspective, all locking will work as if it were writing to a standard FlexVol or FlexGroup with a potential small delay when the write lock is requested.

In its current iteration, if a write-back enabled cache holds the XLD for a file, ONTAP will block **any** access to that file at other caches, including `READ` operations.



There is a limit of 170 XLDs per origin constituent.

Data delegations

A data delegation is a per-file guarantee given to a cache by the origin that the data cached for that file is up-to-date. As long as the cache has a data delegation for a file, it can serve the cached data for that file to the client without having to contact the origin. If the cache doesn't have a data delegation for the file, it must contact the origin to receive the data requested by the client.

In write-back mode, a file's data delegation is revoked if an XLD is taken for that file at another cache or the origin. This effectively fences off the file from clients at all other caches and the origin, even for reads. This is a trade off that must be made to ensure old data is never accessed.

Reads at a write-back-enabled cache generally operate like reads at a write-around cache. In both write-around and write-back-enabled caches, there could be an initial `READ` performance hit when the requested file has an exclusive write lock at a write-back-enabled cache other than where the read is issued. The XLD has to be revoked, and the dirty data must be committed to the origin before the read at the other cache can be serviced.

Tracking dirty data

Write-back from cache to origin happens asynchronously. This means that dirty data isn't immediately written back to the origin. ONTAP employs a dirty data record system to keep track of dirty data per file. Each dirty data record (DDR) represents approximately 20MB of dirty data for a particular file. When a file is actively being written, ONTAP will start flushing dirty data back after two DDRs have been filled and the third DDR is being written. This results in approximately 40MB of dirty data remaining in a cache during writes. For stateful protocols (NFSv4.x, SMB), the remaining 40MB of data will be flushed back to the origin when the file is closed. For stateless protocols (NFSv3), the 40MB of data will be flushed back when either access to the file is requested at a different cache or after the file is idle for two or more minutes, up to a maximum of five minutes. For more information on timer-triggered or space-triggered dirty data flushing, see [Cache scrubbers](#).

In addition to the DDRs and scrubbers, some front-end NAS operations also trigger the flushing of all dirty data for a file:

- `SETATTR`
 - `'SETATTR'`s that modify only `mtime`, `atime`, and/or `ctime` can be processed at the cache, avoiding the penalty of the WAN.

- CLOSE
- OPEN at another cache
- READ at another cache
- REaddir at another cache
- REaddirplus at another cache
- WRITE at another cache

Disconnected mode

When an XLD for a file is held at a write-around cache and that cache gets disconnected from the origin, reads for that file are still allowed at the other caches and origin. This behavior differs when an XLD is held by a write-back-enabled cache. In this case, if the cache is disconnected, reads to the file will hang everywhere. This helps ensure 100% consistency, currency, and coherence are maintained. The reads are allowed in write-around mode because the origin is guaranteed to have all of the data available that has been write-acknowledged to the client. In write-back mode during a disconnect, the origin can not guarantee that all of the data written to and acknowledged by the write-back-enabled cache made it to the origin before the disconnect occurred.

In the event a cache with an XLD for a file is disconnected for an extended period of time, a system administrator can manually revoke the XLD at the origin. This will allow IO to the file to resume at the surviving caches and the origin.



Manually revoking the XLD will result in the loss of any dirty data for the file at the disconnected cache. Manually revoking an XLD should only be done in the event of a catastrophic disruption between the cache and origin.

Cache scrubbers

There are scrubbers in ONTAP that run in response to specific events, such as a timer expiring or space thresholds being breached. The scrubbers take an exclusive lock on the file being scrubbed, effectively freezing IO to that file until the scrub completes.

