

Apple File System

Apple File System (**APFS**) is a proprietary file system developed and deployed by Apple Inc. for macOS Sierra (10.12.4)^[6] and later, iOS 10.3 and later, tvOS 10.2 and later,^[7] watchOS 3.2 and later,^[8] and all versions of iPadOS.^{[9][10]} It aims to fix core problems of HFS+ (also called Mac OS Extended), APFS's predecessor on these operating systems. APFS is optimized for solid-state drive storage and supports encryption, snapshots, and increased data integrity, among other capabilities.^{[11][12]}

Contents

History

Design

[Partition scheme](#)

[Clones](#)

[Snapshots](#)

[Encryption](#)

[Increased maximum number of files](#)

[Data integrity](#)

[Crash protection](#)

[Compression](#)

[Space sharing](#)

Limitations

[Limited integrity checks for user data](#)

[Performance on hard disk drives](#)

[Compatibility with Time Machine prior to macOS 11](#)

Security issues

Support

[macOS](#)

[iOS, tvOS, and watchOS](#)

[Third-party utilities](#)

See also

References

External links

APFS	
Developer(s)	Apple Inc.
Full name	Apple File System
Introduced	March 27, 2017 (iOS), September 25, 2017 (macOS), with <u>iOS 10.3</u> , <u>macOS 10.13</u>
Partition identifier	7C3457EF-0000-11AA-AA11-00306543ECAC (GPT)
Structures	
Directory contents	<u>B-tree</u> ^[1]
Limits	
Max. file size	8 EiB (9,223,372,036,854,775,808 bytes) ^[2]
Max. number of files	9,223,372,036,854,775,808 ^[2]
Allowed characters in filenames	<u>Unicode 9.0</u> encoded in <u>UTF-8</u> ^[3]
Features	
Dates recorded	access, attributes modified, contents modified, created
Date range	January 1, 1970 – July 21, 2554 ^[1]
Date resolution	1 ns ^[2]
File system permissions	Unix permissions, <u>NFSv4 ACLs</u>
Transparent compression	Partial (decmpfs) ^[4]
Transparent encryption	Yes ^[5]
Copy-on-write	Yes ^{[3][5]}
Other	

History

Apple File System was announced at [Apple's developers conference \(WWDC\)](#) in June 2016 as a replacement for [HFS+](#), which had been in use since 1998.^{[11][12]} APFS was released for [64-bit iOS](#) devices on March 27, 2017, with the release of [iOS 10.3](#), and for [macOS](#) devices on September 25, 2017, with the release of [macOS 10.13](#).^{[13][8]}

Supported operating systems	macOS , iPadOS , iOS , tvOS , watchOS
------------------------------------	---

Apple released a partial specification for APFS in September 2018 which supported read-only access to Apple File Systems on unencrypted, non-Fusion storage devices. The specification for software encryption was documented later.^[14]

Design

The file system can be used on devices with relatively small or large amounts of storage. It uses 64-bit [inode](#) numbers,^[2] and allows for more secure storage. The APFS code, like the HFS+ code, uses the [TRIM command](#), for better space management and performance. It may increase read-write speeds on [iOS](#) and [macOS](#),^[8] as well as space on [iOS](#) devices, due to the way APFS calculates available data.^[15]

Partition scheme

APFS uses the [GPT](#) partition scheme. Within the GPT scheme are one or more APFS containers (partition type GUID is [7C3457EF-0000-11AA-AA11-00306543ECAC](#)). Within each container there are one or more APFS volumes, all of which share the allocated space of the container, and each volume may have APFS volume roles. [macOS Catalina](#) (macOS 10.15) introduced the APFS volume group, which are groups of volumes that [Finder](#) displays as one volume. APFS firmlinks lie between [hard links](#) and [soft links](#) and link between volumes.

In macOS Catalina the System volume role (usually named "Macintosh HD") became read-only, and in [macOS Big Sur](#) (macOS 11) it became a signed system volume (SSV) and only volume snapshots are mounted. The Data volume role (usually named "Macintosh HD - Data") is used as an overlay or shadow of the System volume, and both the System and Data volumes are part of the same volume group and shown as one in Finder.

