Secure data storage

Problems (1/3)

- The classical file system protection is limited
  - Physical protection assumptions
    - Physical confinement of storage devices
  - Logical protection assumptions
    - Access control performed by systems managing the devices
      - e.g. operating systems
    - Proper use of ACLs or other authorization mechanisms

Problems (2/3)

- There are numerous scenarios where this protection is useless
  - Direct/physical access to storage devices
    - Mobile computational units
      - Laptops, PDAs, smartphones
    - Removable storage devices
      - Tapes, diskettes, CDs DVDs, memory cards
  - Bypassing of logical access control mechanisms
    - Unethical access by powerful users (e.g. administrators)
    - Personification of users

Problems (3/3)

- Distributed access raises security issues
  - Trust in (unknown) administration teams
  - Remote authentication of users
    - Security level provided
      - i.e. how hard it is to impersonate someone
    - Integration among clients and servers
      - Applications, operating system
    - Interaction model
      - Sessions vs. requests
    - Entities
      - People vs. machines/systems
  - Secure communications
    - Confidentiality, integrity

Solution: File encryption

- ▷ Encryption/decryption of files' contents
  - Can safely circulate along dangerous networks
  - Can safely be stored in insecure storage devices
    - Either mobile or administrated by others
- ▷ Problems
  - Data retrieval
    - End-users cannot loose encryption/decryption keys
    - Illegitimate end-user encryption
      - Corporate data
  - File sharing
    - It implies some sort of key sharing
  - Interference with regular storage administration procedures
    - e.g. backups

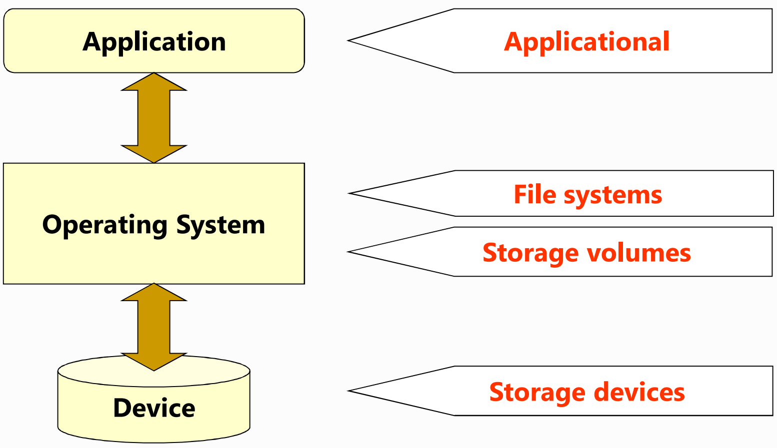
Ideal architecture (1/2)

- ▷ Cipher/decipher transparency
  - At the application level
  - At the level of OS file caches
    - But tacking into consideration authorization issues
- ▷ Visibility of securely stored data
  - Visual awareness
    - Of what is protected and not protected
  - Automatic setting of encryption attributes
    - With customization options

Ideal architecture (2/2)

- Easy sharing of encrypted data
  - By groups of users
- Decryption capacity under special circumstances by authorized people
  - Legal enforcement
  - Protection against the loss of decipher keys

Current approaches



Applicational

- Data transformed by autonomous applications
  - Little or no integration with other applications
  - Usually it is clear what is secure or not
    - e.g. using specific file extensions
- There are vulnerability windows
  - Cleartext resulting files used by other applications
- Data can be transformed with different algorithms
  - Adds flexibility, increases security
  - Complicates recovery procedures
- Hard to share data without sharing keys
  - Secret keys or public keys
- Examples:
  - PGP, AxCrypt, etc.