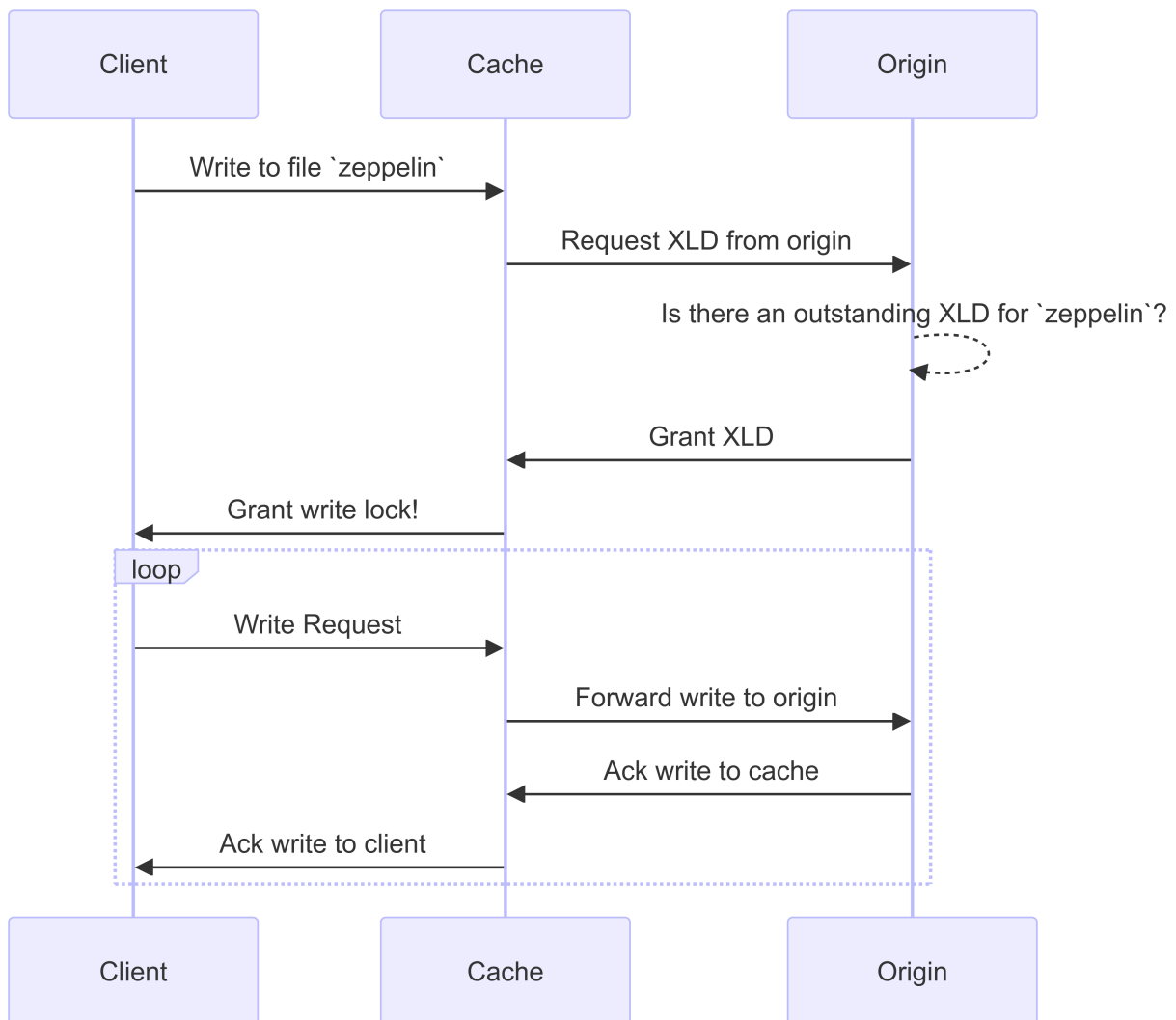
Scrubbers include:

- **mtime-based scrubber on the cache:** This scrubber starts every five minutes and scrubs any file sitting unmodified for two minutes. If any dirty data for the file is still in the cache, IO to that file is quiesced and write-back is triggered. IO will resume after the write-back is complete.
- **mtime-based scrubber on origin:** Much like the mtime-based scrubber at the cache, this also runs every five minutes. However, it scrubs any file sitting unmodified for 15 minutes, recalling the inode's delegation. This scrubber doesn't initiate any write-back.
- **RW limit-based scrubber on origin:** ONTAP monitors how many RW lock delegations are handed out per origin constituent. If this number surpasses 170, ONTAP starts scrubbing write lock delegations on a least-recently-used (LRU) basis.
- **Space-based scrubber on the cache:** If a FlexCache volume reaches 90% full, the cache is scrubbed, evicting on an LRU basis.
- **Space-based scrubber on the origin:** If a FlexCache origin volume reaches 90% full, the cache is scrubbed, evicting on an LRU basis.

