


# IY5512 Computer Security

## Part 7b: Windows security

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# Objectives I


- Final part of the course covers:
  - basic security features of Windows;
  - uses and features of Active Directory and its importance to security in Windows;
  - authentication and access control mechanisms in Windows.
- We focus on security for managed collections (domains) of Windows machines.

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This (final) part of the course covers:

- the basic security features of Windows;
- the uses and features of Active Directory, and its importance to how security is provided in managed Windows environments;
- the authentication and access control mechanisms provided in Windows.

We look at security from the perspective of a managed set of Windows machines, known as a **domain**, i.e. we focus primarily on the security issues that apply within an organisation that wishes to manage a networked collection of PCs using the Windows features designed to support this.



## Objectives II

- Focus on Active Directory, authentication and access control.
  - Active Directory stores information on objects in Windows, including security attributes;
  - discretionary access control has been part of Windows for some time;
  - Active Directory supports fine-grained access control in a domain.
- Windows security is a huge topic:
  - only an overview of security management and audit;
  - do not cover Microsoft PKI or Network Security.

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We focus on Active Directory, authentication and access control, key elements for managing security in an organisation.

- Active Directory is a repository for information on (managed) objects in Windows, including their security attributes;
- a full-featured discretionary access control system has been a feature of Windows for a number of years;
- Active Directory provides support for fine-grained access control within a domain.

Windows security is a huge topic, and hence some features receive little or no attention here. For example:

- we only give a brief overview of security management and audit;
- we will not cover the Microsoft PKI, the Microsoft cryptographic API, or Network Security.



## Agenda

- Introduction
- Active directory
- Domains
- Windows subjects and objects
- Access rights
- Authentication
- Access control
- Security management
- Resources

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We start by reviewing the key components supporting security in Windows.

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## Windows operating systems

- Windows 8/8.1 is part of the Windows NT family of operating systems (including 2000, XP, Vista, 7 and 8).
- NT family differs considerably from older versions (including Win 95, 98 and ME).
- NT family designed with security in mind:
  - file system (NTFS) supports discretionary access control using ACLs (unlike FAT in DOS);
  - each process has a private address space, preventing other (user mode) processes from corrupting it (unlike Windows 95).

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Windows 8 (and 8.1) and Windows Server 2012 are part of the Windows NT family of operating systems (including 2000, XP, Vista, 7 and 8, as well as the Windows Server family). The Windows NT family differs considerably from older versions of Windows (including Windows 95, 98 and ME).  
Of particular importance for this course is the fact that the Windows NT family has been designed with security in mind:

- its file system (NTFS = NT File System) supports discretionary access control in the form of ACLs (unlike the FAT (File Allocation Table) file system used in DOS);
- each process has its own private address space, so preventing other (user mode) processes from corrupting it (unlike in Windows 95 and previous versions of Windows).

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## Windows

- Windows is a 64-bit, virtual memory operating system (32-bit version also exists):
  - runs on multiple hardware platforms.
- Designed with security in mind:
  - has achieved EAL (evaluation assurance level) 4 Common Criteria rating for access control;
  - incorporates Active Directory, providing powerful authentication, access control, security management and audit facilities.
- Windows uses object-oriented programming concepts; has object-based access control.


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Windows is a 64-bit, virtual memory operating system that runs on multiple hardware platforms. A 32-bit version also exists, but the differences are not discussed in this course.

It has been designed with security in mind:

- it has achieved an EAL (evaluation assurance level) 4 Common Criteria rating for access control;
- it incorporates Active Directory, which provides powerful authentication, access control, security management and audit facilities.

Windows uses object-oriented programming concepts, and has an object-based access control model.



## Domains

- Stand-alone Windows machines typically administered by their users.
- In an organisation, more managed approach needed.
- Windows uses **domains** to provide single sign-on and centralised security management.
- In a domain, a server acts as **domain controller**.
- Focus here on security as applied to domains.

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Stand-alone Windows machines are typically administered by their users. However, in an organisation, a more managed approach is usually needed. Windows uses the notion of **domains** to provide single sign-on and centralised security management functions across an interconnected set of machines. Within a domain, at least one server acts as **domain controller**. As previously mentioned, the focus in this course is on Windows security as applied to domains.




## Windows security goals

- Windows security objectives include:
  - single sign-on in the enterprise;
  - integrated security services;
  - delegation and scalability of administration;
  - strong authentication;
  - standards-based protocols for interoperability;
  - auditing services.

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The security objectives of Windows include supporting the following functions:

- single sign-on in the enterprise;
- integrated security services;
- delegation and scalability of administration;
- strong authentication;
- standards-based protocols for interoperability;
- auditing services.



## Windows security features

- **Active directory** stores information about subjects and objects.
- **Kerberos authentication** supports single sign-on within a domain 'forest'.
- **Security reference monitor (SRM)** decides whether to grant access requests.
- **Object manager** enforces decision of SRM, and mediates access to all objects.


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**Active directory** is used to store information about all subjects and objects, using object-based technology.

The **Kerberos authentication protocol** supports single sign-on within a domain 'forest' (a collection of closely related domains).

The **Security reference monitor (SRM)** is used to decide whether or not to grant an access request.

The **Object manager** enforces the decisions of the SRM, and mediates access to all objects.



## Windows memory model

- **32-bit Windows** uses a virtual memory system based on a linear 32-bit (4GB) address space:
  - lower half of address space (addresses in range 0x00000000 to 0x7FFFFFFF) allocated to user mode processes;
  - upper half (0x80000000 to 0xFFFFFFFF) is protected and allocated to privileged mode processes and memory resident parts of the core.
- **Windows** uses paging to increase memory space available to processes.

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32-bit Windows implements a virtual memory system based on a linear 32-bit (4GB) address space:

- the lower half of this address space (addresses in the range 0x00000000 to 0x7FFFFFFF) is allocated to user mode processes;
- the upper half of the address space (0x80000000 to 0xFFFFFFFF) is protected, and is allocated to privileged mode processes and memory resident parts of the core.

Windows uses paging in order to increase the size of the memory space that is available to processes.

However, the 4GB address space means that 32-bit Windows is unable to make use of more than 4GB of physical memory. This limit is removed in 64-bit Windows.

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## Windows privilege levels

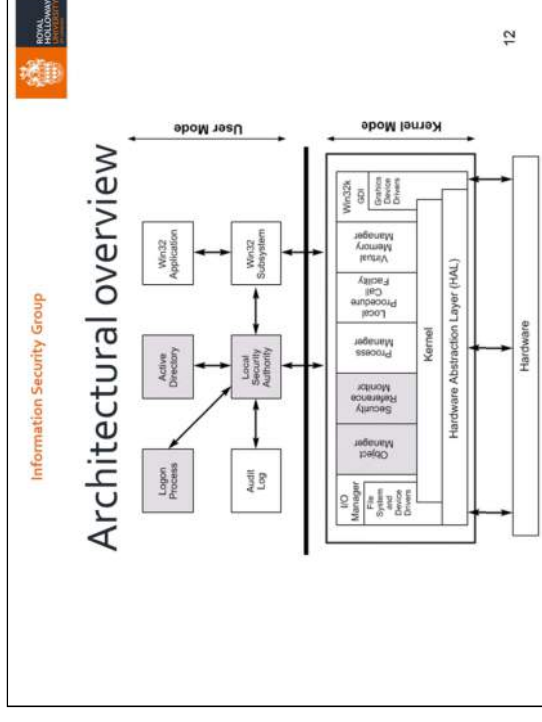
- Application code runs in user mode (privilege level 3 on Intel processors).
- Operating system code runs in kernel mode (privilege 0).
- Process in kernel mode has full access to system memory and CPU instructions.
- If user mode application calls OS service, processor switches calling process to kernel mode (if calling process permitted).

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Application code runs in user mode, i.e. privilege level 3 (the least privileged level) on Intel processors. The operating system code runs in kernel mode, i.e. privilege level 0 (the most privileged level).

When a process runs in kernel mode it has full access to system memory and to the full set of CPU instructions.

When a user mode application calls an OS service, the processor traps the call and switches the calling process to kernel mode (if the calling process is permitted to do so).



The diagram provides a simplified overview of the architecture of 32-bit Windows, showing which tasks run in system (kernel) mode and which run in user mode.



## Windows architecture

- Based on the MACH operating system developed at Carnegie-Mellon University.
- Micro-kernel design minimises size of the kernel by placing most OS functionality in user mode server processes.
- Kernel exposes a set of functions (the **API**) for use by server processes.
- Server processes (**subsystems**) call kernel functions via this API, and expose their own APIs to users and applications.

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Windows is based on the MACH operating system developed at Carnegie-Mellon University (in Pittsburgh, in the US).

The micro-kernel design minimises the size of the kernel by placing the majority of OS functionality in user mode server processes;

The kernel exposes a set of functions that can be used by the server processes. This set of functions is called an API (**application programming interface**)

The server processes (called **subsystems** in Windows) call kernel functions via this API, and expose their own APIs to users and applications.



## Windows core

- Windows core is layered and has 3 components:
  - **hardware abstraction layer (HAL)**:
    - isolates kernel and executive from platform-specific details;
    - presents uniform model of I/O hardware interface to drivers.
  - **kernel calls HAL**, and does low level OS functions:
    - thread scheduling;
    - interrupt and exception dispatching;
    - multiprocessor synchronisation.
  - **executive**:
    - performs higher level operating system functions;
    - can call kernel functions.
- **All the core runs in kernel mode.**

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The Windows core has a layered architecture, and contains three different components:

- the **hardware abstraction layer (HAL)**:
  - isolates the kernel and the executive from platform-specific details; and
  - presents a uniform model of the I/O hardware interface to drivers.
- the **kernel** can call HAL functions, and performs low level operating system functions, including:
  - thread scheduling;
  - interrupt and exception dispatching; and
  - multiprocessor synchronisation.
- the **executive**:
  - performs higher level operating system functions; and
  - can call kernel functions.

