Analysis of the NTFS file system for Windows 11 in a security context

Released in 1993 for Windows NT 3.1, NTFS (New Technology File System) replaced FAT as the default file system on Windows (Custer, 1994). As a modern file system, NTFS places a large importance on security.

Some examples of NTFS security features are:

* Access control lists (ACLs)
* Encrypting File System (EFS)
* BitLocker

Timeline

Description automatically generated with low confidence

Figure Timeline showing Windows releases and when features were introduced **(NOTE: for brevity this does not include all Windows releases)** (Russinovich, 2006) (Dubrawsky, 2003) (Microsoft, 2005)

ACLs are a way of restricting access to system objects on a network or computer. Both users and groups (referred to as security principals) can be defined and are represented by a unique SID (Security identifier). An administrator can then add security principals and assign read, write, modify, or full control permissions for specific objects such as files, folders, printers, and registry keys. Sub-folders of a folder with an access control list will inherit permissions (Microsoft, 2022).

EFS is a NTFS feature that allows a user to encrypt individual files and directories of their choosing (Microsoft, 2023). To encrypt files, EFS uses a combination of a public and a private key – known as “asymmetric encryption”. When a file is encrypted with EFS, a unique File Encryption Key (FEK) is generated. The FEK is used to encrypt the contents of the file in blocks. The FEK is stored in a header of the encrypted file and is then encrypted with a public key taken from the user’s certificate from the user profile (Microsoft, 2012).

Diagram

Description automatically generated

Figure 2 diagram showing the structure of a file encrypted with EFS (Microsoft, 2012)

As shown in the diagram above, “recovery agents” can be created. This is in the event that the private key is damaged or lost. The local or domain administrator will automatically be assigned as recovery agents. Private keys will be created for each agent and can be decrypted with the public keys (Microsoft, 2012). Recovery agents can also be manually created (Microsoft, 2022).

EFS uses transparent encryption, this means that when an authorized user opens the folder the user certificate public key is automatically used to decrypt the private key and decrypt the contents as plaintext. From an authorized user’s perspective, the decryption is seamless (Microsoft, 2012).

There are four different services that EFS uses to encrypt files: CryptoAPI, EFS Service, EFS Driver, and EFS FSRTL (EFS File System Run-Time Library). EFS service uses CryptoAPI to generate the FEK and public key and then creates the header for the encrypted file. EFS driver communicates with EFS service to request key management service from CryptoAPI for encryption and decryption which is then passed to EFS FSRTL to perform file system operations (open, read, write, and append) (Microsoft, 2012).

Diagram

Description automatically generated

Figure 3 diagram to show full operation of EFS (Microsoft, 2012)

BitLocker is a full drive encryption solution for the NTFS file system. BitLocker will prevent the OS (Operating System) from being unlocked until a pre-defined PIN is provided (Microsoft, 2022). It is recommended that BitLocker is enabled in conjunction with a TPM (Trusted Platform Module) chip. However, BitLocker can be used to encrypt a NTFS drive without a TPM, but this requires that a USB startup key to be inserted into the computer on startup (Microsoft, 2022). **[expand TPM?][include info about where keys are stored and what keys are used per** [**this site**](https://learn.microsoft.com/en-us/windows/security/information-protection/bitlocker/bitlocker-key-management-faq)**]**

When BitLocker is installed, an unencrypted system partition is automatically created and is used to boot, decrypt, and load the OS (Microsoft, 2022). For encryption, BitLocker uses AES (Advanced Encryption Standard) with a default key length of 128 bits – this can be changed to 256 bits through group policy (Microsoft, 2022). When data is read from a BitLocker protected drive, sectors are only decrypted as they are requested from system read operations (Microsoft, 2022).

To reduce encryption time, BitLocker can be configured to use “used disk space only encryption” and only encrypt areas of the disk that contain data (Microsoft, 2022). BitLocker can also be configured to only startup after a USB startup key is inserted (Microsoft, 2022). In the event that the drive cannot be unlocked normally, there are three ways of recovering data encrypted using BitLocker:

* Recovery passwords can be stored on a USB drive or accessed through an associated Microsoft account. Note: recovery passwords are only stored on a Microsoft account if the associated PC is a member of a domain. (Microsoft, 2022)
* Data recovery agents can be set-up and enter their credentials to unlock the drive. (Microsoft, 2022)
* BitLocker can be setup to store the recovery password in ADDS (Active Directory Domain Services). An administrator can then access the recovery password from ADDS. (Microsoft, 2022)

**[comparison][mention MacOS FileVault vs BitLocker][Disk Utility vs EFS]**

MacOS uses the filesystem APFS (Apple File System) (Apple, 2023)

APFS offers a similar full-disk encryption service to BitLocker known as FileVault 2. FileVault 2 uses the AES-XTS encryption algorithm compared to AES-128 that BitLocker uses. Unlike BitLocker the encryption algorithm is not configurable. (Apple, 2022) Similar to BitLocker, File Vault utilizes a specialized secure subsystem called the “secure enclave processor (SEP)”. Encryption key storage and any encryption processing occurs in the SEP (Apple, 2021) (Apple, 2022) **[expand on keys, system partitions and how it encrypts compared to BitLocker][mention recovery key per** [**this site**](https://support.apple.com/en-au/guide/mac-help/mh11785/mac)**]**

APFS offers similar utility to EFS. Users can create encrypted disk images that serve as secure containers. Either 128-AES or 256-AES encryption can be used. Files in the container are encrypted and decrypted in real-time (Apple, 2022) **[possibly expand this?]**

ACLs exist in APFS and are practically identical to NTFS ACLs. Similar to NTFS ACLs, both individual users and groups of users can be assigned individual permissions. However, the privilege options are less extensive with only “read & write” and “read only” being available (Apple, 2023). APFS ACLs also use ID for groups and users to verify that they can access the file (Apple, 2020)

# Appendix

BitLocker was originally known as “Secure Startup”