



Mission Statement

Safe cryptographic steganographic advanced filesystem

Arkadiusz Bulski

Abstract

Cameleonica is a prototype of a highly versatile filesystem. This paper explains what the project is about, what the mission statement is for the project, and what the ultimate end-goals are. Purposefully omitted are any technical details and means to ends. Overall project is mostly described through basic definitions and examples. Use cases showing obvious benefits are also presented.

Introduction

Cameleonica is a safe cryptographic steganographic advanced filesystem.

This succinct definition best describes the overall project (and is the official description for the project on GitHub). That is however exactly because it uses loaded terms. Each of the terms carries a very elaborate meaning which will be discussed below. Above statement can be expanded into:

It aims to guarantee confidentiality, authenticity, plausible deniability, transactions, snapshots, versioning, instantaneous copying, permanent deletion, high performance, low delays, compression, and hashing.

These properties are more elaborately explained through definitions and examples:

Filesystem is a data structure that maps a structure or hierarchy of regular files and directories into a flat storage. Access to the files is governed by rules that make up so called semantics. Most semantics are already well defined by POSIX standard. The fact that open files can be removed and replaced while still being open is a notable example. Linux man-pages define even more fancy semantics. For example, `fallocate` allows to remove a range of bytes without leaving a hole, stitching together both sides. For another example, `creat` can create an anonymous temporary file that can later be renamed and thus retained. Replacing files is an atomic action, which is often used in modern software as means of ensuring that some consistent version remains on disk in case of a failure. All these semantics are interesting but are not the main selling point. They only build a foundation for a useful general purpose filesystem.

Cryptographic filesystem is a filesystem that provides two attributes: confidentiality and authenticity. Confidentiality is a property that easily translates to filesystems. If a filesystem is encrypted, it should not reveal any information about it's file structure,

names, sizes or content until a valid password is provided. Authenticity is a property that guarantees that the files read now are same as the files written earlier. That is, a valid password must be provided before any changes can be made to the file structure. No file can be moved, truncated, or its content changed without a valid password. Random or malicious changes to files are not allowed to remain undetected. If bytes being read were modified without a valid password, an error must be returned upon read. It is not allowed for a read operation to return garbage bytes in this situation.

Steganographic filesystem is a filesystem that provides more than one file structure using only one backend storage. Every file structure is encrypted with an independent valid password. Steganographic confidentiality is a property that demands that if one valid password is revealed, it does not aid in discovery of any other valid password or even existence thereof. In other words, existence of valid passwords remain concealed on top of their corresponding file structures. Steganographic confidentiality is a stronger notion than cryptographic confidentiality in this respect. Multiple independent valid passwords, or equivalently independent file structures, can exist at same time within a given filesystem. As a matter of contrast, cryptography usually deals with only one password at a time. More importantly, the mere existence of that one password is hardly a secret. In steganography, zero or one or more passwords may exist and their existence is a secret in its own right.

Safe filesystem is a filesystem that refuses to become unusable or loose access to already existing files in event of abrupt interruption. Modern filesystems are able to reliably recover from an unexpected power loss or system crash encountered at any point in time. This safety guarantee comes without any extra settings turned on. It is commonly expected from any popular filesystem to handle interruptions gracefully and reliably. However, commonly established semantics of what state is returned to after recovery are far from being acceptable. For example, once a file was opened for writing, an interrupted write can be partially successful, leaving content neither in the state before opening, neither in the state expected after a complete write. This outcome is completely unacceptable. Content from before changes started should be available for recovery. Another scenario is when a user copies a file overwriting the destination file. Old destination file gets truncated to zero before new content is written into it, which may take several minutes. After interruption, user can expect old content to be gone while new content is only partially present, ending at random position. This outcome is also unacceptable. Old content from before truncation should be available for recovery. Another scenario is when a program modifies a series of files in a related way. Consider for example rotating pictures in a photo album. User could not only expect a rotation of a single image to be atomic, but could also expect the whole album to be processed seemingly at once. After interruption, user could demand the whole album to be reverted to original state. Mentioned problems are not new and can be solved using existing mechanisms. Snapshots are becoming quite popular lately, however they are too cumbersome to be of practical use. They have to be taken manually, often enough, and usually cover a whole volume at once. This is clearly not the right way to go. Versioning infrastructure should retain the state of file structure after every significant change, making save points automatically and transparently. Usable recovery scenario should be easily discoverable for any of mentioned scenarios. User should be able to recover from non atomic changes made to whole sets of data.