All parts of the core run in kernel mode.

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## Windows executive

- Provides generic operating system functions:
  - creating/deleting processes and threads;
  - memory management;
  - I/O;
  - inter-process communication;
  - security.
- It executes in kernel mode.
- The API is not documented and is accessed indirectly via subsystem APIs.

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The Windows executive provides generic operating system functions, including:

- creation and deletion of processes and threads;
- memory management;
- input/output (I/O);
- interprocess communication; and
- security.

It executes in kernel mode.

The API it provides is not documented and is not accessed directly by applications – instead applications call subsystem APIs (running in user mode) which themselves interact with the executive.

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## Device drivers

- Device driver is a kernel module providing interface between I/O manager and hardware component:
  - drivers call HAL functions to interface with hardware.
- In Windows (like UNIX) device drivers run in kernel mode protected memory space:
  - any OS component or device driver (including third party code) can access and potentially corrupt data being used by other OS components;
- Windows uses driver signing to help protect unsuspecting users from malicious device drivers:
  - driver signing forms part of the local security policy that is stored in the local security authority of a Windows machine.

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A device driver is a kernel module that act as an interface between the I/O manager and a specific hardware component. Drivers call HAL functions to interface with the hardware.

In Windows (as in UNIX), device driver code uses the kernel mode protected memory space. As a result any OS component or device driver can potentially corrupt data being used by other OS components. In particular third party device drivers run in kernel mode and have access to all operating system data.

Windows uses driver signing to help protect unsuspecting users from malicious device drivers; driver signing forms part of the local security policy that is stored in the local security authority of a Windows machine.



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- Resources

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We next consider the core repository of information that enables a Windows domain to be managed.



## Introduction I

- **Active Directory** is key to domain-based Windows security.
- Active Directory replaces security accounts manager (SAM) database on domain controller:
  - SAM was store for security information in earlier Windows NT family operating systems.
- **Active Directory:**
  - is trusted component of the **Local Security Authority (LSA)** that enforces security on a Windows machine;
  - stores user information to support both authentication and access control functions.

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**Active Directory** is a key component in supporting Windows security functions in a managed domain.

Active Directory replaces the security accounts manager (SAM) database on a domain controller (where every domain has at least one domain controller machine). SAM was the repository for security information in earlier Windows NT family operating systems.

Active Directory is a trusted component of the Local Security Authority (LSA), and stores user information that supports both authentication and access control functions.

The **Local Security Authority Subsystem Service (LSASS)**, is a Windows process that is responsible for enforcing the security policy on an individual Windows system. It verifies users logging on to a Windows computer, handles password changes, and creates access tokens (part of the access control system – see later slides). It also writes to the Windows Security Log. Forcible termination of lsass.exe will result in the Welcome screen losing its accounts, prompting a restart of the machine.

Depending on whether the Windows system is part of a domain or not, either the LSA on the domain controller or the local machine will verify user logins.

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## Introduction II

- Active Directory is a **hierarchical directory service** (based on LDAP), providing store of information about system entities:
  - used to support system management and communication;
- Active Directory enables identification of users, software and hardware, and also the policies (including security) assigned to them.

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Active Directory is a **hierarchical directory service**. That is, it is a structured repository of information about entities within an information system.

- it is used to support Windows system management and communication;
- Active Directory, as a networked directory service, is used to support identification of users, software and hardware, as well as the policies (including security) assigned to these entities.

The X.500 directory service, as standardised by the ITU (and by ISO), allows heterogeneous networks to share information. The LDAP (lightweight directory access protocol) is based on X.500, and was developed by the IETF. Active Directory is based on LDAP versions 2 and 3.

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## Introduction III

- Active Directory uses **hierarchical names based on the Domain Name System (DNS) scheme**:
  - every object has a unique name in the Active Directory hierarchical namespace;
  - form of the namespace determined by the structure of domains and organisational units.
- Active Directory is a **single administration point (including security) for all resources**.

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Active Directory uses the Internet Domain Name System (DNS) concept of a namespace within its directory service:

- every object in a Windows environment has a unique name in the Active Directory hierarchical namespace;
- the form of the hierarchical namespace is determined by the structure of domains and organisational units (where an organisational unit is a sort of sub-domain).

Active Directory provides a single administration point (including security administration) for all resources.

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## Active Directory hierarchy

- Domains connected in tree structure.
- Domain can contain organisational units (OUs), also arranged hierarchically.
- Diagram shows possible structure for a University of London (u.l.) domain:
  - sub-domains include Imperial College, Royal Holloway and University College London;
  - OUs include Maths and the ISG.

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Multiple domains can be connected to form a tree structure. Each domain can contain organisational units (OUs), also arranged in a hierarchical structure.

The diagram illustrates part of a possible Active Directory structure for a hypothetical University of London (u.l.) domain:

- the sub-domains include Imperial College, Royal Holloway and University College London;
- the organisational units include Maths and the ISG.

[Note that this is now an out of date example, since Imperial College is no longer part of the University of London! It also incorrectly shows the ISG as part of Mathematics, whereas they are both component parts of a single school]

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## Active Directory objects

- Object is set of attributes representing element of system, e.g. user, computer or printer:
  - some attribute values (such as the **globally unique identifier**) automatically assigned by Active Directory;
  - others (e.g. user name) manually assigned.
- Objects either **container** or **leaf** objects (container object stores other objects, whereas leaf object does not):
  - file object is a leaf object;
  - directory object is container object (containing files).

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An object is a set of attributes (properties) representing something tangible within a system, e.g. a user, computer or printer:

- some attribute values (such as the **globally unique identifier**) are automatically assigned by Active Directory;
- others (such as user name) are manually assigned by an administrator.

Objects are either **container** or **leaf** objects, where container objects can store other objects, but a leaf object cannot. For example:

- a file object is a leaf object;
- a directory object is a container object (that contains files).

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## Active Directory schema

- All resources in Active Directory are objects:
  - e.g. Bob is an instance of the `User` class.
- Every object has a set of attributes:
  - e.g. Bob has a `SID` attribute, where:
  - `SID` (security identifier) is an attribute of the `User` class.
- **Schema** defines the classes of objects in a **domain forest**, i.e. a collection of domains that trust each other;
- All domains in a forest share same schema; hence have same types of objects with same attributes.
- Active Directory stores schema as an object:
  - a protected object like other Active Directory objects.

ROYAL HOLLOWAY  
UNIVERSITY OF LONDON

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All resources in Active Directory are handled as objects, and each object has a **class** (indicating the kind (or type) of the object). Specifically, each object is said to be an **instance** of a particular **class**, simply meaning the object is of a particular type. This is all 'standard' object-oriented language, designed to make computer scientists sound clever by using fancy language for simple ideas (cf. the language associated with Java).

- For example, Bob is an instance of the `User` class.

Every object has a set of **attributes** (i.e. well-defined properties, where the available attributes depend on the class):

- for example, Bob has a `SID` attribute, where a `SID` (security identifier) is an attribute of the `User` class;

A **schema** is a description of the defined classes of objects within a **domain forest**, i.e. a collection of domains that trust each other.

Put simply, a schema simply lists the available classes (types of object), and the available attributes for each class.

All domains within a forest share the same schema and hence have the same types of objects with the same categories of attributes.

Active Directory stores the schema as an object. It is a protected object like other Active Directory objects.

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## Active Directory names I

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An example of an Active Directory name is highlighted in the figure.



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## Active Directory names II



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- **LDAP distinguished name (DN)** is sequence of (attribute-name, attribute-value) pairs making a unique path to object in hierarchical namespace:
  - attribute-names include common name (cn), organisational unit (ou), domain component (dc);
  - e.g. (cn jason), (ou isg), (ou maths), (dc rh), (dc ul).
- **Relative distinguished name (RDN)** is part of object's DN uniquely identifying the object, e.g.:
  - jason

An **LDAP distinguished name (DN)** is a sequence of (attribute-name, attribute-value) pairs, separated by commas, identifying a unique path to an object in a hierarchical namespace.


Common attribute-names include common name (cn), organisational unit (ou) and domain component (dc).

An example of an DN would be:

- (cn jason), (ou isg), (ou maths), (dc rh), (dc ul).


A **Relative distinguished name (RDN)** is the part of an object's DN that uniquely identifies the object, e.g.:

- jason



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## Active Directory names III



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- **Canonical name** is displayed by Active Directory administrative tools – based on the LDAP distinguished name of the principal, e.g.
  - rh.ul/maths/isg/jason
- **Globally unique identifier (GUID)** is 128-bit number that is assigned when an object is created:
  - it is an attribute of every object and never changes (unlike the SID, DN, RDN, and canonical name).

A **Canonical name** is the version of an object name that is displayed by Active Directory administrative tools. It is based on the LDAP distinguished name of the principal, e.g.

- rh.ul/maths/isg/jason

A **Globally unique identifier (GUID)** is a 128-bit number that is assigned to an object when that object is created. It is an attribute of every object and never changes (unlike the SID, DN, RDN and canonical name).



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## Agenda

- Introduction
- Active directory
- **Domains**
- Windows subjects and objects
- Access rights
- Authentication
- Access control
- Security management
- Resources

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## Domains


- Every Active Directory contains at least one **domain** which:
  - has a DNS domain name;
  - is the basic unit of security administration in Windows.
- Windows domain incorporates a set of user, group and computer accounts:
  - security settings and policies for one domain are not valid in another.

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Every instance of Active Directory contains at least one **domain**:

- it is identified by a DNS (domain name service) domain name;
  - it is the basic unit of security administration within Windows.
- A Windows domain incorporates a set of user, group and computer accounts:
- the security settings and policies for one domain are not valid in another.

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## Domain controllers

- Windows machine becomes a **domain controller** by installing Active Directory:
  - domain can contain several peer domain controllers;
  - but a domain controller can only host one domain;
  - domain controllers host a copy of Active Directory;
  - domain controllers store domain security policy, and manage user logon and authentication;
- Machines that aren't domain controllers maintain local SAM database for local users/groups.
- A server that is not a domain controller is called a **member server**.