Clones

Clones allow the operating system to make efficient file copies on the same volume without occupying additional storage space. Changes to a cloned file are saved as [delta extents](#), reducing storage space required for document revisions and copies.^[10] There is, however, no interface to mark two copies of the same file as clones of the other, or for other types of [data deduplication](#).

Snapshots

APFS volumes support [snapshots](#) for creating a point-in-time, read-only instance of the file system.^[10]

Encryption

Apple File System natively supports [full disk encryption](#),^[2] and file encryption with the following options:

- no encryption

- single-key encryption
- multi-key encryption, where each file is encrypted with a separate key, and metadata is encrypted with a different key.^[10]

Increased maximum number of files

APFS supports 64-bit inode numbers, supporting over 9 quintillion files (2^{63}) on a single volume.^{[2][5]}

Data integrity

Apple File System uses checksums to ensure data integrity for metadata.^[16]

Crash protection

Apple File System is designed to avoid metadata corruption caused by system crashes. Instead of overwriting existing metadata records in place, it writes entirely new records, points to the new ones and then releases the old ones, an approach known as redirect-on-write. This avoids corrupted records containing partial old and partial new data caused by a crash that occurs during an update. It also avoids having to write the change twice, as happens with an HFS+ journaled file system, where changes are written first to the journal and then to the catalog file.^[16]

Compression

APFS supports transparent compression on individual files using Deflate (Zlib), LZVN (libFastCompression), and LZFSE. All three are Lempel-Ziv-type algorithms. This feature is inherited from HFS+, and is implemented with the same AppleFSCompression / decmpfs system using resource forks or extended attributes. As with HFS+, the transparency is broken for tools that do not use decmpfs-wrapped routines.^[17]

Space sharing

APFS adds the ability to have multiple logical drives (referred to as volumes) in the same container where free space is available to all volumes in that container (block device).^[18]

Limitations

While APFS includes numerous improvements relative to its predecessor, HFS+, a number of limitations have been noted.

Limited integrity checks for user data

APFS does not provide checksums for user data.^[19] It also does not take advantage of byte-addressable non-volatile random-access memory.^{[20][21]}

Performance on hard disk drives

Enumerating files, and any inode metadata in general, is much slower on APFS when it is located on a hard disk drive. This is because instead of storing metadata at a fixed location like HFS+ does, APFS stores them alongside the actual file data. This fragmentation of metadata means more seeks are performed when listing files, acceptable for SSDs but not HDDs.^[22]

Compatibility with Time Machine prior to macOS 11

Unlike HFS+, APFS does not support hard links to directories.^{[3][23]} Since the version of the Time Machine backup software included in Mac OS X 10.5 (Leopard) through macOS 10.15 (Catalina) relied on hard links to directories, APFS was initially not a supported option for its backup volumes.^{[24][23]} This limitation was overcome starting in macOS 11 Big Sur, wherein APFS is now the default file system for new Time Machine backups (existing HFS+-formatted backup drives are also still supported).^[25] macOS Big Sur's implementation of Time Machine in conjunction with APFS-formatted drives enables "faster, more compact, and more reliable backups" than were possible with HFS+-formatted backup drives.^{[26][27]}

Security issues

- In March 2018, the APFS driver in High Sierra was found to have a bug that causes the disk encryption password to be logged in plaintext.^[28]
- In January 2021, the APFS driver in iOS < 14.4, macOS < 11.2, watchOS < 7.3, and tvOS < 14.4 was found to have a bug that allowed a local user to read arbitrary files, regardless of their permissions.^{[29][30][31][32]}

Support

macOS

Limited, experimental support for APFS was first introduced in macOS Sierra 10.12.4. Since macOS 10.13 High Sierra, all devices with flash storage are automatically converted to APFS.^[33] As of macOS 10.14 Mojave, Fusion Drives and hard disk drives are also upgraded on installation.^[34] The primary user interface to upgrade does not present an option to opt out of this conversion, and devices formatted with the High Sierra version of APFS will not be readable in previous versions of macOS.^[33] Users can disable APFS conversion by using the installer's `startosinstall` utility on the command line and passing `--converttoapfs NO`.^[35]

FileVault volumes are not converted to APFS as of macOS Big Sur 11.2.1. Instead macOS formats external FileVault drives as CoreStorage Logical Volumes formatted with Mac OS Extended (Journaled). FileVault drives can be optionally Encrypted.