Advanced filesystem is a filesystem with outstanding usability. Usability can be meant as performance (achieving speeds of underlying hardware), as functionality (instant

copying), as security (deletions equivalent to permanent wiping), as introspectability (versioning, snapshots), as utilisation (lower disk usage), as integration (speeding up utilities). Let us briefly look at all these features.

Performance of modern filesystems is getting close to physical limitations of underlying hard-drives. Processing of big files would be expected to be happening at high throughput close to underlying device performance. Processing of small files would be expected to be happening at high rate due to write-back caches.

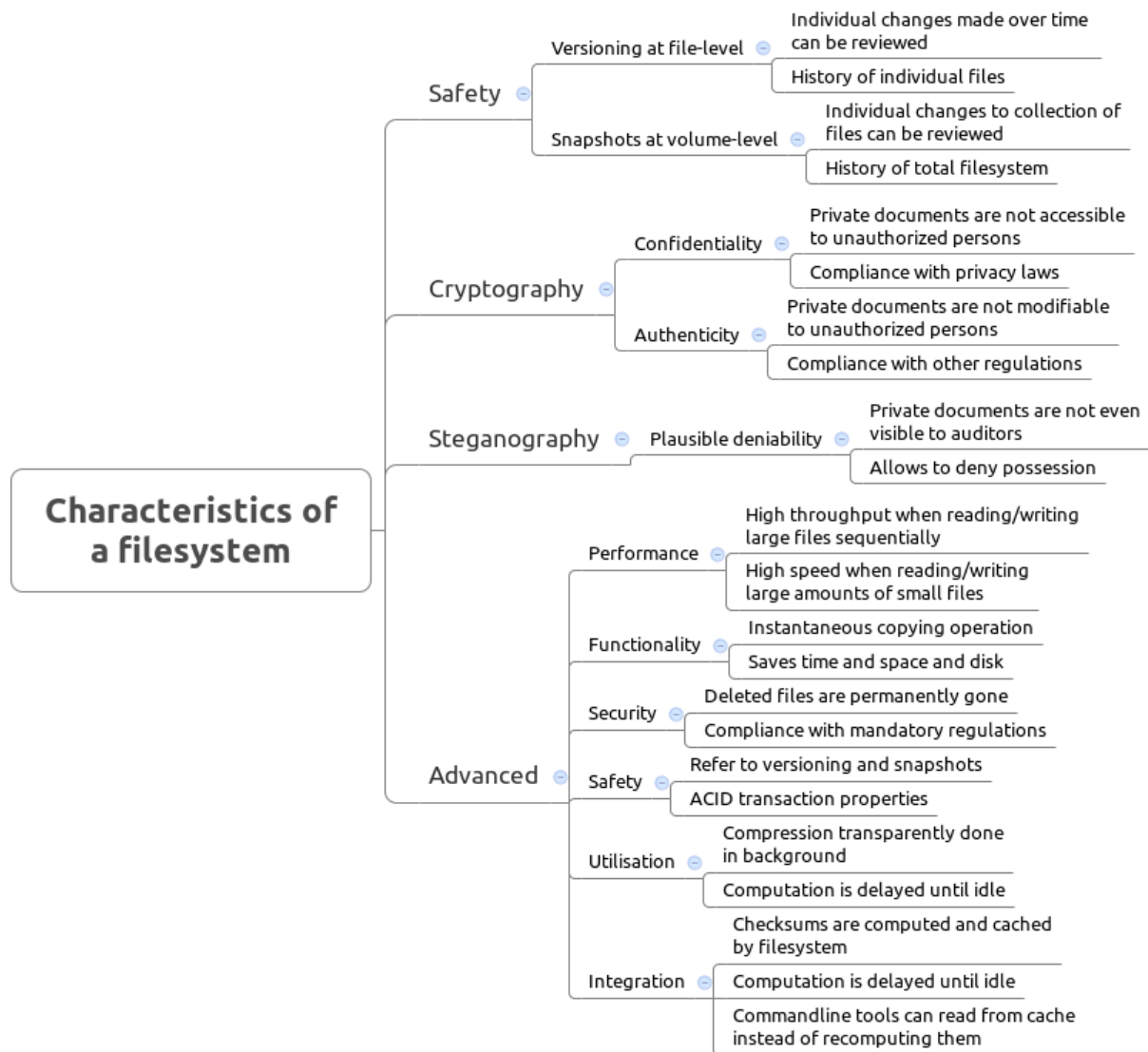
Functionality of modern filesystems is mostly ancient. Paradigm of opening a file for writing, then changing it one fragment at a time has not changed since practically ever. There is still room for improvement however. Hard-links were invented as means of instantaneous forking of files. This however only works in a shared-state fashion, where subsequent changes are also shared. It is possible to achieve similar performance characteristics for copying operation, resulting in independently writable forks sharing an immutable copy of common data.