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Any Windows server machine can become a **domain controller** by installing Active Directory:

- a domain can contain several domain controllers;
- however, a domain controller can only host a single domain;
- all domain controllers are peers and they each host a copy of Active Directory;
- domain controllers store the domain's security policy and manage user-domain interactions such as user logon and authentication;

Machines that are not domain controllers retain a local SAM database for locally defined users and groups.

Any server within a domain that is not a domain controller is called a **member server**.

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## Organisational units

- Windows also uses the concept of an **organisational unit** (part of a domain):
  - can subdivide Active Directory to match enterprise structure and business activities;
  - allows deployment of specific security policies to different parts of an enterprise;
  - administrators created for each OU to manage the security settings for that unit.
- OUs used to organise and contain Active Directory objects.

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Windows also uses the concept of an **organisational unit** (OU) which forms part of a domain:

- OUs can be used to sub-divide the scope of an instance of Active Directory in a way that corresponds to an enterprise's internal structure and business activities;
- OUs can simplify security management by allowing fine-grained deployment of security policies to different parts of the enterprise;
- administrators are created for each OU to manage the security settings for that unit.

OUs are used to organise and contain Active Directory objects.

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## Use of domains & OUs I

- **Organisation network should be split into separate domains if:**
  - organisation decentralised, and different users and resources managed by completely different sets of administrative personnel;
  - network has parts separated by a slow link:
    - e.g. if two LANs are connected by a WAN, probably desirable to have a domain for each LAN;
  - replication of domain information to all domain controllers could damage performance.

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The network of an organisation should be split into separate domains in the following circumstances:

- an organisation is decentralised, and different users and resources are managed by completely different sets of administrative personnel;
- the network contains two (or more parts) separated by a slow link:
  - e.g. if two LANs are connected by a WAN it is probably desirable to have one domain for each LAN;
- a single domain would mean that the replication of domain information to all domain controllers could have a detrimental effect on performance.

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## Use of domains & OUs II

- **Network should be split into separate organisational units if:**
  - important for the domain structure to reflect the structure of the enterprise;
  - desirable to delegate administrative control to small groups of users, groups and resources;
  - the organisation structure is volatile:
    - far easier to move or split organisational units than domains.

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A network should be split into separate organisational units in the following circumstances:

- when it is important for the organisation of Windows to reflect the structure of the enterprise;
- when it is desirable to delegate administrative control to small groups of users, groups and resources;
- when the organisational structure is volatile:
  - it is far easier to move or split organisational units than it is for domains.

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## Trust

- Trust relationships can be defined between Windows domains, allowing users with accounts in one domain to be authenticated by servers in other domain.
- User belonging to domain **A (trusted domain)** can be authenticated by a domain controller and access resources in domain **B (trusting domain)** if domain **B** trusts domain **A**.

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Trust relationships can be defined between Windows domains, allowing users with accounts in one domain to be authenticated by servers in another domain:  
 A user belonging to domain **A** (the **trusted** domain) can be authenticated by a domain controller and access resources in domain **B** (the **trusting** domain) if domain **B** trusts domain **A**.

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## Domain trees

- A **domain tree** consists of a set of domains sharing a common schema and configuration:
  - forms a contiguous namespace in Active Directory;
  - all Windows domains in a domain tree are linked by two-way transitive trust relationships:
    - if domain **A** trusts domain **B**, and domain **B** trusts domain **C**, then domain **A** trusts domain **C** (and vice versa);
  - when a domain is added to a domain tree, Windows automatically creates the two-way trust relationship;
  - relationship is based on a secret key shared by the parent and child domains.

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Closely linked domains can be linked together to form a domain tree. A **domain tree** consists of a set of domains sharing a common schema and configuration:

- it forms a contiguous namespace within Active Directory;
- all Windows domains within a domain tree are linked by two-way transitive trust relationships:
  - if domain **A** trusts domain **B**, and domain **B** trusts domain **C**, then domain **A** trusts domain **C** (and vice versa);
- when a domain is added to a domain tree, Windows automatically creates the two-way trust relationship;
- the trust relationship is based on a secret key shared by the parent and child domains.

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## Domain forests

- **(Domain) forest** consists of two or more trees sharing a common schema but **not** forming a contiguous namespace in Active Directory.
- Two-way transitive trust relationships exist between all domains in a forest:
  - one-way or two-way non-transitive trust relationships can be established manually between Windows domains in different forests.
- For many organisations, a single tree, or even a single domain, will be sufficient to meet the organisation's administrative requirements.

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A **(domain) forest** consists of two or more trees that share a common schema but do not form a contiguous namespace in Active Directory.

Two-way transitive trust relationships exist between all domains in a forest:

- one-way or two-way non-transitive trust relationships can be established manually between Windows domains in different forests.

For many organisations, a single tree, or even a single domain, will be sufficient to meet the organisation's administrative requirements. However, a domain forest may well be necessary for large and/or de-centralised organisations.

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## Trust and domain forests

- May be necessary to isolate certain domains from other domains, because:
  - all administrators of all domains in forest can modify configuration information replicated throughout forest:
    - so only domains with trusted admins can join.
- Solution is to create multiple forests:
  - users from unmanaged domains can use resources in managed domains in a forest by explicitly creating one-way trust relationships.

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It may be necessary to isolate certain domains from other domains. Why? Well:

- administrators of any domain in forest can modify configuration information that is replicated throughout the forest:
  - thus it is important that only **managed domains**, whose administrators are trustworthy, are allowed to join a forest.
- there thus may be a need to create multiple forests:
  - users from unmanaged domains can use resources in managed domains within a forest by explicitly creating one-way trust relationships.

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## Domain forests – examples

- Unlike that college sub-domains trust each other.
- Best solution is to have multiple forests:
  - even in the Royal Holloway domain different forests may be needed.

A single domain tree

Multiple domain trees (in a single forest)

Dotted lines show trust boundaries

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Returning to our university example, it is unlikely that the college sub-domains will trust each other.

The best solution is to have multiple forests.

Indeed, even within the Royal Holloway domain, different forests may be required.

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## Agenda

- Introduction
- Active directory
- Domains
- Windows subjects and objects
- Access rights
- Authentication
- Access control
- Security management
- Resources

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We next consider the notions of subject and object, fundamental to how Windows provides access control.

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## Security principals I

- Active Directory represents entities such as users and computers using **accounts**.
- User and computer accounts referred to as **security principals**, and assigned **security identifiers (SIDs)**.
- User and computer accounts are used to:
  - authenticate users and computers;
  - allow or deny access to domain resources;
  - perform audit functions.
- Each account has unique name in a domain.

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Active Directory represents physical entities, such as users and computers, using **accounts**.

User and computer accounts are referred to as **security principals** and are assigned **security identifiers (SIDs)**, discussed later.

User and computer accounts are used to:

- authenticate users and computers;
- allow or deny access to domain resources;
- perform audit functions.

Each account has a name that is unique within a domain.

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## Security principals II

- Each user has a unique user account and password, enabling user to be identified and authenticated.
- Every computer in a domain has an account, used to monitor access to the computer, domain, and domain resources.
- A computer account (in a domain) belongs to the **Domain Computers** group.

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Each user has a unique user account and password, enabling the user to be identified and authenticated.

Every computer in a domain has an account, used to monitor access to the computer, the domain and domain resources.

A computer account (in a domain) belongs to the **Domain Computers** group.

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## Groups I

- **Group accounts** are Active Directory or local computer objects, representing collections of users and computers.
- Active Directory recognises two group types: **security groups** (the main focus here) and (e-mail) **distribution groups**:
  - security group has security identifier (SID) – can appear in an entry in the ACL of an object;
  - a distribution group can only be used with e-mail applications and is not security-enabled.

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Accounts can also represent collections of entities. **Group accounts** are Active Directory or local computer objects that typically represent collections of users or computers.

Active Directory recognises two group types: **security groups** (the main focus of our interest in this course) and (e-mail) **distribution groups**:

- a security group has a security identifier (i.e. a SID) that can appear in an access control entry in the DACL (i.e. the Windows name for an ACL) of an object (thereby controlling access to that object by members of the group);
- a distribution group can only be used with e-mail applications and is not security-enabled. Distribution groups have only one function, namely to create e-mail distribution lists. Distribution groups are used with e-mail applications (such as Microsoft Exchange) to send e-mail to the members of the group. As with a security group, a contact can be added to a distribution group so that the contact receives e-mail sent to the group.

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## Groups II

- Every group has a scope defining its membership and the way access control rules can be applied to its members:
  - **universal** group can contain users and groups from any domain – can be used for access control in any domain;
  - **global** group contains users and groups from one domain – can be used for access control in any domain;
  - **domain local** group can contain users and groups from any domain – can only be used for access control in a single domain.

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Every group has a scope which limits its membership and the way in which access control rules can be applied to its members. There are different types of group:

- a **universal** group can contain users and groups from any domain, and can be used for access control in any domain;
- a **global** group contains users and groups from a single domain, but can be used for access control in any domain;
- a **domain local** group can contain users and groups from any domain, and can only be used for access control within a single domain.

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## Groups III

- **Windows provides predefined groups:**
  - Account Operators, Administrators, Guests, Power Users and Users are domain groups installed in the Built-In folder of Active Directory;
  - Domain Computers, Domain Users and Domain Admins are predefined global groups installed in the Users folder of Active Directory.

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Windows provides certain predefined groups:

- Account Operators, Administrators, Guests, Power Users and Users are domain groups installed in the Built-In folder of Active Directory;
- Domain Computers, Domain Users and Domain Admins are predefined global groups installed in the Users folder of Active Directory.