An experimental version of APFS, with some limitations, is available in macOS Sierra through the command line `diskutil` utility. Among these limitations, it does not perform Unicode normalization while HFS+ does,^[36] leading to problems with languages other than English.^[37] Drives formatted with Sierra's version of APFS may also not be compatible with future versions of macOS or the final version of APFS, and the Sierra version of APFS cannot be used with Time Machine, FileVault volumes, or Fusion Drives.^[38]

iOS, tvOS, and watchOS

iOS 10.3, tvOS 10.2, and watchOS 3.2 convert the existing HFSX file system to APFS on compatible devices.^{[13][8][39]}

Third-party utilities

Despite the ubiquity of APFS volumes in today's Macs and the format's 2016 introduction, third-party repair utilities continue to have notable limitations in supporting APFS volumes, due to Apple's delayed release of complete documentation. According to Alsoft, the maker of DiskWarrior, Apple's 2018 release of partial APFS format documentation has delayed the creation of a version of DiskWarrior that can safely rebuild APFS disks.^[40] Competing products, including MicroMat's TechTool and Prosoft's Drive Genius, are expected to increase APFS support as well.

Paragon Software Group has published a software development kit under the 4-Clause BSD License that supports read-only access of APFS drives.^[41] An independent read-only open source implementation by Joachim Metz, libfsapfs, is released under GNU Lesser General Public License v3. It has been packaged into Debian and Ubuntu software repositories.^[42] Both are command-line tools that do not expose a normal filesystem driver interface. There is a Filesystem in Userspace (FUSE) driver for Linux called apfs-fuse with read-only access.^[43] An "APFS for Linux" project is working to integrate APFS support into the Linux kernel.^[44]

See also

- Comparison of file systems

References

- Hansen, K.H.; Toolan, F. (September 21, 2017). "Decoding the APFS file system". *Digital Investigation*. **22**: 107–132. doi:10.1016/j.diin.2017.07.003 (<https://doi.org/10.1016%2Fj.diin.2017.07.003>). ISSN 1742-2876 (<https://www.worldcat.org/issn/1742-2876>).
- "Volume Format Comparison" (https://developer.apple.com/library/content/documentation/FileManagement/Conceptual/APFS_Guide/VolumeFormatComparison/VolumeFormatComparison.html). *Apple Developer*. Retrieved May 25, 2018.
- "Apple File System Guide / Frequently Asked Questions" (https://developer.apple.com/library/content/documentation/FileManagement/Conceptual/APFS_Guide/FAQ/FAQ.html). Retrieved May 25, 2018.
- Bertin, René. "Compression and APFS" (<https://github.com/RJVB/afsctool/issues/3>). *GitHub*. Retrieved February 2, 2019.
- Apple Inc. "Apple File System Guide (Features)" (https://developer.apple.com/library/content/documentation/FileManagement/Conceptual/APFS_Guide/Features/Features.html). Retrieved May 25, 2018.
- Vigo, Jesus (April 13, 2017). "How to set up and use Apple's APFS file system on macOS Sierra" (<https://www.techrepublic.com/article/how-to-set-up-and-use-apples-apfs-file-system-on-macos-sierra/>). TechRepublic.
- "tvOS 10.2" (https://developer.apple.com/library/content/releasenotes/General/WhatsNewinTVOS/Articles/tvOS10_2.html). *What's New in tvOS*. Apple Inc.
- Warren, Tom (March 27, 2017). "Apple is upgrading millions of iOS devices to a new modern file system today" (<https://www.theverge.com/2017/3/27/15076244/apple-file-system-apfs-ios-10-3-features>). *The Verge*. Vox Media. Archived (<https://web.archive.org/web/20170327184802/http://www.theverge.com/2017/3/27/15076244/apple-file-system-apfs-ios-10-3-features>) from the original on March 27, 2017. Retrieved March 27, 2017.