Secure deletion is another area where modern filesystems are lacking. Wiping files is not practical. User has to manually take action, and if he fails to do it right, unwanted evidence remains on disk basically forever. Performance of a wipe operation is usually comparable to writing few times more than the amount of data to be wiped. Reliability is also a problem, as popular filesystems do not always make guarantees whether overwriting is reliably destroying data or not. File removal could be made quick and permanent using basic cryptography.

Versioning is another functionality that is commonly missing. Users do often enough start modifying their documents without considering that they may later want to revert the changes, merely as a matter of changed mind. Even worse, programs do not always apply changes in an atomic manner. This poses a risk of losing data. Risk could be minimized by underlying filesystem by automatically creating a continuous history of changes, an ongoing list of save-points that keep being added on front of the list and being scrubbed away from the end of the list after some time.

Disk utilisation can be increased through compression of selected files. Compression can happen transparently, with the user only noticing that he can store files with more total size than the hard-disk capacity. Furthermore compressed representation of file content can be directly accessible to compressing software making re-compression unnecessary. Current filesystems use compression only internally and do not expose encoded representation to user processes. This could make compression software significantly faster.

Hashing can also be speeded up when using common utilities. Filesystem can compute checksums on file content and provide system utilities with checksums instead of all the data necessary to compute it. Computation can both be done in advance when system is idle, on the fly during a sequential write, or on demand when a user process requests it. Once computed, results can be cached for future use. System utilities can be modified to take advantage of filesystem provided computation when available and revert to usual method of reading file otherwise.



Use cases

People with different needs can benefit from using a versatile filesystem. There are several reasons why someone might want to use any given feature. Provided below are possible scenarios of people benefiting from different subsets of functionality:

Graphic designer. He works at an advertising company. Everyday he edits images and photographs provided by his agency. At regular meetings he exchanges materials with his coworkers, where everybody copy source materials from a shared drive and also copy their produced work to their superior's drive. Processing of medium sized files at high rate is beneficial, as it regularly saves time. After morning meeting, he started working on his last assignment. He would like to browse history of his changes to see what remains to be done. Regular snapshots and individual file versioning makes reviewing done work easy. He can now resume his work. While editing an image, his editor crashed. He would like to revert to a state few changes back but the image was saved after they were made and there is no undo possible after editor was closed. Even worse, editor crashed before saving was done, corrupting the only copy of the file. Filesystem keeps a continuous history of recent changes and fine grained undo is possible. He can revert to any state after a successful close operation. After a day full of work, he copies his files onto another drive, overwriting several files. Right after he started copying files power went off. After power was restored, some files were already partially overwritten and thus not usable. Replacing operation triggered a save-point however, and old version of entire file structure was quickly recovered.

