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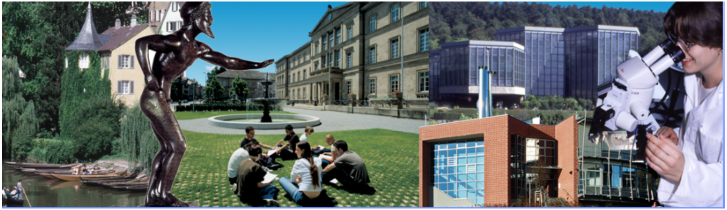

Introduction to Computer Security

Windows Security

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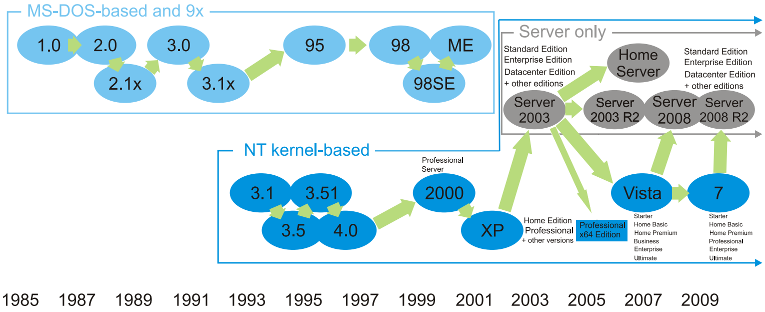
Microsoft Windows Family Tree



MS-DOS-based and 9x

1.0 2.0 2.1x 3.0 3.1x 95 98 98SE ME

Server only

Standard Edition
Enterprise Edition
Datacenter Edition
+ other editions

Home Server

Standard Edition
Enterprise Edition
Datacenter Edition
+ other editions

Server 2003 Server 2003 R2 Server 2008 Server 2008 R2

NT kernel-based

3.1 3.51 3.5 4.0

Professional
Server

2000 XP

Home Edition
Professional
+ other versions

Professional x64 Edition

Vista

Starter
Home Basic
Home Premium
Business
Enterprise
Ultimate

7

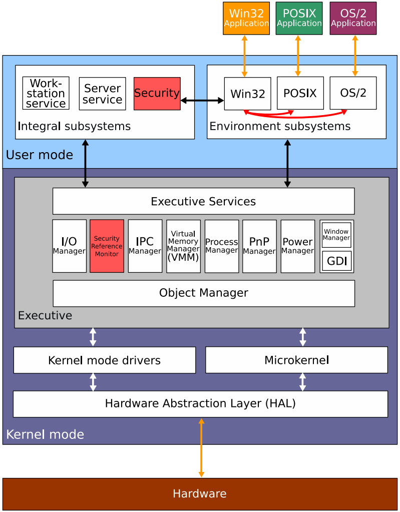
Starter
Home Basic
Home Premium
Professional
Enterprise
Ultimate

1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009

Key security milestones:

- NT 3.51 (1993): network drivers and TCP/IP
- Windows 2000: Active Directory, Kerberos, security architecture.
- Server 2003: security policies, LAN and wireless security
- Vista (2007): no “admin-by-default”, firewall, DEP, ASLR
- 64-bit versions (Vista+): mandatory kernel code signing

Architecture of modern Windows OS



Security components of Windows OS

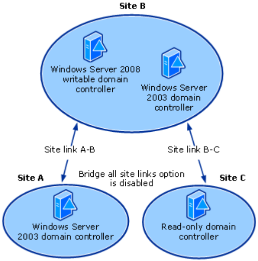
- Kernel mode:
  - Security Reference Monitor: ACL verification
- User mode:
  - Log-on process (winlogon): user logon
  - Local Security Authority (LSA): password verification and change, access tokens, audit logs (MS04-11 buffer overflow: Sasser worm!)
  - Security Accounts Manager (SAM): accounts database, password encryption
  - User Account Control (UAC, Vista): enforcement of limited user privileges

Windows registry

- A hierarchical database containing critical system information
- Key-value pairs, subkeys, 11 values types
- A registry hive is a group of keys, subkeys, and values
- Security-related registry hives:
  - HKEY_LOCAL_MACHINE\SAM: SAM database
  - HKEY_LOCAL_MACHINE\Security: security logs, etc
  - HKEY_LOCAL_MACHINE\Software: paths to programs!
- Security risks:
  - manipulated registry entries
  - missing security-related registry keys