Storage volumes / devices

- Cipher/decipher operations at the volume / device level
  - Total transparency for applications and possibly to the OS
  - The visibility of protected data has volume / device granularity
  - Not required to handle file systems issues
    - Protection of meta-information and file data
    - Users and access rights
  - Cannot differentiate accesses by different users
    - More suitable for personal storage devices
- Cannot solve issues raised by distributed file systems
  - Decipher occurs when data is fetched from devices to server caches
- Examples:
  - PGPdisk, LUKS (Linux Unified Key Setup)
  - Self-Encrypting Drives

Secure file systems: Approaches

- ▷ Data is transformed in the path between storage devices and the memory of applications
  - Storage device ⇔ file cache
    - No protection for remote accesses (server deciphers)
    - The access to caches gets more complex
      - Coordination with ACLs
      - Knowledge of cipher/decipher keys by the OS
  - File cache ⇔ memory of applications
    - Protection for remote accesses (clients decipher)
    - Can take place outside the OS (e.g. STDIO in UNIX)
- ▷ Examples:
  - CFS (Cryptographic File System), encfs
  - EFS (Encrypted File System)

Secure file systems: Limitations (1/2)

- ▷ File system integrity must be preserved
  - Some file attributes cannot be hidden
    - For keeping the regular file system operation
    - Because of other administration tools (e.g. backup tools)
- ▷ Attributes that can easily be hidden
  - Arbitrary file/directory names
    - Encrypted versions must conform FS naming rules
  - File contents
    - Preferably without changing file's size

Secure file systems: Limitations (2/2)

- Attributes that **cannot** (should not) be hidden/changed
  - Object types
    - They define the structure of the file system
  - Contents of directories
  - Some well-defined names
    - e.g. "**.**" and "**..**" in UNIX
  - Dates
    - For managing backups
  - Dimension
    - For knowing the real occupation of storage devices
  - Ownership
    - For managing storage quotas
  - Access protection
    - For keeping the normal access control policies

Secure file systems: Practical encryption issues

- Uniform random access to encrypted data
  - Ciphers with feedback are not suitable
- Confidentiality
  - Not advised to use the same key for different files
    - Similar patterns could reveal similar files
  - Not advised to use the same key for an entire file
    - Similar patterns along a file could reveal its semantics
  - Stream ciphers are not advised w/ the same key for different files
    - Known-plaintext attacks could reveal contents of other files

CFS (Cryptographic File System)

- NFS extension
  - OS ⇔ local CFS server ⇔ local or remote NFS server
  - The NFS interface is kept
  - The MOUNT interface changes
    - Includes a password
- Encryption / decryption operations
  - Performed by the local CFS server
    - Files circulate encrypted in the network
    - Decrypted file contents are maintained in the client OS file cache
      - All local users with READ access to the file can read the decrypted contents
  - Cipher/decipher keys supplied per each mount point
    - Communicated to the local CFS server by a modified mount command
    - This command uses the new MOUNT interface

CFS

- Encrypts file names and file contents
  - Using two keys (K1 and K2) derived from a password
- Name
  - Concatenated with and integrity control value
  - Encrypted with ECB
- File contents
  - Stream with OFB ⊕ block ECB
    - OFB with K1
    - ECB com K2 (disk blocks are not increased)
  - OFB mask computed with K1 per mount point
  - Random IV per file
    - Applied between XOR with OFB mask and ECB
    - Stored in the i-node GID
    - CFS provides the directory GID instead of the file GID

EFS (Encrypted File System)

- Windows NTFS extension
  - First appeared in Windows 2000
  - Provides encryption facilities to NTFS 5
- Functionality
  - Each user is bound to an asymmetric key pair
    - Stored and managed by the OS
  - Each file is encrypted with a unique symmetric key
    - FEK (File Encryption Key)
  - An encrypted file can be accessed by many users
    - For each file EFS stores copy of FEK encrypted with the public key of each authorized user
    - Encrypted FEKs are stored in a STREAM associated to the file
      - NTFS files are formed by sets of STREAMS
  - Each encrypted file is clearly visible
    - Using the Explorer file navigator

EFS cryptographic technology

- Algorithms
  - Asymmetric encryption of FEKs: RSA
  - Symmetric encryption with FEKs: DESX

    DESX ≡ DES with whitening

    FEK = (K1, K2, K3)

    C = K1 ⊕ DES(K2, P ⊕ K3)
- Problems
  - Asymmetric key pairs are stored in disk
    - Loss risk
    - Illegitimate access by administrators
  - Files are decrypted by servers
    - No network protection for files stored remotely