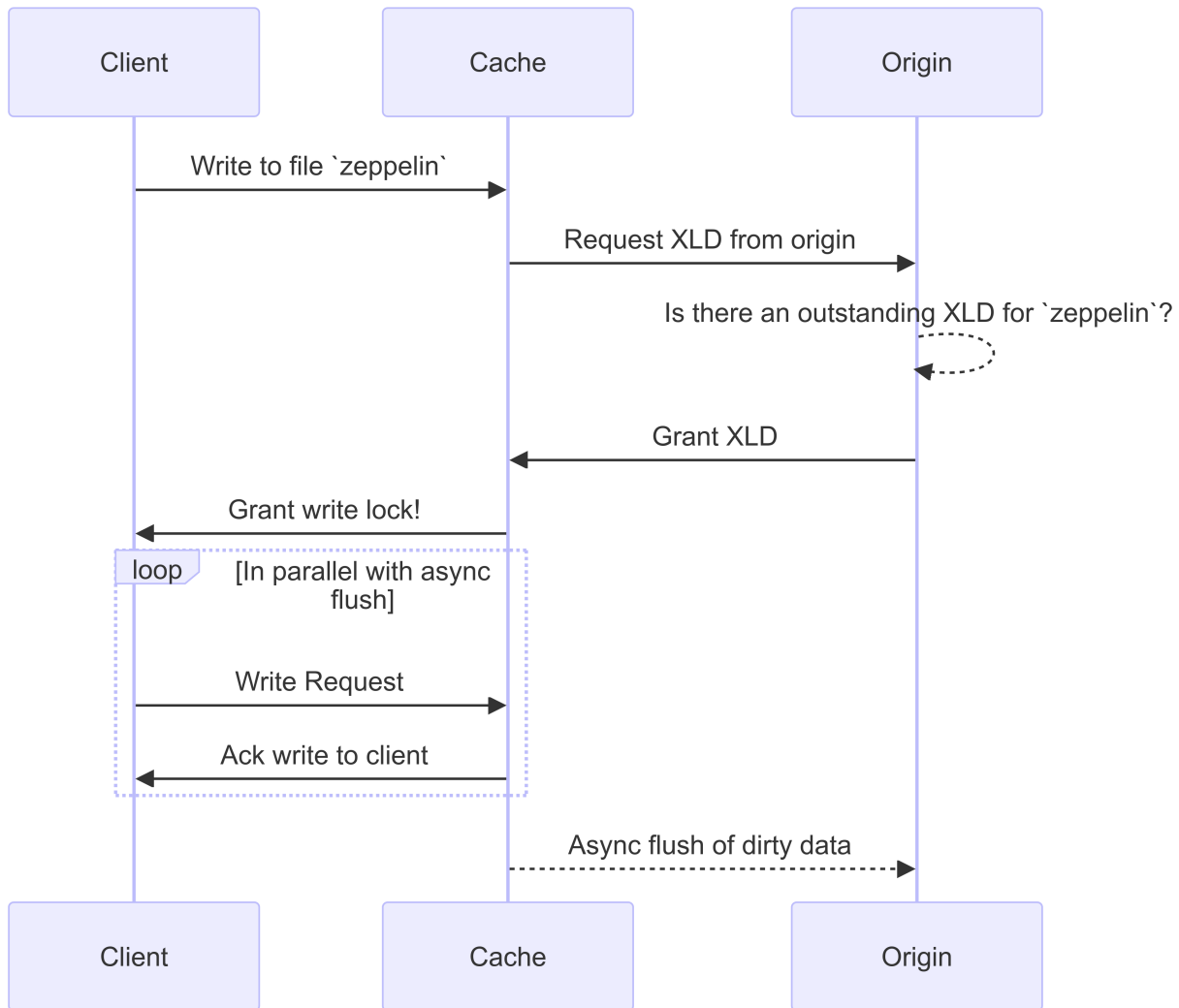
Sequence diagrams

These sequence diagrams depict the difference in write acknowledgements between write-around and write-back mode.

Write-around



Write-back



FlexCache writeback use cases

These are write profiles best suited for a write-back-enabled FlexCache. You should test your workload to see if write-back or write-around provides the best performance.



Write-back is not a replacement for write-around. Although write-back is designed with write-heavy workloads, write-around is still the better choice for many workloads.

Target workloads

File size

File size is less important than the number of writes issued between the `OPEN` and `CLOSE` calls for a file. Small files inherently have fewer `WRITE` calls, making them less ideal for write-back. Large files might have more writes between `OPEN` and `CLOSE` calls, but this isn't guaranteed.

Write size

When writing from a client, other NAS calls are involved other than write calls:

- `CREATE`

- OPEN
- CLOSE
- REaddir/REaddirplus
- SETATTR: SETATTR calls that only modify `mtime`, `atime`, or `ctime` are processed at the cache.

These calls must be processed at the origin and trigger a write-back of any dirty data accumulated at the write-back-enabled cache for the file being operated on. IO to the file will be quiesced until the write-back is complete.

Knowing that these calls must traverse the WAN helps you to identify workloads suited for write-back. Generally, the more writes that can be done between `OPEN` and `CLOSE` calls without one of the other calls listed above being issued, the better the performance gain write-back provides.