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## Identifying security principals

- **Security principal name** uniquely identifies a principal in a domain:
  - used for interactive login;
  - security principal object must be authenticated by a domain controller in its domain; it can then be granted (or denied) access to domain resources.
- **Security identifier (SID)** is issued when an account is created for a security principal:
  - Windows uses SIDs to uniquely identify security principals;
  - SIDs are used in access tokens, security descriptors and access control entries;
  - a SID identifies an entity in a hierarchical namespace using a sequence of one or more **identifying authorities**.

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A **security principal name** uniquely identifies a principal within a domain:

- it is used for interactive login;
- a security principal object must be authenticated by a domain controller within its domain; it can be subsequently granted (or denied) access to domain resources.

A **security identifier (SID)** is issued when an account is created for a security principal:

- Windows uses SIDs to uniquely identify security principals;
- SIDs are used in access tokens, security descriptors and access control entries;
- a SID identifies an entity within a hierarchical namespace using a sequence of one or more **identifying authorities**.

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## Structure of a security identifier

- Similar to name in a hierarchical namespace; contains:
  - revision number;
    - e.g. 1 in Windows 2000;
  - identifying authority;
  - sequence of sub-authorities;
  - relative identifier.
- E.g.:

1

A

a<sub>1</sub>

.....

a<sub>n</sub>

I

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A security identifier is similar to a name in a hierarchical namespace. It consists of:

- a revision number, e.g. 1 in Windows 2000;
- an identifying authority;
- a sequence of sub-authorities;
- a relative identifier.

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## Windows objects

- Windows implements an **object model** in order to support consistent and secure access:
  - the **object manager** is responsible for managing objects.
- The term 'object' is used here with a range of meanings:
  - in computer security, object is a passive entity in a system that a process (subject) attempts to access;
  - in object-oriented computer programming, an object is an instance of a class (the meaning here).

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Windows implements an **object model** in order to support consistent and secure access:

- the **object manager** is responsible for managing objects. Unfortunately, we use the term 'object' with a range of meanings:
- in computer security, an object is a passive entity within the system that a process (subject) attempts to access;
- in object-oriented computer programming, an object is an instance of a class (and this is the meaning of the term used in our description of Windows security).

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## Object-based security

- Active Directory entities are **objects** (in object-oriented programming sense)
  - Each object has **attributes** (or properties):
    - access to attributes controlled using access control lists (ACLs);
    - e.g., a User object has e-mail address attribute, and ACL associated with object controls who can read the e-mail address.
- Each object has a **class**, that determines:
  - which Windows service maintains the object;
  - the access rights that are available for that object.

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Active Directory entities are **objects** (in the object-oriented programming sense)

Each object has **attributes** (also referred to as **properties**):

- access to attributes can be controlled using access control lists (ACLs);
- e.g., a User object (i.e. an object of the user class) has an e-mail address attribute, and an ACL associated with a User object can control who can read the e-mail address of a user.

Each object has a **type** (or **class**), that determines:

- which Windows service is responsible for maintaining the object;
- the access rights that are available for that object.

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## Object structure

- Every object has **header, body and type**:
  - object headers are controlled by the object manager;
  - object bodies are controlled by the relevant Windows service:
    - the service is determined by the type of the object;
    - e.g., NTFS creates file objects and controls the bodies of file objects.

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Every object has a **header**, a **body** and a **type**:

- object headers are controlled by the object manager;
- object bodies are controlled by the relevant Windows service:
  - the particular service responsible for looking after an object body is determined by the type of the object;
  - for example, NTFS (the file system) creates file objects and controls the bodies of file objects.

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## Object headers

- **Object header contains:**
  - object name;
  - object security descriptor;
  - pointer to a list of processes that are currently accessing the object;
  - pointer to type information for that object.
- **Information in header is used by object manager to control access to object (irrespective of its type).**

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An object header contains (amongst other things):

- the object name;
- the object security descriptor (see next slide);
- a pointer to a list of processes that are currently accessing the object;
- a pointer to type information for that object.

Information in the header is used by the object manager to control access to the object (irrespective of its type). That is, the header is used to support the access control function.

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## Securable objects

- **Securable objects have a security descriptor that contains security attributes:**
  - examples of securable objects include files, user objects and registry keys.
- **Security descriptor contains:**
  - **discretionary access control list (DACL)** that controls which subjects can access the object;
  - **system access control list (SACL)** that controls auditing of object accesses;
  - SID of object owner.


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**Securable objects** have a **security descriptor** that contains security attributes. Examples of securable objects include files, user objects and registry keys.

The security descriptor contains:

- a **discretionary access control list (DACL)** that controls which users and groups are able to access the object;
- a **system access control list (SACL)** that controls which entities are permitted to audit object accesses;
- the SID of the object owner.

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## The object manager


- **Object manager** is key part of the security architecture.
- All access requests controlled by the object manager.
- Object manager provides single uniform interface to system resources, and isolates object protection in a single component.
- Such an interface is a requirement for EAL 4 in the Common Criteria.

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The **object manager** is a vital part of the Windows security architecture. All access requests are controlled by the object manager in a uniform way. The object manager provides a single uniform interface to system resources, and hence isolates object protection in a single component.

Such an interface is a requirement for EAL 4 in the Common Criteria.

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## Object handles I

- **Object handles** are created by object manager:
- When process creates or opens an object it receives a handle from the object manager:
  - the handle determines how the process can access the object;
  - kernel-mode code, e.g. executive components and device drivers, can access objects in memory directly.
- **Object handles have same structure for all objects; gives consistent way to access objects.**

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**Object handles** (a temporary reference (label) used by a process accessing an object) can only be created by the object manager.

When a process creates or opens an object it receives a **handle** from the object manager:

- the handle determines the way in which the process can access the object;
- note that kernel-mode code, including executive components and device drivers, can access objects in memory directly, i.e. without using a handle.

Object handles have the same structure for every type of object, and provide a consistent interface through which to access objects.

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## Object handles II

- Every process has a **handle table** to store object handles:
  - user-mode process must own a handle to an object before thread in the process can access the object.
- Object manager has exclusive right to create object handles and to locate (in memory) an object to which a handle refers:
  - object manager is aware of every user-mode interaction with an object, and ensures that access to that object is strictly controlled.

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Every process maintains a **handle table** that stores object handles:

- a user-mode process must own a handle to an object before a threads in the process can access the object.
- The object manager has the exclusive right to create object handles and to locate (in memory) an object to which a handle refers:
- the object manager is aware of every user-mode interaction with an object, and ensures that access to that object is strictly controlled.

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## Object handles III

- Object handle is 64-bit data structure containing:
  - 28-bit address (pointer) to object header;
  - 32-bit access mask stating how object can be accessed;
  - lock (L), protect (P), audit (A) and inherit (I) flags, used to control: access, generation of audit information, and creation of additional handles to object for child processes.

L	A	P	I
Access mask			
31			54
0			

An object handle is a 64-bit data structure that contains:

- a 28-bit address (pointer) to an object header;
- a 32-bit access mask that indicates the ways in which the object can be accessed;
- lock (L), protect (P), audit (A) and inherit (I) flags, that are used by the object manager to control access to the object, the generation of audit information, and the creation of additional handles to the object for child processes.




## Agenda

- Introduction
- Active directory
- Domains
- Windows subjects and objects
- **Access rights**
- Authentication
- Access control
- Security management
- Resources

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Within an authorisation system, access rights specify what sorts of accesses subjects may have to objects.



## Standard access rights

- **Standard access rights** (those applying to all object types), mainly used to control changes to an object's security descriptor:
  - READ\_CONTROL permits the security descriptor to be read;
  - WRITE\_DAC permits the DACL to be modified;
  - WRITE\_OWNER permits the owner field of the descriptor to be modified;
  - DELETE permits the object to be deleted.

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**Standard access rights**, i.e. those access rights which apply to objects of all types, are mainly used to control who can make changes to an object's security descriptor:

- READ\_CONTROL permits the security descriptor to be read;
- WRITE\_DAC permits the DACL to be modified;
- WRITE\_OWNER permits the owner field of the descriptor to be modified;
- DELETE permits the object to be deleted.

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## Object-specific access rights

- Determined by the type of the object.
- E.g. access rights for file objects include:
  - FILE\_APPEND\_DATA
  - FILE\_EXECUTE
  - FILE\_READ\_DATA
  - FILE\_READ\_EA
  - FILE\_WRITE
  - FILE\_WRITE\_EA

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**Object-specific** access rights are determined by the type of the object. For example, access rights for **file objects** (i.e. objects of type file) include:

```
FILE_APPEND_DATA
FILE_EXECUTE
FILE_READ_DATA
FILE_READ_EA
FILE_WRITE
FILE_WRITE_EA
```

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## Generic access rights

- Generic access rights are easy ways of using standard and object-specific rights:
  - R denotes 'read';
  - W denotes 'write';
  - X denotes 'execute';
  - A denotes 'all' (R, W and X).
- Meaning of these rights depends on type of the object to which the access right refers:
  - X when applied to a program (an executable file) has the obvious meaning, but means list when applied to a directory.

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**Generic** access rights are designed to make it easier to use access rights. They map onto specific standard and object-specific rights:

- R denotes 'read';
- W denotes 'write';
- X denotes 'execute';
- A denotes 'all' (R, W and X).

The precise meaning of each of these rights depends on the type of the object to which the access right refers:

- X when applied to a program (an executable file) has the obvious meaning, but it means the right to list when applied to a directory.

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## Access masks I

- An access mask is a 32-bit data structure that is used to represent access rights:
  - each bit represents a particular access right.
- Access masks used in variety of contexts:
  - object handles;
  - access control entries;
  - requested access mask;
  - granted access mask.

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An access mask is a 32-bit data structure that is used to represent a set of access rights:

- each bit represents a particular access right, i.e. a bit set to 1 indicates possession of the right corresponding to that bit position.

Access masks are used in a variety of contexts:

- object handles;
- access control entries;
- the **requested access mask**;
- the **granted access mask**.