9. Roger Fingas (June 13, 2016). "'Apple File System' will scale from Apple Watch to Macs, replace HFS+" (<http://appleinsider.com/articles/16/06/13/apple-file-system-will-scale-from-apple-watch-to-macs-replace-hfs>). Apple Insider. Archived (<https://web.archive.org/web/20160723030751/http://appleinsider.com/articles/16/06/13/apple-file-system-will-scale-from-apple-watch-to-macs-replace-hfs>) from the original on July 23, 2016.
10. Hutchinson, Lee (June 13, 2016). "Digging into APFS, Apple's new file system" (<http://arstechnica.co.uk/apple/2016/06/apfs-apple-new-file-system-dev-details/>). *Ars Technica UK*. Retrieved June 15, 2016.
11. Weintraub, Seth (June 13, 2016). "Apple File System (APFS) announced for 2017, scales 'from Apple Watch to Mac Pro' and focuses on encryption" (<https://9to5mac.com/2016/06/13/apple-file-system-apfs/>). *9to5Mac*. Archived (<https://web.archive.org/web/20170328195315/https://9to5mac.com/2016/06/13/apple-file-system-apfs/>) from the original on March 28, 2017. Retrieved March 27, 2017.
12. Hutchinson, Lee (June 13, 2016). "New file system spotted in macOS Sierra [Updated]" (<https://arstechnica.com/apple/2016/06/new-apfs-file-system-spotted-in-new-version-of-macos/>). *Ars Technica*. Condé Nast. Archived (<https://web.archive.org/web/20170328195529/https://arstechnica.com/apple/2016/06/new-apfs-file-system-spotted-in-new-version-of-macos/>) from the original on March 28, 2017. Retrieved March 27, 2017.
13. Clover, Juli (March 27, 2017). "Apple Releases iOS 10.3 With Find My AirPods, APFS, App Store Review Tweaks and More" (<https://www.macrumors.com/2017/03/27/apple-releases-ios-10-3/>). *MacRumors*. Archived (<https://web.archive.org/web/20170327194444/https://www.macrumors.com/2017/03/27/apple-releases-ios-10-3/>) from the original on March 27, 2017. Retrieved March 27, 2017.
14. "Apple File System Reference" (<https://developer.apple.com/support/downloads/Apple-File-System-Reference.pdf>) (PDF). Apple Developer.
15. Alan Loughnane. "Updating your iPhone will give you one major benefit" (<https://www.joe.co.uk/tech/updating-iphone-will-give-one-major-benefit-119704>). *joe.co.uk*. Archived (<https://web.archive.org/web/20170520045551/https://www.joe.co.uk/tech/updating-iphone-will-give-one-major-benefit-119704>) from the original on May 20, 2017.
16. Adam Leventhal (June 19, 2016). "APFS in Detail: Data Integrity" (<http://dtrace.org/blogs/ahl/2016/06/19/apfs-part5/>). Archived (<https://web.archive.org/web/20160621060302/http://dtrace.org/blogs/ahl/2016/06/19/apfs-part5/>) from the original on June 21, 2016.
17. Søgaaard, Jens K. "How do I enable transparent compression on APFS?" (<https://apple.stackexchange.com/a/360124>). *Ask Different*. Retrieved November 13, 2019.
18. "Archived copy" (http://devstreaming.apple.com/videos/wwdc/2016/701q0pnn0ietcautcrv/701/701_introducing_apple_file_system.pdf) (PDF). Archived (https://web.archive.org/web/20161023155942/http://devstreaming.apple.com/videos/wwdc/2016/701q0pnn0ietcautcrv/701/701_introducing_apple_file_system.pdf) (PDF) from the original on October 23, 2016. Retrieved June 10, 2017.
19. A ZFS developer's analysis of the good and bad in Apple's new APFS file system (<https://arstechnica.com/apple/2016/06/a-zfs-developers-analysis-of-the-good-and-bad-in-apples-new-apfs-file-system/>) Archived (<https://web.archive.org/web/20170202044416/https://arstechnica.com/apple/2016/06/a-zfs-developers-analysis-of-the-good-and-bad-in-apples-new-apfs-file-system/>) February 2, 2017, at the Wayback Machine
20. Robin Harris (June 24, 2016). "Why Apple's APFS won't last 30 years" (<https://www.zdnet.com/article/why-apples-apfs-wont-last-30-years/>). *ZDNet*.
21. Adam Leventhal (June 19, 2016). "APFS in Detail: Overview" (<http://dtrace.org/blogs/ahl/2016/06/19/apfs-part1/>). Retrieved October 1, 2017.
22. "An analysis of APFS enumeration performance on rotational hard drives" (<https://bombich.com/blog/2019/09/12/analysis-apfs-enumeration-performance-on-rotational-hard-drives>). *Carbon Copy Cloner*. Retrieved January 8, 2020.