Human rights activist. She works for a local newspaper. Country in which they operate is ruled by an oppressive government. Her daily job activities revolve around gathering incoming reports and writing articles to be printed. She drives a lot around the country and encounters random checkpoints. She must protect her sources and cannot allow her notes to be seized by an opportunist militia soldier. If randomly searched, her laptop is encrypted and does not provide access to unauthorized persons. She refuses to decrypt it until a warrant is presented and her agency lawyer arrives. She is briefly questioned about her business and let go. After getting back home she gets detained by a security force and questioned about any involvement with anti-government organizations. She admits having no involvement. She is presented with a warrant to search her computers. She agrees to comply and provides a valid password that decrypts some documents on her laptop. To the auditors it is clear that the provided password is indeed valid and she complied. Her laptop is thoroughly checked and only expected agency documents are discovered. Her interrogators do not stop accusing her of being a suspected member and keep searching her laptop for incriminating evidence. Indeed, she was regularly in contact with rebel forces and her laptop contains illegally obtained documents. If these documents were found, or even a hint of their existence was found, she would likely be taken to jail. Secret documents are kept on a separate file structure which is unlocked by a different password that she did not disclose or even mentioned. Filesystem itself does not reveal how many more file structures exist on the hard disk, if any. Ultimately, no evidence is found on her computer showing that she hides any documents and she is cleared of suspicion.

Medical center maintenance staff. He works at a major hospital that processes dozens

of patients every day. His job is to maintain a database of medical records of current patients. Regularly he has to delete old records of former patients. Government regulations demand that these records are permanently purged when no longer needed. Medical center has an obligation to guard privacy of its patients and keep their records confidential. If these records would resurface later the center would get fined for breaking regulations. He can rest assured that deleted files are permanently gone, as the filesystem guarantees it. Aside of regular tasks, there is a need to retire some hard-drives that were used for years. He needs to remove any remaining files from them before he can send them for disposal. Again, data needs to be purged permanently or the center would be liable and would have to pay damages. He can rest assured that quick formatting done on the hard drives destroyed everything permanently as the filesystem guarantees it.

Linux distro maintainer. He works for a company maintaining a linux distro repository. Everyday he compiles and archives whole collections of source code and binaries. When he compiles, scripts often copy files which actually takes no space and no time. This takes away some time from compilation time. After a day worth of work, he sends a big disk image with upgrades. Big files are being copied at high throughput, which again saves time. Afterwards he needs to obtain sha1 checksums. Filesystem computed checksums already during copy operation. When he uses a standard command-line utility to obtain a checksum it gets results immediately from cache.

Computer forensics expert. He works for FBI as a consultant. He is often being sent to crime-scenes to secure evidence. When a computer gets seized his job is to make disk images of confiscated hard-drives. Disk images take a huge amount of space. High throughput is necessary to make copies in acceptable amount of time. Also a fraction of the disk image is full of zero bytes allowing the filesystem to compress some of the data. Hash of the image gets calculated on the fly during the long process of sequential writing. Hash of the image then gets digitally signed and handed over to the court. After this is done, he needs to keep a copy in his possession until further notice. Court later demands evidence to be presented and jury needs to be assured that these copies were not modified after being obtained. The expert can remain calm as he was the only user with a password and the filesystem can guarantee that no one else could modify the files in his possession. If defense asks for a proof that the image presented in court is the same as the image obtained during a search, expert can present a hash computed by the filesystem or the image itself.

Software engineer. He works for a major software vendor. His company has a policy that employees can bring work home only on encrypted devices. After work he took a copy of current project on a company laptop and drove back home. When shopping, his car got burglarized and the company laptop was stolen. Filesystem was encrypted and he can be sure that no company secrets fell into wrong hands. Company executives are relieved that there was no major loss and a new laptop was issued to the employee.