As we discuss later, the requested access mask and the granted access mask are generated by the Security Reference Monitor during the process of deciding whether a particular request for access should be granted.

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## Access masks II

- In mask, access rights grouped in 3 categories:
  - Generic (highlighted);
  - Standard;
  - Object-specific.
- S flag indicates whether the system ACL (SACL) can be read.
- Meaning of a bit in the access mask determined by type of object.

31	R	W	X	A	Reserved	S	Standard access rights	16
15	Object-specific access rights						0	60

Within an access mask, access rights are grouped into three categories:

- Generic (shaded-in in the diagram on the slide);
- Standard;
- Object-specific.

The S flag indicates whether the system ACL (SACL) can be read.

The precise meaning of a particular bit in the access mask is determined by the type of the object to which the mask refers.

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## Privileges

- **Privileges** enable user or group account to do system-related operations on local computer, e.g.:
  - loading device drivers;
  - shutting down the system;
  - changing the system time.
- **Take-ownership privilege** enables user to take ownership of any object without being granted discretionary access in the object's DACL:
  - can be granted to Administrators when need for system security takes precedence over owner rights;
  - grant this privilege with care!

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A **privilege** enables a user or group account to perform system-related operations on the local computer, for example:

- loading device drivers;
- shutting down the system; or
- changing the system time.

The **take-ownership privilege** enables a user to take ownership of any object without being granted discretionary access (in the object's DACL):

- can be granted to Administrators when the need to maintain the system security takes precedence over the owners' right to control access;
- this privilege is clearly very powerful, and so should therefore only be granted with care!

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## Use of privileges I

- Account database is stored in the LSA on each installation of Windows.
- Database stores the privileges held by user and group accounts.
- **Access token** (created at login) contains list of user's privileges, including those:
  - granted directly to the user;
  - granted indirectly through group membership.

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An account database is stored in the LSA (Local Security Authority) on each installation of Windows.

The database stores the privileges held by user and group accounts.

The access token (created when a user logs in) contains a list of the user's privileges, including those granted directly to the user and those granted indirectly through group membership.



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## Use of privileges II

- Privileges apply only to local computer:
  - domain account can have different privileges on different computers.
- When user tries to perform a privileged operation, system checks the user's access token to determine whether:
  - user holds the necessary privilege;
  - privilege is enabled.

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Note that the privileges apply only to the local computer:

- a domain account can have different privileges on different computers.
- When the user tries to perform a privileged operation, the system checks the user's access token to determine whether:
- the user holds the necessary privilege;
  - the privilege is enabled.



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## Privileges vs. access rights

- Privileges control access to system resources and system-related tasks.
- System administrator assigns privileges to user and group accounts.
- System allows user to exercise a privilege if in the user's access token:
  - privilege is more like a capability than an accessright;
  - privilege list acts as a primitive form of capability list.
- Access rights control access to securable objects.
- Access rights are assigned to an ACL by the object's owner.
- System grants or denies access to a securable object based on the access rights granted in the ACEs in the object's DACL.

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Privileges control access to system resources and system-related tasks. Access rights control access to securable objects.

A system administrator assigns privileges to user and group accounts. Access rights are assigned to an ACL by the object's owner.

The system permits a user to exercise a privilege if it is contained in the user's access token:

- a privilege is more like a capability than an access right;
- the privilege list acts as a primitive form of capability list.

The system grants or denies access to a securable object based on the access rights granted in the ACEs in the object's DACL.



## Agenda

- Introduction
- Active directory
- Domains
- Windows subjects and objects
- Access rights
- Authentication
- Access control
- Security management
- Resources

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## Overview

- Windows authentication and access control in brief:
  - logon process interacts with the local security authority (LSA) and/or with Active Directory in order to determine if user is legitimate;
  - LSA generates an access token for user;
  - validity of subsequent access requests by that user is determined by the Security Reference Monitor, and is based on user's access token.

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In brief, Windows authentication and access control operates as follows:

- the logon process interacts with the local security authority (LSA) and/or with Active Directory (depending on whether it is a local or a domain account) in order to determine if the user is legitimate;
- if authentication succeeds, the LSA generates an access token for the authenticated user;
- the validity of subsequent access requests made by that user (or more specifically made by processes acting on behalf of that user) is determined by the Security Reference Monitor (the Windows term for the reference monitor), and is based on the user's access token.



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## Authentication I




- Authentication is performed by Windows in two situations: **interactive logon** and **network authentication**.
- User can perform an interactive logon (enter username and password) to a domain account or a local computer account.

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Authentication is performed by Windows in two situations: **interactive logon** and **network authentication**, as described in the next few slides.

A user can perform an interactive logon (e.g. enter a username and password) to either a domain account (i.e. a managed account) or to a local computer account (i.e. one which only applies on the machine being used).



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## Authentication II




- Authentication involves a user providing information that proves their **identity**.
- User identity is either the:
  - (local) Security Accounts Manager (SAM) account name, or
  - (domain) User Principal Name (UPN).
- To prove their identity, they must provide secret information, called the **authenticator**.
- An authenticator can take various forms depending on the authentication method.
- Combination of identity and authenticator is called an **authentication credential**.

When a user or service wants to access a computing resource, they must provide information that proves their identity. This identity is typically in the form of an account user name. This might be a (local) user name in the form of a Security Accounts Manager (SAM) account name or a (domain) User Principal Name (UPN).

To prove ownership of an identity, the user must provide secret information, called the *authenticator*. An authenticator can take various forms depending on the authentication protocol and method. The combination of an identity and an authenticator is called an *authentication credential*.

The process of creating, submitting, and verifying credentials is described simply as authentication, which can be implemented using a variety of authentication protocols, such as the Kerberos protocol. Authentication establishes the identity of the user, but not necessarily the user's permission to access or change a specific computing resource. That process is known as *authorisation*.

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## Authentication III

- If user logs on to a local computer account, network authentication is a manual process required for each network service the user attempts to access.
- User logged on to domain account gets 'single sign-on' within the domain:
  - network authentication is performed automatically (using domain's prior authentication of the user) whenever user requests a network service.

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If a user only logs on to a local computer account, network authentication is a manual process that is required for each network service the user attempts to access.

On the other hand, a user logged on to a domain account benefits from 'single sign-on' within the domain:

- network authentication is performed automatically (based on the domain's prior authentication of the user) whenever a user requests a network service.

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## Authentication methods

- Windows uses **Kerberos v5.0** as default authentication mechanism for interactive logons and network authentication:
  - Kerberos **key distribution centre (KDC)** is installed on every domain controller;
  - every Windows machine includes a Kerberos v5.0 client.

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Windows uses a modified version of **Kerberos v5.0** as the default authentication mechanism for interactive logons and network authentication:

- a Kerberos **key distribution centre (KDC)** is installed on every domain controller;
- every Windows machine includes a Kerberos v5.0 client.



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## Interactive logon I

- User enters credentials based on a shared secret:
  - usually username and password.
- Could also use other methods, e.g.:
  - biometric identification, such as fingerprints or retinal scans;
  - hardware token.

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The user starts the process of interactive logon by entering credentials based on a shared secret. This is typically a username and password. However, the system could also be configured to employ other techniques, for example:

- biometric identification, such as fingerprints or retinal scans; or
- a hardware token.



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## Interactive logon II

- Interactive logon uses:
  - the WinLogon process;
  - one or more **credential providers**;
  - the local security authority (LSA);
  - a repository of user information:
    - SAM (for a local computer account);
    - Active Directory (for a domain account).
- **Next describe each of these in greater detail.**

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The interactive logon procedure uses:

- the WinLogon Windows module (a process);
- one or more **credential providers**;
- the local security authority (LSA);
- a repository of user information, which is either:
  - the Security Account Manager (SAM) – in the case of a local computer account;
  - Active Directory – in the case of a domain account.

In the next few slides we describe each of these in greater detail.

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## The Winlogon Process

- Winlogon is only process that intercepts logon requests from the keyboard:
  - Requests are initiated by the **secure attention sequence (SAS)**;
  - Default SAS is **Ctrl+Alt+Del** – used to provide trusted path to OS to ensure other (malicious) applications can't capture passwords.
- The Winlogon process uses a **credential provider** to capture user credentials.


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Winlogon is the only process that intercepts logon requests from the keyboard:

- a logon request is initiated by the **secure attention sequence (SAS)**;
- the default SAS is **Ctrl+Alt+Del**, and is used to provide a trusted path to the operating system to ensure that other (malicious) applications cannot capture user passwords.

The Winlogon process uses a credential provider to capture the user credentials, i.e. the information used to identify and authenticate the user.

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## Credential providers I

- Typically a user enters username and password to claim and verify his/her identity.
- Alternatively, for a smart card logon, user credentials are on the card, and card reader allows computer to interact with the card.
- Credential providers are used to collect the user credentials, of whatever type.

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Typically, a user who logs on to a computer must enter a user name and password. These credentials are used to identify the user and verify the user's identity.

Alternatively, for a smart card logon, a user's credentials are contained on the smart card's security chip, and a smart card reader lets the computer interact with the security chip on the smart card. During a smart card logon, a user enters a personal identification number (PIN) instead of a user name and password.

Credential providers are Windows components used to collect credentials, whether they are passwords, smart card interactions, biometrics, or whatever.

In summary, the logon user interface (UI) provides interactive UI rendering. Winlogon provides the interactive logon infrastructure, and credential providers work with both of these components to help gather and process credentials.



## Credential providers II

- Winlogon instructs logon UI to display credential provider tiles after an SAS event.
- Logon UI queries each credential provider for the credential tiles it wants.
- Credential providers have option of specifying one of these tiles as the default.
- Logon UI displays tiles to the user.
- The user interacts with a tile to supply credentials.
- Logon UI submits credentials for authentication.

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Winlogon instructs the logon UI to display credential provider tiles after it receives a SAS event. The logon UI queries each credential provider for the number of credentials it wants to display to the user. Credential providers have the option of specifying one of these tiles as the default. After all the providers have specified their tiles, the logon UI displays them to the user. The user interacts with a tile to supply his or her credentials. The logon UI submits these credentials for authentication.