23. Leventhal, Adam H. (June 26, 2016). "A ZFS developer's analysis of the good and bad in Apple's new APFS file system" (<https://arstechnica.com/gadgets/2016/06/a-zfs-developers-analysis-of-the-good-and-bad-in-apples-new-apfs-file-system/>). *Ars Technica*. "APFS right now is incompatible with Time Machine due to the lack of directory hard links, a fairly disgusting implementation that likely contributes to Time Machine's questionable reliability."
24. "Disks you can use with Time Machine" (<https://support.apple.com/guide/mac-help/disks-you-can-use-with-time-machine-mh15139/mac>). Retrieved December 17, 2019.
25. "APFS changes in Big Sur" (<https://eclecticlight.co/2020/06/29/apfs-changes-in-big-sur-how-time-machine-backs-up-to-apfs-and-more/>). Retrieved November 26, 2020.
26. "macOS Big Sur 11.0.1 Release Notes" (https://developer.apple.com/documentation/macos-release-notes/macos-big-sur-11_0_1-release-notes). *Apple*. Retrieved December 13, 2020.
27. Cunningham, Andrew (November 12, 2020). "macOS 11.0 Big Sur: The Ars Technica review" (<https://arstechnica.com/gadgets/2020/11/macos-11-0-big-sur-the-ars-technica-review/>). *Ars Technica*. Retrieved March 6, 2021.
28. "Uh Oh! Unified Logs in High Sierra (10.13) Show Plaintext Password for APFS Encrypted External Volumes via Disk Utility.app" (<https://www.mac4n6.com/blog/2018/3/21/uh-oh-unified-logs-in-high-sierra-1013-show-plaintext-password-for-apfs-encrypted-external-volumes-via-disk-utilityapp>). *mac4n6*. Retrieved November 11, 2019.
29. "About the security content of iOS 14.4 and iPadOS 14.4 - Apple Support" (<https://support.apple.com/en-us/HT212146>). *Apple Support*. Retrieved February 7, 2021.
30. "About the security content of macOS Big Sur 11.2, Security Update 2021-001 Catalina, Security Update 2021-001 Mojave - Apple Support" (<https://support.apple.com/en-us/HT212147>). *Apple Support*. Retrieved February 7, 2021.
31. "About the security content of watchOS 7.3 - Apple Support" (<https://support.apple.com/en-us/HT212148>). *Apple Support*. Retrieved February 7, 2021.
32. "About the security content of tvOS 14.4 - Apple Support" (<https://support.apple.com/en-us/HT212149>). *Apple Support*. Retrieved February 7, 2021.
33. "Prepare for APFS in macOS High Sierra" (<https://support.apple.com/en-gb/HT208018>). *Apple.com*. September 7, 2017. Retrieved September 19, 2017.
34. "macOS 10.14 Mojave: The Ars Technica review" (<https://arstechnica.com/features/2018/09/macos-10-14-mojave-the-ars-technica-review/3/>). *arstechnica.com*. September 25, 2018. Retrieved December 20, 2018.
35. Trouton, Rich (September 26, 2017). "Using the macOS High Sierra OS installer's startosinstall tool to avoid APFS conversion" (<https://derflounder.wordpress.com/2017/09/26/using-the-macos-high-sierra-os-installers-startosinstall-tool-to-avoid-apfs-conversion/>). *Der Flounder*. Retrieved January 16, 2018.
36. APFS's "Bag of Bytes" Filenames (<http://mjtsai.com/blog/2017/03/24/apfs-bag-of-bytes-filenames/>)
37. APFS is currently unusable with most non-English languages – The Eclectic Light Company (<https://eclecticlight.co/2017/04/06/apfs-is-currently-unusable-with-most-non-english-languages/>) Archived (<https://web.archive.org/web/20170608180050/https://eclecticlight.co/2017/04/06/apfs-is-currently-unusable-with-most-non-english-languages/>) June 8, 2017, at the [Wayback Machine](#)
38. "How to Format a Drive With the APFS File System on macOS Sierra" (<https://www.howtogeek.com/272741/how-to-format-a-drive-with-the-apfs-file-system-on-macos-sierra/>). Archived (<https://web.archive.org/web/20161026171416/http://www.howtogeek.com/272741/how-to-format-a-drive-with-the-apfs-file-system-on-macos-sierra/>) from the original on October 26, 2016. Retrieved October 26, 2016.
39. "jakepetroules/Filesystem" (<https://github.com/jakepetroules/Filesystem>). *GitHub*. Retrieved March 29, 2017.