Windows domains

- A domain is a collection of machines sharing user accounts and security policies.
- Domain authentication is carried out by a domain controller (DC).
- To avoid a single point of failure, a DC may be replicated

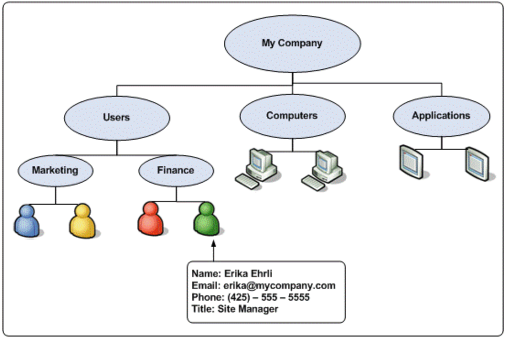

Site B
Windows Server 2008 writable domain controller
Windows Server 2003 domain controller
Site link A-B
Site link B-C
Bridge all site links option is disabled
Site A
Site C
Windows Server 2003 domain controller
Read-only domain controller

Active directory

Active directory introduced in Windows 2000 is an LDAP-like directory service for organization of system resources:

- Users and groups
- Security credentials and certificates
- System resources (desktops, servers, printers)
- Security policies
- DNS service
- Trust management

Active Directory structure



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Title: Site Manager

Access control in Windows

- Access control is applied to objects: files, registry keys and hives, Active Directory objects.
- More than just access control on files!
- Various means exist for expressing security policies:
  - groups
  - roles
  - ownership and inheritance rules
  - complex access rights

Principals

- Principals are active entities in security policies
- Principals can be
  - local users
  - aliases
  - domain users
  - groups
  - machines
- Principals have a human readable user name and a unique security identifier (SID)
- Local principals are created by a LSA, e.g.

  $$\text{principal} = \text{MACHINE}\backslash\text{principal}$$

- Domain principals are administered by DC, e.g.

  $$\text{principal@domain} = \text{DOMAIN}\backslash\text{principal}$$

Security identifiers

- A security identifier (SID) is a unique, machine generated code of varying length used to identify principals.
- Format: S-1-IA-SA-SA-SA-N, where
  - IA (identifier authority): characterizes an issuer, e.g. World Authority (1) or Local Authority (2)
  - SA (subauthority): identifies a specific SID issuer, e.g. a domain controller
  - N: relative identifier, unique for each authority
- Examples:
  - Everyone (World): S-1-1-0
  - System: S-1-5-18
  - Administrator: S-1-5-21-<domain>-500

Principals used for access control

- SID: an individual principal
- Group: a collection of principals managed by DC; groups have their own SIDs and can be nested
- Alias: a local group managed by LSA; cannot be nested
- Aliases implement logical roles: an application may define an alias to which SIDs are assigned at run-time

Subjects

- Subjects are active entities in OS primitives.
- Windows subjects are processes and threads.
- Security credentials for a subject are stored in a token.
- Tokens provide a principal/subject mapping and may contain additional security attributes.
- Tokens are inherited (possibly with restrictions) during creation of new processes.

Token contents

- Identity and authorisation contents
  - user SID, group SIDs, alias SIDs
  - privileges
- Defaults for new securable objects
  - owner SID, group SID, DACL
- Miscellaneous attributes
  - logon SID

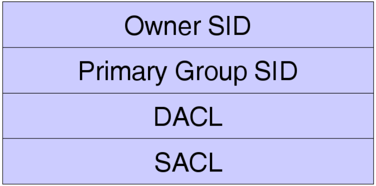
Privileges

- A set of fixed privileges is defined by numeric constants in Winnt.h
- Privileges control access to system resources.
- Example privileges:
  - load or unload a device driver
  - lock a page in a physical memory
  - create a computer account
  - shut down a system
  - modify a system time
- Privileges are not access rights!