Read-after-write

Read-after-write workloads have historically performed poorly at FlexCache. This is due to the write-around mode of operation before 9.15.1. The `WRITE` call to the file has to be committed at the origin, and the subsequent `READ` call would have to pull the data back to the cache. This results in both operations incurring the penalty of the WAN. Therefore, read-after-write workloads are discouraged for FlexCache in write-around mode. With the introduction of write-back in 9.15.1, data is now committed at the cache, and can immediately be read from the cache, eliminating the WAN penalty. If your workload includes read-after-write at FlexCache volumes, you should configure the cache to operate in write-back mode.



If read-after-write is a critical part of your workload, you should configure your cache to operate in write-back mode.

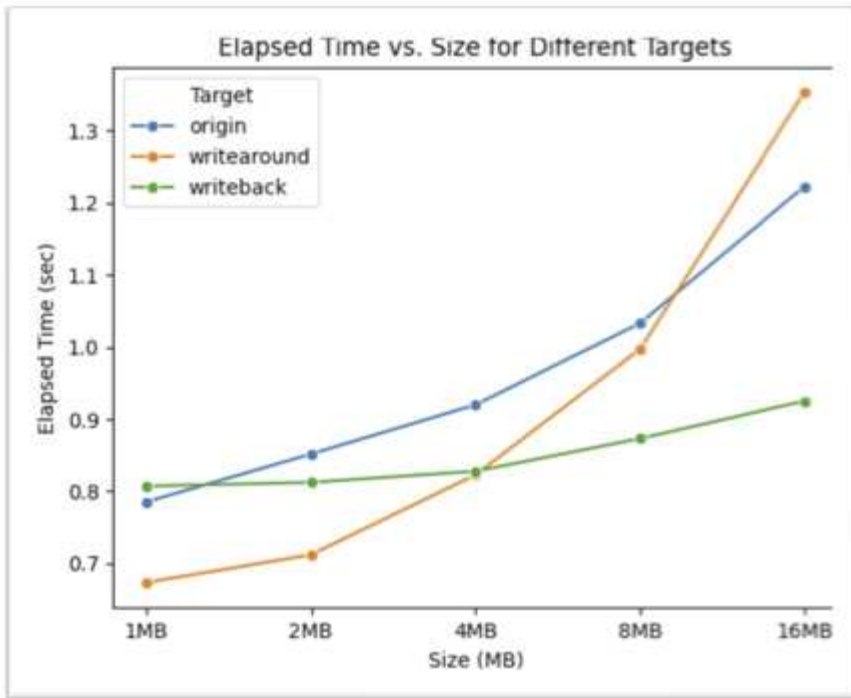
Write-after-write

When a file accumulates dirty data in a cache, the cache asynchronously writes the data back to the origin. This naturally leads to times when the client closes the file with dirty data still waiting to be flushed back to origin. If another open or write comes in for the file that was just closed and still has dirty data, the write will be suspended until all the dirty data has been flushed to origin.

Latency considerations

When FlexCache operates in write-back mode, it becomes more beneficial to NAS clients as latency increases. There is a point, however, at which the overhead of write-back outweighs the advantages gained in low-latency environments. In some NetApp tests, writeback benefits started around a minimum latency between cache and origin of 8ms. This latency varies with workload, so be sure to test to know your benefits point-of-return.

The following graph shows the point-of-return for write-back in NetApp lab tests. The `x` axis is the file-size, and the `y` axis is the elapsed time. The test used NFSv3, mounting with an `rsize` and `wsizes` of 256KB, and 64ms of WAN latency. This test was performed using a small ONTAP Select instance for both the cache and origin, and a single threaded-write operation. Your results might vary.



Write-back should not be used for intracluster caching. Intracluster caching occurs when the origin and cache are in the same cluster.

FlexCache write-back prerequisites

Before you deploy FlexCache in write-back mode, ensure you have met these software, licensing, and system configuration requirements.

ONTAP version

- The origin **must** be running ONTAP 9.15.1 or later.
- Any caching cluster that needs to operate in write-back mode **must** be running ONTAP 9.15.1 or later.
- Any caching cluster that does not need to operate in write-back mode can run any supported ONTAP version.

Licensing

FlexCache, including the write-back mode of operation, is included with your ONTAP purchase. No extra license is required.

Peering

- The origin and cache clusters must be [cluster peered](#)
- The server virtual machines (SVMs) on the origin and cache cluster must be [vserver peered](#) with the FlexCache option.



You do not need to peer a cache cluster to another cache cluster. There is also no need to peer a cache SVM to another cache SVM.

FlexCache Writeback interoperability

Understand these interoperability considerations when deploying FlexCache in write-back mode.

ONTAP version

To use the write-back mode of operation, both the cache and origin **must** be running ONTAP 9.15.1 or later.



Clusters where a write-back-enabled cache is unnecessary can run earlier versions of ONTAP, but that cluster can only operate in write-around mode.