40. "DiskWarrior 5.2 & Apple File System (APFS)" (<https://www.alsoft.com/diskwarrior5apfs>). Retrieved June 28, 2020.
41. "Paragon Software Group Releases Free Paragon APFS SDK Community Edition for Software Developers, OEMs, Forensic Experts" (<https://www.paragon-software.com/paragon-software-group-releases-free-paragon-apfs-sdk-community-edition-for-software-developers-oems-forensic-experts/>). *Paragon Software Group*. GitHub (https://github.com/Paragon-Software-Group/paragon_apfs_sdk_ce)
42. "libyal/libfsapfs" (<https://github.com/libyal/libfsapfs>). *GitHub*. November 7, 2019. "Library and tools to access the Apple File System (APFS)"
43. Ross, Alistair (February 23, 2019). "How to mount macOS APFS disk volumes in Linux" (<https://linuxnewbieguide.org/how-to-mount-macos-apfs-disk-volumes-in-linux/>). *The Ultimate Linux Newbie Guide*. (Github (<https://github.com/sgan81/apfs-fuse>))
44. "linux-apfs/linux-apfs-oot: APFS module for linux (out-of-tree repository)" (<https://github.com/linux-apfs/linux-apfs-oot>). *GitHub*. APFS for Linux. March 30, 2020.

External links

- Apple Developer: Apple File System Guide (https://developer.apple.com/documentation/foundation/file_system/about_apple_file_system)
- Apple Developer: Apple File System Reference (<https://developer.apple.com/support/apple-file-system/Apple-File-System-Reference.pdf>)
- WWDC 2016: Introduction of APFS (<https://developer.apple.com/videos/play/wwdc2016/701/>) by Apple software engineers [Dominic Giampaolo](#) and [Eric Tamura](#)
- Detailed Overview of APFS (<http://dtrace.org/blogs/ahl/2016/06/19/apfs-part1/>) by independent file system developer [Adam Leventhal](#)

Retrieved from "https://en.wikipedia.org/w/index.php?title=Apple_File_System&oldid=1016020395"

This page was last edited on 4 April 2021, at 23:44 (UTC).

Text is available under the Creative Commons Attribution-ShareAlike License; additional terms may apply. By using this site, you agree to the Terms of Use and Privacy Policy. Wikipedia® is a registered trademark of the Wikimedia Foundation, Inc., a non-profit organization.