

Technical Writeup: File System Internals – ext4 vs NTFS vs ZFS

A **file system** organizes how data is stored and retrieved on storage media. While all file systems aim to manage files and directories, their internal architecture and feature sets can differ significantly.

In this writeup, we explore the internals of three major file systems:

- **ext4** – default on most Linux systems
- **NTFS** – Windows default file system
- **ZFS** – enterprise-grade file system with built-in volume management

2. NTFS (New Technology File System)

Overview:

- Default file system for Windows since Windows XP
- Designed for security, recoverability, and scalability

Internal Structures:

Component	Description
Master File Table (MFT)	Core metadata structure; each file is a record in MFT
File Record	Contains attributes: standard info, filename, data, etc.
Attribute-Based	Data and metadata stored as named attributes

Component	Description
Journaling	Transactional logging for recoverability

🌟 **Key Features:**

- **NTFS Journaling:** Logs changes to the MFT and critical metadata
- **Access Control Lists (ACLs):** Fine-grained permissions
- **Compression & Encryption:** File-level NTFS compression and EFS
- **Alternate Data Streams (ADS):** Allows multiple data forks per file
- **Sparse Files, Reparse Points, Hard Links:** Advanced features for performance and compatibility

⚠️ **Limitations:**

- No native snapshot support
- Windows-only support (read-only in Linux without extra drivers)

⚖️ **Comparison Table**

Feature	ext4	NTFS	ZFS
OS Support	Linux	Windows	Linux, FreeBSD
Journaling	Yes (metadata)	Yes (metadata + data)	Copy-on-Write (CoW)
Snapshots	No	No	Yes
Volume Management	External (LVM)	Basic (Disk Mgmt)	Built-in (Zpool)
Checksumming	Journal only	Partial (metadata)	Full (data + metadata)

Feature	ext4	NTFS	ZFS
Max Volume Size	1 EB	256 TB (theoretical)	256 quadrillion zettabytes
Compression / Deduplication	No	Compression only	Yes
Self-healing	No	No	Yes
Memory Requirement	Low	Moderate	High

Conclusion

- **ext4** is reliable, fast, and easy to manage, ideal for general Linux workloads.
- **NTFS** is tightly integrated with Windows, supporting ACLs and journaling.
- **ZFS** offers enterprise-grade reliability with advanced features like snapshots, CoW, and self-healing.

Each file system comes with trade-offs. Understanding their internals helps in choosing the right one based on performance, integrity, and feature needs.