You can have a mix of ONTAP versions in your environment.

Table 1. Mixed cluster versions example 1

Cluster	ONTAP version	Write-back supported?
Origin	ONTAP 9.15.1	N/A †
Cluster 1	ONTAP 9.15.1	Yes
Cluster 2	ONTAP 9.14.1	No

Table 2. Mixed cluster versions example 2

Cluster	ONTAP version	Write-back supported?
Origin	ONTAP 9.14.1	N/A †
Cluster 1	ONTAP 9.15.1	No
Cluster 2	ONTAP 9.15.1	No

† Origins aren't a cache, so neither write-back nor write-around support is applicable.



In [Mixed cluster versions example 2](#), neither cluster can enable write-back mode because the origin is not running ONTAP 9.15.1 or later, which is a strict requirement.

Client interoperability

Any client generally supported by ONTAP can access a FlexCache volume regardless of whether it is operating in write-around or write-back mode. For an up-to-date list of supported clients, refer to NetApp's [interoperability matrix](#).

Although the client version doesn't matter specifically, the client must be new enough to support NFSv3, NFSv4.0, NFSv4.1, SMB2.x, or SMB3.x. SMB1 and NFSv2 are deprecated protocols and are not supported.

Write-back and write-around

As seen in [Mixed cluster versions example 1](#), FlexCache operating in write-back mode can co-exist with caches operating in write-around mode. It is advised to compare write-around against write-back with your specific workload.



If the performance for a workload is the same between write-back and write-around, use write-around.

ONTAP feature interoperability

For the most up-to-date list of FlexCache feature interoperability, refer to [the supported and unsupported features for FlexCache volumes](#).

Enable and manage FlexCache write-back

Beginning with ONTAP 9.15.1, you can enable FlexCache write-back mode on FlexCache volumes to provide better performance for edge computing environments and caches with write-heavy workloads. You can also determine whether write-back is enabled on a FlexCache volume or disable write-back on the volume when necessary.

When write-back is enabled on the cache volume, write requests are sent to the local cache rather than to the origin volume.

Before you begin

You must be in advanced privilege mode.

Create a new FlexCache volume with write-back enabled


Steps

You can create a new FlexCache volume with write-back enabled by using ONTAP System Manager or the ONTAP CLI.

System Manager

1. If the FlexCache volume is on a different cluster than the origin volume, create a cluster peer relationship:
 - a. On the local cluster, click **Protection > Overview**.
 - b. Expand **Intercluster Settings**, click **Add Network Interfaces**, and add intercluster interfaces to the cluster.

Repeat this on the remote cluster.

- c. On the remote cluster, click **Protection > Overview**. Click  in the Cluster Peers section and click **Generate Passphrase**.
 - d. Copy the generated passphrase and paste it in the local cluster.
 - e. On the local cluster, under Cluster Peers, click **Peer Clusters** and peer the local and remote clusters.
2. If the FlexCache volume is on a different cluster than the origin volume, create an SVM peer relationship:

Under **Storage VM Peers**, click  and then **Peer Storage VMs** to peer the storage VMs.

If the FlexCache volume is on the same cluster, you cannot create an SVM peer relationship using System Manager.

3. Select **Storage > Volumes**.
4. Select **Add**.
5. Select **More Options** and then select **Add as cache for a remote volume**.
6. Select **Enable FlexCache write-back**.

CLI

1. If the FlexCache volume to be created is in a different cluster, create a cluster peer relationship:
 - a. On the destination cluster, create a peer relationship with the data protection source cluster:

```
cluster peer create -generate-passphrase -offer-expiration
MM/DD/YYYY HH:MM:SS|1...7days|1...168hours -peer-addr
s <peer_LIF_IPs> -initial-allowed-vserver-peers <svm_name>,...|*
-ipospace <ipospace_name>
```

Beginning with ONTAP 9.6, TLS encryption is enabled by default when creating a cluster peer relationship. TLS encryption is supported for the intercluster communication between the origin and FlexCache volumes. You can also disable TLS encryption for the cluster peer relationship, if required.

```
cluster02::> cluster peer create -generate-passphrase -offer  
-expiration 2days -initial-allowed-vserver-peers *
```

```
Passphrase: UCa+6lRVICXeL/gq1WrK7ShR  
Expiration Time: 6/7/2017 08:16:10 EST  
Initial Allowed Vserver Peers: *  
Intercluster LIF IP: 192.140.112.101  
Peer Cluster Name: Clus_7ShR (temporary generated)
```

Warning: make a note of the passphrase - it cannot be displayed again.