## Credential providers III

- With supporting hardware, credential providers can extend Windows to enable users to log on using:
  - biometrics,
  - password or PIN,
  - smart card certificate, or ..
- Custom authentication mechanisms could be deployed and mandated for all domain users.
- Credential providers are not enforcement mechanisms – they gather and serialize credentials.
- The LSA and authentication packages enforce security.

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Combined with supporting hardware, credential providers can extend Windows to enable users to log on by using biometrics (for example, fingerprint, retinal, or voice recognition), password, PIN, smart card certificate, or any custom authentication package.

Enterprises and IT professionals could develop and deploy custom authentication mechanisms for all domain users and can choose to explicitly require users to use this custom logon mechanism.

Credential providers are not enforcement mechanisms. They are used to gather and serialize credentials. The LSA and authentication packages (e.g. NTLM and Kerberos) enforce security.



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## Credential providers IV

- Multiple credential providers can co-exist on a computer.
- Credential providers must be registered on a Windows computer and are responsible for:
  - describing credentials used for authentication;
  - communicating with external authentication authorities;
  - packaging credentials for interactive and network logon.
- The Credential Provider API does not render the UI – instead it describes what needs to be rendered.

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Credential providers may be designed to support single sign-on (SSO), authenticating users to a secure network access point (by using RADIUS and other technologies) and computer logon. Credential providers are also designed to support application-specific credential gathering, and may be used for authentication to network resources, joining computers to a domain, or to provide administrator consent for UserAccount Control (UAC).

Multiple credential providers may co-exist on a computer.

Credential providers must be registered on a Windows computer and are responsible for:

- Describing the credential information required for authentication.
  - Handling communication and logic with external authentication authorities.
  - Packaging credentials for interactive and network logon.
- The Credential Provider API does not render the UI. Instead it describes to the logon UI what needs to be rendered.



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## Local Security Authority (LSA) I

- **Local Security Authority Subsystem Service (LSASS)**, is a Windows process that enforces security policy on the system.
- **The LSASS:**
  - verifies users logging on,
  - handles password changes,
  - creates access tokens and
  - writes to the **Windows Security Log**.


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The **Local Security Authority Subsystem Service (LSASS)**, is a process in Windows responsible for enforcing the security policy on the system.

It verifies users logging on to a Windows computer or server, handles password changes, and creates access tokens. It also writes to the Windows Security Log.

Forcible termination of lsass.exe (the LSASS process) will result in the Welcome screen losing its accounts, prompting a restart of the machine.

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## Local Security Authority II

- If the user is attempting to log on to a local machine account, the LSA:
  - passes information to MSV1\_0 authentication package;
  - interrogates local Security Accounts Manager (SAM) database for user's account details.
- If the user is attempting to log on to a domain account, the LSA:
  - interacts with the Kerberos authentication package;
  - interrogates Active Directory to verify logon credentials.

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If the user is attempting to log on to a local machine account, the LSA:

- passes the information to the MSV1\_0 authentication package;
- interrogates the local Security Accounts Manager (SAM) database for the user's account details.

If the user is attempting to log on to a domain account, the LSA:

- interacts with the Kerberos authentication package;
- interrogates Active Directory to verify the logon credentials.

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## Local Security Authority III

- If Kerberos client cannot locate a domain controller, the LSA checks for locally cached credentials from a previous logon (used to authenticate the user with the MSV1\_0 authentication package).
- If authentication is successful the LSA creates an access token for the user.

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If a Kerberos client cannot locate a domain controller, the LSA checks for locally cached credentials from a previous logon (which are used to authenticate the user with the MSV1\_0 authentication package).

If authentication is successful the LSA creates an access token for the user.



## Cached logon information I

- All previous user logon information is cached locally:
  - if a domain controller is unavailable during a domain logon attempt, and user's logon info is cached, then the user is still able to log on;
  - if a domain controller is unavailable and a user's logon information is not cached, then the user will not be able to log on to a domain account.

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- All previous user logon information is cached locally. As a result:
- if a domain controller is unavailable during subsequent domain account logon attempts, then the user is still able to log on;
  - if a domain controller is unavailable and a user's logon information is not cached, then the user will not be able to log on to a domain account.



## Cached logon information II

- Number of previous logons cached is a setting in the local security policy.
- Caching such information clearly has implications for security:
  - a user whose account has been deleted can still log on to a cached domain account!

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- The number of previous logons that are cached is a setting in the local security policy.
- Caching such information clearly has implications for security. For example, a user whose account has been deleted can still log on to a cached domain account!



## Kerberos in Windows I


- Kerberos provides one-way or mutual authentication between parties based on a shared secret without revealing the secret.
- Kerberos used in Windows to authenticate users to the system, and to enable access to network resources.
- Shared secret is (a key based on) the user's password.

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The Kerberos protocol provides either one-way or mutual authentication between two parties based on a shared secret, without revealing the secret.

Kerberos is used in Windows to authenticate users to the system, and to enable access to network resources:

The shared secret is a cryptographic key derived from the user's password.



## Kerberos in Windows II

- Kerberos also used to support single sign-on.
- If user logged on to a domain account, the Kerberos service can issue service tickets based on the user's logon that act as credentials, enabling the user to access network resources.

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Kerberos is also used to support single sign-on.

If a user is logged on to a domain account, the Kerberos service can issue service tickets based on the user's logon; these serve as credentials, enabling the user to access network resources.

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## The KDC

- Kerberos Key Distribution Centre (KDC) installed on each domain controller
- KDC hosts:
  - an **authentication service**;
  - a **ticket-granting service**.
- Kerberos client is installed on each Windows machine.

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A Kerberos Key Distribution Centre (KDC) is installed on each domain controller  
The KDC hosts:

- a Kerberos **authentication service**; and
- a Kerberos **ticket-granting service**.

A Kerberos client is installed on each Windows machine.

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## Kerberos summary

1. Client enters username and password, & sends pre-authentication data.
2. Authentication service returns TGT.
3. Client requests session ticket.
4. TGS returns session ticket for network service.
5. Client sends session ticket to network service.

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The operation of Kerberos in Windows can be summarised as follows.

1. The Client receives the username and password from the user, and sends the pre-authentication data to the Authentication Service.
2. The Authentication service returns a ticket-granting ticket (TGT).
3. The Client requests a session ticket (for a specific network service).
4. The Ticket-granting server (TGS) returns a session ticket for the specified network service.
5. The Client sends the session ticket to the network service.



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## Single sign-on I

- Applications may use several servers to perform a task:
  - e.g. web application may use Web server and database server to support a browser-based client.
- Every domain in a Windows forest trusts every other domain in that forest.
- Windows uses this to extend single sign-on beyond domain to which user logs on:
  - a client only authenticates once rather than re-authenticating to servers in different domains.

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It is becoming increasingly common for applications to use several servers to perform a task. For example, a Web-based application might use both a Web server and a database server to provide information to a browser-based client. These servers might be in different domains.

Every domain in a Windows forest trusts every other domain in that forest. Windows uses this to extend single sign-on beyond the boundary of the domain to which a user logs on. A client only needs to authenticate once, rather than re-authenticating to servers in different domains.



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## Single sign-on II

- Building on Active Directory, Windows provides a single security system for defining user accounts and managing access permissions.
  - define settings once in Active Directory;
  - used by all the application servers in the same forest.

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Building on Active Directory, Windows provides a single security model and infrastructure for defining user accounts and for managing access permissions. As a result it is only necessary to define settings once in the Active Directory. Active Directory is used by all the application servers in the same forest.

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## Single sign-on III

- A (Web) server can **impersonate** a client and obtain tickets from the TGS on the client's behalf to access another (database) server:
  - user does not have to provide any input to the authentication process.
- Although server impersonates the client, an audit trail to the originating client is preserved:
  - when a server handles a request forwarded by another server, its log will show the client's name rather than that of the intermediary server.

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To enable a type of delegation, a (Web) server can **impersonate** a client and obtain tickets from the TGS on the client's behalf to access another (database) server. The user does not have to provide any input to the authentication process.

Although the server 'impersonates' the client, an audit trail to the originating client is preserved:

- when a server handles a request forwarded by another server, its log will show the client's name rather than that of the intermediary server.

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## Single sign-on – summary

1. Client logs on and obtains TGT and session ticket for Web service.
2. Client presents session ticket to Web server.
3. Web server impersonates client and requests session ticket for database server.
4. Web server impersonates client using session ticket for database server.

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The single sign-on process can be summarised as follows.


1. The Client logs on and obtains a TGT and a session ticket for the Web service.
2. The Client presents the session ticket to the Web server.
3. The Web server impersonates the client and requests a session ticket for the database server.
4. The Web server impersonates the client using the session ticket for the database server.



## Agenda

- Introduction
- Active directory
- Domains
- Windows subjects and objects
- Access rights
- Authentication
- Access control
- Security management
- Resources

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## Overview

- **Fundamental mechanism:**
  - Compare security info of subject (process) with security info of object (file).
- Security information of subject held in **access token**, generated at logon.
- Security information of object held in **security descriptor:**
  - generated when object created;
  - contains **access control list**.

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The fundamental mechanism used by the Windows **Security Reference Monitor** is to compare the security information of the subject (process) with the security information of object (file).

The security information of the subject is held in an **access token**, which is generated at logon.

The security information of the object is held in the **security descriptor**, which is generated when the object is created. The security descriptor contains an **access control list** (the DACL).

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## Access tokens

- When user logs on and authenticates successfully to a Windows system, the local security authority creates an **access token**.
- Access token includes the following information:
  - SID of the authenticated user;
  - SIDs of the groups to which the user belongs;
  - SID of the default owner of any new objects the user creates (typically the SID of the user);
  - list of privileges assigned to the user.


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When a user logs on and authenticates successfully to a Windows system, the local security authority creates an **access token**.