Objects

- Objects represent various passive OS entities
- Example Windows objects:
  - files or directories
  - pipes
  - processes and threads
  - file mappings
  - access tokens
  - window-management objects
  - registry keys
  - printers
  - network shares
  - synchronization objects
  - job objects
  - Active Directory objects
- Security of built-in objects is managed by OS
- Security of private objects must be managed by applications
- Securable objects are equipped with a security descriptor

Security descriptor


Owner SID

Primary Group SID

DACL

SACL

- Owner: a principal who owns an object
- Primary group: for POSIX compatibility
- DACL: specifies who is granted and who is denied access
- SACL: specifies a security audit policy

Access rights: an overview

- Describe what one can do to an object
- Encoded as a 32-bit mask
- Standard access rights (bits 16–23) are common to most object types
  - DELETE
  - READ_CONTROL: read object's security descriptor
  - SYNCHRONIZE: use object for synchronization (not all objects)
  - WRITE_DAC: change object's DACL
  - WRITE_OWNER: change object's owner
- Object-specific rights (bits 0–15) are tailored to each class of objects
- Extended rights can be specified for Active Directory entries.

Generic access rights

- The highest 4 bits (28–31) represent generic access rights:
  - GENERIC_READ
  - GENERIC_WRITE
  - GENERIC_EXECUTE
  - GENERIC_ALL
- Each class of objects maps its generic rights to object-specific rights.
- Generic rights are used to simplify design: they provide an intermediate description level for access rights.

ACLs in Windows

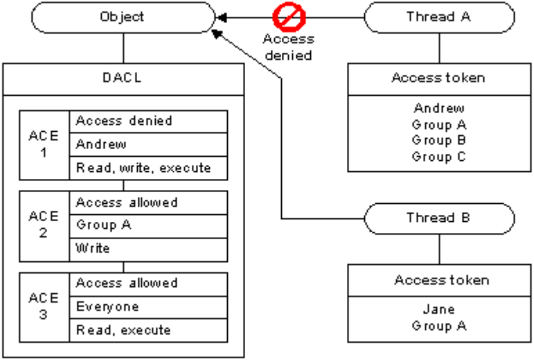
- DACL in a security descriptor is a list of Access Control Entries (ACE)
- ACE format:
  - ACE type: positive or negative permissions
  - Principal SID
  - Access rights mask
  - Inheritance flags
- ACEs are processed sequentially until either some entry denies all requested access rights or a set of ACEs grants all requested access rights

ACE matching algorithm

For any objects that do not have DACL, access is always granted. For all other objects, the subject's token is compared sequentially with each ACE as follows:

- ACE does not contain a matching SID: skip and continue.
- SID matches and contains a negative permission: deny access and stop.
- SID matches and contains a positive permission:
    - if accumulated access rights match access mask, grand access and stop.
    - otherwise add ACE to the accumulated access rights and continue.

ACL processing example



Object

Access denied

Thread A

DACL

ACE 1: Access denied / Andrew / Read, write, execute

ACE 2: Access allowed / Group A / Write

ACE 3: Access allowed / Everyone / Read, execute

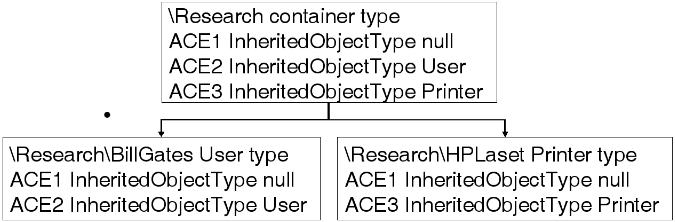
Access token: Andrew, Group A, Group B, Group C

Thread B

Access token: Jane, Group A

ACL inheritance

- When a new object is created, its ACL is inherited from that of the enclosing container, e.g. a directory.
- Only ACEs with a matching object type are inherited



\Research container type
ACE1 InheritedObjectType null
ACE2 InheritedObjectType User
ACE3 InheritedObjectType Printer

\Research\BillGates User type
ACE1 InheritedObjectType null
ACE2 InheritedObjectType User

\Research\HPLaset Printer type
ACE1 InheritedObjectType null
ACE3 InheritedObjectType Printer

Summary

- Windows systems contain complex security mechanisms for user account and object management as well as access control.
- DACLs enable fine-grained access control of heterogeneous entities in Windows itself as well as applications.
- The complexity of Windows security mechanisms is also its enemy: misconfiguration as well as implementation bugs may lead to severe security incidents.