- b. On the source cluster, authenticate the source cluster to the destination cluster:

```
cluster peer create -peer-addr <peer_LIF_IPs> -ip-space <ip-space>
```

```
cluster01::> cluster peer create -peer-addr  
192.140.112.101,192.140.112.102
```

Notice: Use a generated passphrase or choose a passphrase of 8 or more characters.

To ensure the authenticity of the peering relationship, use a phrase or sequence of characters that would be hard to guess.

```
Enter the passphrase:  
Confirm the passphrase:
```

Clusters cluster02 and cluster01 are peered.

2. If the FlexCache volume is in a different SVM than that of the origin volume, create an SVM peer relationship with flexcache as the application:

- a. If the SVM is in a different cluster, create an SVM permission for the peering SVMs:

```
vserver peer permission create -peer-cluster <cluster_name>  
-vserver <svm-name> -applications flexcache
```

The following example illustrates how to create an SVM peer permission that applies for all of the local SVMs:

```
cluster1::> vservers peer permission create -peer-cluster cluster2
-vserver "*" -applications flexcache
```

Warning: This Vserver peer permission applies to all local Vservers. After that no explicit "vservers peer accept" command required for Vserver peer relationship creation request from peer cluster "cluster2" with any of the local Vservers. Do you want to continue? {y|n}: y

b. Create the SVM peer relationship:

```
vservers peer create -vserver <local_SVM> -peer-vserver
<remote_SVM> -peer-cluster <cluster_name> -applications flexcache
```

3. Create a FlexCache volume with write-back enabled:

```
volume flexcache create -vserver <cache_vserver_name> -volume
<cache_flexgroup_name> -aggr-list <list_of_aggregates> -origin
-vserver <origin_flexgroup> -origin-vserver <origin_vserver name>
-junction-path <junction_path> -is-writeback-enabled true
```

Enable FlexCache write-back on an existing FlexCache volume

You can enable FlexCache write-back on an existing FlexCache volume using ONTAP System Manager or the ONTAP CLI.

System Manager

1. Select **Storage > Volumes** and select an existing FlexCache volume.
2. On the volume's Overview page, click **Edit** in the upper right corner.
3. In the **Edit Volume** window, select **Enable FlexCache write-back**.

CLI

1. Enable write-back on an existing FlexCache volume:

```
volume flexcache config modify -volume <cache_flexgroup_name> -is
-writeback-enabled true
```

Check if FlexCache writeback is enabled

Steps

You can use System Manager or the ONTAP CLI to determine whether FlexCache write-back is enabled.

System Manager

1. Select **Storage > Volumes** and select a volume.
2. In the volume **Overview**, locate **FlexCache details** and check if FlexCache write-back is set to **Enabled** on the FlexCache volume.

CLI

1. Check if FlexCache write-back is enabled:

```
volume flexcache config show -volume cache -fields is-writeback-enabled
```

Disable write-back on a FlexCache volume

Before you can delete a FlexCache volume you need to disable FlexCache write-back.

Steps

You can use System Manager or the ONTAP CLI to disable FlexCache write-back.

System Manager

1. Select **Storage > Volumes** and select an existing FlexCache volume that has FlexCache write-back enabled.
2. On the volume's Overview page, click **Edit** in the upper right corner.
3. In the **Edit Volume** window, deselect **Enable FlexCache write-back**.

CLI

1. Disable write-back:

```
volume flexcache config modify -volume <cache_vol_name> -is-writeback-enabled false
```

Manage FlexCache volumes

Considerations for auditing FlexCache volumes

Beginning with ONTAP 9.7, you can audit NFS file access events in FlexCache relationships using native ONTAP auditing and file policy management with FPolicy.

Beginning with ONTAP 9.14.1, FPolicy is supported for FlexCache volumes with NFS or SMB. Previously, FPolicy was not supported for FlexCache volumes with SMB.

Native auditing and FPolicy are configured and managed with the same CLI commands used for FlexVol volumes. However, there is some different behavior with FlexCache volumes.

- **Native auditing**

- You can't use a FlexCache volume as the destination for audit logs.
- If you want to audit read and writes on FlexCache volumes, you must configure auditing on both the cache SVM as well as on the origin SVM.

This is because file system operations are audited where they are processed. That is, reads are audited on the cache SVM and writes are audited on the origin SVM.

- To track the origin of write operations, the SVM UUID and MSID are appended in the audit log to identify the FlexCache volume from which the write originated.
- Although system access control lists (SACLs) can be set on a file using NFSv4 or SMB protocols, FlexCache volumes support only NFSv3. Therefore, SACLs can only be set on the origin volume.