An access token includes the following information:

- the SID of the authenticated user;
- the SIDs of the groups to which the user belongs;
- the SID of the default owner of any new objects the user creates (typically the SID of the user);
- a list of privileges assigned to the user.

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## Primary access tokens

- When user executes a program, process is created that inherits the user's access token:
  - called the **primary access token** (for process).
- Security reference monitor uses this token to determine security context of process.
- This is used to determine whether an access request should be granted:
  - SIDs in the access token are compared with SIDs in the DACL.

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When a user executes a program, a process is created that inherits a copy of the user's access token. This is called the **primary access token** (for that process).

The security reference monitor uses this token to determine the security context of the process and determine whether an access request should be granted:

- SIDs in the access token are compared with SIDs in the DACL of the object to which access is requested.

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## Impersonation

- Processes may have multiple **threads of execution**:
  - **impersonation** is ability of thread to execute in security context different from context of process owning it;
  - server process may create thread to run for a client;
  - when running in the client's security context the server 'is' the client.
- File server may host files containing confidential information:
  - each of these files is protected by an ACL;
  - server impersonates the client before accessing the files in order to limit file access to that allowed for the client.

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Processes can run multiple **threads of execution**:

- **impersonation** is the ability of a thread to execute in a security context that is different from the context of the process that owns the thread;
- a server process may create a thread to run on behalf of a client;
- when running in the client's security context the server 'is' the client.

A file server may host files containing confidential information:

- each of these files is protected by an ACL;
- the server impersonates the client before accessing the files in order to limit file access to that allowed for the client.

This is the approach used by Windows to support the notion of **delegation**.

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## Impersonation access tokens


- Server thread uses access token representing the client's credentials to obtain access to the objects to which the client has access:
  - impersonating thread has both a primary access token and an **impersonation token**;
  - primary access token is server's own access token;
  - impersonation token represents the client's security context, and is used for access checks during impersonation;
  - when impersonation is over, thread reverts to using the primary access token.

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The server thread uses an access token representing the client's credentials to obtain access to the objects to which the client has access:

- the impersonating thread has both a primary access token and an **impersonation token**;
- the primary access token is a copy of the server's own access token;
- the impersonation token represents the client's security context, and is used for access checks during impersonation;
- when impersonation is over, the thread reverts to using the primary access token.

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## Impersonation tokens

- Impersonation token can both expand or limit ability of impersonating thread to access securable objects and to perform privileged operations.
- Impersonation token is a copy of the client process's (primary) access token but can be restricted by:
  - removing privileges from the client's primary token;
  - applying deny-only attribute to SIDs in the token so that such SIDs cannot be used to access secured objects.

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An impersonation token can both expand or limit the ability of an impersonating thread to access securable objects and to perform privileged operations.

An impersonation token is a copy of the client process's (primary) access token but can be restricted by:

- removing privileges from the client process's primary token;
- applying the deny-only attribute to SIDs in the token so that such SIDs cannot be used to access secured objects.

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## Security descriptors

- Access token describes security context of a user (subject).
- **Security descriptor** is associated with securable object and defines security settings for that object:
  - it provides an object's security context;
  - every security descriptor has a similar structure;
  - exact contents of descriptor depend on type of object to which it refers, and how the object was created.


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An access token describes the security context of a user (subject).

A **security descriptor** is associated with a securable object and defines security settings for that object:

- it provides an object's security context;
- every security descriptor has a similar structure;
- the exact contents of the descriptor depend on the type of object to which it refers, and how the object was created.

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## Security descriptor contents I

- **Control flags:**
  - single bits that provides information about the descriptor;
  - special flags used to indicate the presence (or not) of a DACL or SACL in the descriptor.
- **Owner:**
  - SID of the object's owner;
  - by default, field is assigned value of the Owner SID in object creator's access token.

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**Control flags:**

- each flag is a single bit that provides information about the descriptor;
- these 'special' flags are used to indicate the presence (or not) of a DACL or SACL in the descriptor.

**Owner:**

- the SID of the object's owner;
- by default, this field is assigned the value of the Owner SID in the object creator's access token.

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## Security descriptor contents II

- **Primary Group:**
  - SID of the primary group of the object;
  - by default this is the Default Primary Group SID in the creator's access token.
- **Discretionary access control list (DACL):**
  - a security descriptor may not have a DACL.
- **System access control list (SACL):**
  - a security descriptor may not have a SACL.

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**Primary Group:**


- the SID of the primary group of the object;
- by default this is the Default Primary Group SID in the creator's access token.

**Discretionary access control list (DACL):**

- a security descriptor may not have a DACL.

**System access control list (SACL):**

- a security descriptor may not have a SACL.



## DACLS

- DACL used to control which and how principals can access the object.
- DACL consists of zero or more access control entries (ACEs).
- Contents of the DACL in security descriptor of a new object depend on:
  - the inheritance properties of the ACEs in the container object's DACL;
  - the Active Directory schema.


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The DACL is used to control which principals can access the object and how such principals can access the object.

The DACL consists of zero or more access control entries (ACEs).

The contents of the DACL in the security descriptor of a new object depend on:

- the inheritance properties of the ACEs in the container object's DACL;
- the Active Directory schema.



## Two special cases

1. The object's security descriptor does not contain a DACL:
  - any process has unrestricted access to the object;
  - i.e. the object has no protection.
2. The object's security descriptor has a DACL that contains no entries:
  - no process can access the object.

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There are two special cases:

1. If the object's security descriptor does not contain a DACL, then every process has unrestricted access to the object, i.e. the object has no protection.
2. If the object's security descriptor has a DACL that contains no entries, then no process can access the object.

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## ACEs in Windows I

- ACE contains:
  - type field,
  - SID,
  - inheritance mask, and
  - 32-bit access mask.
- SID identifies a security principal (the **trustee**) to whom the ACE applies:
- Trustee is usually a user or a group.

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An ACE contains a type field, a SID, an inheritance mask and a 32-bit access mask.

The SID identifies a security principal (referred to as the **trustee**) to whom the ACE applies. The trustee is usually a user or a group.

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## ACEs in Windows II

- Windows supports five types of ACE, including:
  - **Access-denied**: permissions in access mask are denied to principal identified in the SID.
  - **Access-allowed**: permissions in access mask are granted to principal identified in the SID.
  - **System-audit**: audit record is created whenever access rights in access mask are requested by principal identified in SID.


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Windows supports five types of ACE, including:

- **Access-denied**:
    - permissions specified in the access mask are denied to the principal identified in the SID.
  - **Access-allowed**:
    - permissions specified in the access mask are granted to the principal identified in the SID.
  - **System-audit**:
    - an audit record is created whenever the access rights specified in the access mask are requested by the principal identified in the SID.
- [Also supports 'system alarm' and 'access allowed compound' ACEs].

[In fact, Windows also supports object-specific ACEs used for Active Directory objects, but we do not cover these here. Such objects support fine grained access control to Active Directory objects].

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## Ordering of ACEs in a DACL I

- **Ordering** of ACEs in DACL is important, as the DACL is traversed from first entry to last and there may be conflicting entries.
- ACEs are first grouped by inheritance:
  - ACEs that have been explicitly added to an object's ACL precede inherited ACEs:
  - 1st generation inherited ACEs precede 2nd generation inherited ACEs, etc.


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The **ordering** of ACEs in the DACL is important, as the DACL is traversed from first entry to last and there may be conflicting entries. Moreover, once enough ACEs have been examined to enable an access decision, the decision is made and all further ACEs are ignored.

ACEs are first grouped by inheritance:

- ACEs that have been explicitly added to an object's ACL precede inherited ACEs, and hence the owner has the most control over access;
- 1st generation inherited ACEs precede 2nd generation inherited ACEs, etc.

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## Ordering of ACEs in a DACL II

- Within each 'inheritance' group, access-denied ACEs precede access-allowed ACEs.
- Hence if an access right is both allowed and denied then it is denied.
- Normal ACEs precede object-specific ACEs.

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Within each 'inheritance' group, access-denied ACEs precede access-allowed ACEs. Hence if an access right is both allowed and denied then it is denied. Normal ACEs precede object-specific ACEs.

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## Inheritance of ACEs I

- An ACE contains a **5-bit inheritance mask** (part of the **AceFlags**).
- This is used to indicate the way in which the ACE should be propagated to children of the object.

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An ACE contains a **5-bit inheritance mask** (part of the **AceFlags**). This is used to indicate the way in which the ACE should be propagated to children of the object.

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## Inheritance of ACEs II

- The inheritance flags (bits) are:
  - **Inherited Ace (ID)**
    - indicates whether the ACE was inherited from a parent container;
  - **Inherit Only (IO)**
    - indicates whether this ACE applies to the current object;
    - an ACE with the IO flag set is used purely for controlling inheritance;
  - **Container Inherit (CI)**
    - indicates whether subordinate containers will inherit this ACE;
  - **Object Inherit (OI)**
    - indicates whether subordinate objects will inherit the ACE;
  - **Non-Propagate (NP)**
    - indicates whether the subordinate object will not propagate the inherited ACE any further.

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The inheritance flags (bits) are:

### **Inherited Ace (ID)**

indicates whether the ACE was inherited from a parent container;

### **Inherit Only (IO)**

indicates whether this ACE applies to the current object;

an ACE with the IO flag set is used purely for controlling inheritance;

### **Container Inherit (CI)**

indicates whether subordinate containers will inherit this ACE;


### **Object Inherit (OI)**

indicates whether subordinate objects will inherit the ACE;

### **Non-Propagate (NP)**

indicates whether the subordinate object will not propagate the inherited ACE any further.

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## Processing Access Requests I


- Access request interpreted as 32-bit access mask, where bits corresponding to the requested rights are set to 1.
- When process attempts to access a securable object, relevant service sends the security reference monitor:
  - access token of the process,
  - DACL of the object, and
  - requested access mask.