- **FPolicy**

- Although writes to a FlexCache volume are committed on the origin volume, FPolicy configurations monitor the writes on the cache volume. This is unlike native auditing, in which the writes are audited on the origin volume.
- While ONTAP does not require the same FPolicy configuration on cache and origin SVMs, it is recommended that you deploy two similar configurations. You can do so by creating a new FPolicy policy for the cache, configured like that of the origin SVM but with the scope of the new policy limited to the cache SVM.

Synchronize properties of a FlexCache volume from an origin volume

Some of the volume properties of the FlexCache volume must always be synchronized with those of the origin volume. If the volume properties of a FlexCache volume fail to synchronize automatically after the properties are modified at the origin volume, you can manually synchronize the properties.

About this task

The following volume properties of a FlexCache volume must always be synchronized with those of the origin volume:

- Security style (`-security-style`)
- Volume name (`-volume-name`)
- Maximum directory size (`-maxdir-size`)
- Minimum read ahead (`-min-readahead`)

Step

1. From the FlexCache volume, synchronize the volume properties:

```
volume flexcache sync-properties -vserver svm_name -volume flexcache_volume
```

```
cluster1::> volume flexcache sync-properties -vserver vs1 -volume fcl
```

Update the configurations of a FlexCache relationship

After events such as volume move, aggregate relocation, or storage failover, the volume configuration information on the origin volume and FlexCache volume is updated automatically. In case the automatic updates fail, an EMS message is generated and then you must manually update the configuration for the FlexCache relationship.

If the origin volume and the FlexCache volume are in the disconnected mode, you might need to perform some additional operations to update a FlexCache relationship manually.

About this task

If you want to update the configurations of a FlexCache volume, you must run the command from the origin volume. If you want to update the configurations of an origin volume, you must run the command from the FlexCache volume.

Step

1. Update the configuration of the FlexCache relationship:

```
volume flexcache config-refresh -peer-vserver peer_svm -peer-volume  
peer_volume_to_update -peer-endpoint-type [origin | cache]
```

Enable file access time updates

Beginning with ONTAP 9.11.1, you can enable the `-atime-update` field on the FlexCache volume to permit file access time updates. You can also set an access time update period with the `-atime-update-period` attribute. The `-atime-update-period` attribute controls how often access time updates can take place and when they can propagate to the origin volume.

Overview

ONTAP provides a volume-level field called `-atime-update`, to manage access time updates on files and directories that are read using `READ`, `READLINK`, and `REaddir`. Atime is used for data lifecycle decisions for files and directories that are infrequently accessed. The infrequently accessed files are eventually migrated to archive storage and are often later moved to tape.

The `atime-update` field is disabled by default on existing and newly created FlexCache volumes. If you are using FlexCache volumes with ONTAP releases earlier than 9.11.1, you should leave the `atime-update` field disabled so caches aren't unnecessarily evicted when a read operation is performed on the origin volume. With large FlexCache caches, however, administrators use special tools to manage data and help to ensure that hot data remains in the cache and cold data is purged. This is not possible when `atime-update` is disabled. However, beginning with ONTAP 9.11.1, you can enable `-atime-update` and `-atime-update-period`, and use the tools required to manage the cached data.

Before you begin

All FlexCache volumes must be running ONTAP 9.11.1 or later.

About this task

Setting `-atime-update-period` to 86400 seconds allows no more than one access time update per 24-hour period, regardless of the number of read-like operations performed on a file.

Setting the `-atime-update-period` to 0 sends messages to the origin for each read access. The origin then informs each FlexCache volume that the atime is outdated, which impacts performance.

Steps

1. Enable file access time updates and set the update frequency:

```
volume modify -volume vol_name -vserver SVM_name -atime-update true -atime-update-period seconds
```

The following example enables `-atime-update` and sets `-atime-update-period` to 86400 seconds, or 24 hours:

```
c1: volume modify -volume origin1 vs1_c1 -atime-update true -atime-update-period 86400
```

2. Verify that `-atime-update` is enabled:

```
volume show -volume vol_name -fields atime-update,atime-update-period
```

```
c1::*> volume show -volume cachel_origin1 -fields atime-update,atime-update-period
vserver volume          atime-update atime-update-period
-----
vs2_c1  cachel_origin1 true          86400
```

Enable global file locking

Beginning with ONTAP 9.10.1, global file locking can be applied to prevent reads across all related cached files.

With global file locking enabled, modifications to the origin volume are suspended until all FlexCache volumes are online. You should only enable global file locking when you have control over the reliability of the connections between cache and origin due to suspension and possible timeouts of modifications when FlexCache volumes are offline.

Before you begin

- Global file locking requires the clusters containing the origin and all associated caches to be running ONTAP 9.9.1 or later. Global file locking can be enabled on new or existing FlexCache volumes. The command can be run on one volume and applies to all associated FlexCache volumes.

- You must be in the advanced privilege level to enable global file locking.
- If you revert to a version of ONTAP earlier than 9.9.1, global file locking must first be disabled on the origin and associated caches. To disable, from the origin volume, run: `volume flexcache prepare-to-downgrade -disable-feature-set 9.10.0`
- The process to enable global file locking depends on whether the origin has existing caches:
 - [Enable global file locking on new FlexCache volumes](#)
 - [Enable global file locking on existing FlexCache volumes](#)

Enable global file locking on new FlexCache volumes

Steps

1. Create the FlexCache volume with `-is-global-file-locking` set to `true`:

```
volume flexcache create volume volume_name -is-global-file-locking-enabled true
```



The default value of `-is-global-file-locking` is “false”. When any subsequent `volume flexcache create` commands are run on a volume, they must be passed with `-is-global-file-locking enabled` set to “true”.

Enable global file locking on existing FlexCache volumes

Steps

1. Global file locking must be set from the origin volume.
2. The origin cannot have any other existing relationships (for example, SnapMirror). Any existing relationships must be dissociated. All caches and volumes must be connected at the time of running the command. To check the connection status, run:

```
volume flexcache connection-status show
```

The status for all the listed volumes should display as `connected`. For more information, see [View the status of a FlexCache relationship](#) or [Synchronize properties of a FlexCache volume from an origin](#).

3. Enable global file locking on the caches:

```
volume flexcache origin config show/modify -volume volume_name -is-global-file-locking-enabled true
```

Prepopulate a FlexCache volume

You can prepopulate a FlexCache volume to reduce the time it takes to access cached data.

What you'll need

- You must be a cluster administrator at the advanced privilege level
- The paths you pass for prepopulation must exist or the prepopulate operation fails.

About this task

- Prepopulate reads files only and crawls through directories
- The `-isRecursion` flag applies to the entire list of directories passed to prepopulate

Steps

1. Prepopulate a FlexCache volume:

```
volume flexcache prepopulate -cache-vserver vs2 -cache-volume -path
-list path_list -isRecursion true|false
```

- The `-path-list` parameter indicates the relative directory path you want to prepopulate starting from the origin root directory. For example, if the origin root directory is named `/origin` and it contains directories `/origin/dir1` and `/origin/dir2`, you can specify the path list as follows: `-path-list dir1, dir2` or `-path-list /dir1, /dir2`.
- The default value of the `-isRecursion` parameter is `True`.

This example prepopulates a single directory path:

```
cluster1::*> flexcache prepopulate start -cache-vserver vs2 -cache
-volume fg_cachevol_1 -path-list /dir1
(volume flexcache prepopulate start)
[JobId 207]: FlexCache prepopulate job queued.
```

This example prepopulates files from several directories:

```
cluster1::*> flexcache prepopulate start -cache-vserver vs2 -cache
-volume fg_cachevol_1 -path-list /dir1,/dir2,/dir3,/dir4
(volume flexcache prepopulate start)
[JobId 208]: FlexCache prepopulate job queued.
```

This example prepopulates a single file:

```
cluster1::*> flexcache prepopulate start -cache-vserver vs2 -cache
-volume fg_cachevol_1 -path-list /dir1/file1.txt
(volume flexcache prepopulate start)
[JobId 209]: FlexCache prepopulate job queued.
```

This example prepopulates all files from the origin:

```
cluster1::*> flexcache prepopulate start -cache-vserver vs2 -cache
-volume fg_cachevol_1 -path-list / -isRecursion true
(volume flexcache prepopulate start)
[JobId 210]: FlexCache prepopulate job queued.
```

This example includes an invalid path for prepopulation:

```
cluster1::*> flexcache prepopulate start -cache-volume  
vol_cache2_vs3_c2_vol_origin1_vs1_c1 -cache-vserver vs3_c2 -path-list  
/dir1, dir5, dir6  
(volume flexcache prepopulate start)  
  
Error: command failed: Path(s) "dir5, dir6" does not exist in origin  
volume  
"vol_origin1_vs1_c1" in Vserver "vs1_c1".
```

2. Display the number of files read:

```
job show -id job_ID -ins
```

Delete a FlexCache relationship

You can delete a FlexCache relationship and the FlexCache volume if you no longer require the FlexCache volume.

Steps

1. From the cluster that has the FlexCache volume, take the FlexCache volume offline:

```
volume offline -vserver svm_name -volume volume_name
```

2. Delete the FlexCache volume:

```
volume flexcache delete -vserver svm_name -volume volume_name
```

The FlexCache relationship details are removed from the origin volume and the FlexCache volume.

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