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An access request for a specific set of access rights is interpreted as a 32-bit access mask, where the bits corresponding to the requested rights are set to 1 (and all other bits are set to 0).

When a process attempts to access a securable object, the relevant service sends the access token of the process, the DACL of the object, and the requested access mask to the security reference monitor.

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## Processing Access Requests II


- The access checking algorithm constructs a **granted access mask** by comparing the SIDs in the access token with corresponding entries in the object's DACL:
  - If at any time the **granted access mask matches the requested access mask**, then access is granted;
  - In this case, the SRM forwards the granted access mask to the object manager, which creates a handle entry in the process handle table and returns a handle to the process.

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The SRM performs an access checking algorithm that constructs a granted access mask by comparing the SIDs in the access token with corresponding entries in the object's DACL:

- if at any stage the **granted access mask matches the requested access mask**, then access is granted;
- in this case, the SRM forwards the granted access mask to the object manager, which creates a handle entry in the process handle table and returns a handle to the process.

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## Access token restrictions

- Every SID in the **access token** has two associated flags that determine how the SID is used when evaluating an access request:
  - a SID is **enabled** if the SE\_GROUP\_ENABLED flag is set;
  - a SID is **deny-only** if the SE\_GROUP\_USE\_FOR\_DENY\_ONLY flag is set;
  - if the SE\_GROUP\_USE\_FOR\_DENY\_ONLY flag is set then the SE\_GROUP\_ENABLED flag is not set.


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Every SID in an access token has two associated flags that determine how the SID is used when evaluating an access request:

- a SID is **enabled** if the SE\_GROUP\_ENABLED flag is set;
- a SID is **deny-only** if the SE\_GROUP\_USE\_FOR\_DENY\_ONLY flag is set;
- if the SE\_GROUP\_USE\_FOR\_DENY\_ONLY flag is set then the SE\_GROUP\_ENABLED flag is not set.

The deny-only flag means that the SID cannot be used to gain positive access rights.

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## Processing access requests III


- Following rules are used when evaluating access requests:
  - ACEs that have the inherit-only flag set are ignored;
  - access token SIDs that are not enabled are ignored;
  - deny-only SIDs are used when processing access-denied ACEs, but are ignored when processing access-allowed ACEs.

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The following rules are used when evaluating an access request against a DACL (note this is a simplified version of the process):

- ACEs that have the inherit-only flag set are ignored;
- access token SIDs that are not enabled are ignored;
- deny-only SIDs are used when processing access-denied ACEs, but are ignored when processing access-allowed ACEs.

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## Processing access requests IV

- In other words, the existence of deny-only SIDs can only reduce the access rights of the holder of the access token.
- Typically such SIDs are used in impersonation tokens.

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In other words, the existence of deny-only SIDs can only reduce the access rights of the holder of the access token.

Typically such SIDs are used in impersonation tokens.

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## The checking algorithm I

*Preliminary checks*

- Granted access mask is initialised to all zeros.
- If object has no DACL, then access is **granted** (since the object has no protection defined).
- If caller has take-ownership privilege then write-owner access right is added to the granted access mask:
  - If the granted access mask matches the requested access mask then access is **granted**.
- If requestor is owner of object then read-control and write-DACL access rights are added to the granted access mask:
  - If the granted access mask matches the requested access mask then access is **granted**.

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Before starting, the granted access mask is set to all zeros. (Adding rights to the granted access mask involves setting the relevant bit(s) to one).

If the object has no DACL, then access is **granted** (since the object has no protection defined).


If the caller has the take-ownership privilege then the write-owner access right is added to the granted access mask:

- if the granted access mask matches the requested access mask then access is **granted**.

If the requestor is the owner of the object then the read-control and write-DACL access rights are added to the granted access mask:

- if the granted access mask matches the requested access mask then access is **granted**.

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## The checking algorithm II

*Traversing the DACL*


- Each ACE in the DACL is examined, starting at the beginning of the list:
  - If the ACE is not marked inherit-only then:
    - If the SID in the ACE matches an enabled SID in the access token) or (it is an access-allowed ACE and its SID matches an SID in the access token that is not deny-only) then:
      - if it is an access-allowed ACE then the rights in the access mask in the ACE that match those in the requested mask are added to the granted access mask;
      - if it is an access-denied ACE and any of the access rights in the requested access mask match those in the ACE access mask then access is **denied**.
    - if the granted access mask matches the requested access mask then access is **granted**.

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Each ACE in the DACL is examined, starting at the beginning of the list:

- if the ACE is not marked inherit-only then:
  - if (the SID in the ACE matches an enabled SID in the access token) or (it is an access-allowed ACE and its SID matches an SID in the access token that is not deny-only) then:
    - if it is an access-allowed ACE then the rights in the access mask in the ACE that match those in the requested mask are added to the granted access mask;
    - if it is an access-denied ACE and any of the access rights in the requested access mask match those in the ACE access mask then access is **denied**.
  - if the granted access mask matches the requested access mask then access is **granted**.

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## The checking algorithm III

*Reaching the end of the DACL*

- If the end of the DACL is reached and the granted access mask does not match the requested access mask then access is **denied**.
  - (If the DACL has no entries, the end of the list is reached immediately and the granted access mask will consist of zeros).
- If the end of the DACL is reached and the granted access mask matches the requested access mask and the access token contains no restricted SIDs then access is **granted**.

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If the end of the DACL is reached and the granted access mask does not match the requested access mask then access is **denied**.

- (If the DACL has no entries, the end of the list is reached immediately and the granted access mask will consist of zeros).

If the end of the DACL is reached and the granted access mask matches the requested access mask and the access token contains no restricted SIDs then access is **granted**.

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## Simplified walk-through I

- We use a 4-bit permission mask.
- Some fields in access token and DACL are omitted.
- Use numbers to represent SIDs.
- Assume that `INHERIT_ONLY` flag is turned off in inheritance mask of every ACE.

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In our simplified example we use a 4-bit permission mask to make the description simpler. Some of the fields in the access token and DACL are omitted. We use numbers to represent SIDs. We assume that the `INHERIT_ONLY` flag is turned off in the inheritance mask of every ACE.

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## Simplified walk-through II

Access token

User = 9

Groups = 2, 10, 11

DACL

- SID = 2  
Mask = 0100

+ SID = 9  
Mask = 0001

+ SID = 3  
Mask = 1100

+ SID = 10  
Mask = 0110

Security information associated with **subject**

Security information associated with **object**

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In our simple examples we assume that the requesting process has an associated access token containing user SID 9, and three group SIDs (2, 10 and 11). We also suppose that the object to which access is requested has a DACL with four ACEs.

Note that the first ACE is an 'access denied' ACE, i.e. it indicates a SID which is **not permitted** to have access (this is signified by the minus sign at the top of the box). The other three ACEs are 'access granted' ACEs, as signified by the plus sign.

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### Example 1

- Requested access mask = **0110**
- SID 2 matches first ACE in DACL
- Permission mask in ACE overlaps with requested access mask
- Access denied

Access token	DACL
User = 9 Groups = 2, 10, 11	- SID = 2 Mask = 0100
	+ SID = 9 Mask = 0001
	+ SID = 3 Mask = 1100
	+ SID = 10 Mask = 0110

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We first consider the case where the requested access mask is 0110.

The SID in the first ACE is 2. Hence this ACE may apply to this request, since 2 is one of the SIDs in the access token. The second bit in the mask in this ACE is set. The second bit in the requested access mask is also set, and hence **this ACE applies**. Since this ACE is an **access denied** ACE, access is denied, and processing of the ACL stops at this point.

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### Example 2

- Requested access mask = **1010**
- First matching SID/mask in last ACE
- Granted access mask = 0010
- Access denied

Access token	DACL
User = 9 Groups = 2, 10, 11	- SID = 2 Mask = 0100
	+ SID = 9 Mask = 0001
	+ SID = 3 Mask = 1100
	+ SID = 10 Mask = 0110

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We second consider the case where the requested access mask is 1010. The granted access mask is initially set to **0000**.

The SID in the first ACE is 2. Hence this ACE may apply to this request, since 2 is one of the SIDs in the access token. However, there is no match between any of the bits in the mask in the ACE and the requested access mask. Hence this ACE **does not apply**.

The SID in the second ACE is 9. Hence this ACE may apply to this request, since 9 is one of the SIDs in the access token. However, there is no match between any of the bits in the mask in the ACE and the requested access mask. Hence this ACE **does not apply**.

The SID in the third ACE is 3. Hence this ACE **does not apply** to this request, since 3 is not one of the SIDs in the access token.

The SID in the fourth ACE is 10. Hence this ACE may apply to this request, since 10 is one of the SIDs in the access token. There is also a match between one of the bits in the mask in the ACE and the requested access mask, namely the third bit. This matching bit is now added to the granted access mask, i.e. the granted access mask becomes **0010**.

There are no more ACEs, and hence at this point the granted access mask (0010) is compared to the requested access mask (1010). They are not equal and hence **access is denied**.

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### Example 3

- **Requested access mask = 0001**
- **First matching SID/mask in second ACE**
- **Granted access mask = 0001**
- **Access granted**

Access token	DACL
User = 9 Groups = 2, 10, 11	- SID = 2 Mask = 0100
	+ SID = 9 Mask = 0001
	+ SID = 3 Mask = 1100
	+ SID = 10 Mask = 0110

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Finally we consider the case where the requested access mask is **0001**. The granted access mask is initially set to **0000**.

The SID in the first ACE is 2. Hence this ACE may apply to this request, since 2 is one of the SIDs in the access token. However, there is no match between any of the bits in the mask in the ACE and the requested access mask. Hence this ACE **does not apply**.

The SID in the second ACE is 9. Hence this ACE may apply to this request, since 9 is one of the SIDs in the access token. There is also a match between one of the bits in the mask in the ACE and the requested access mask, namely the fourth bit. This matching bit is now added to the granted access mask, i.e. the granted access mask becomes **0001**.

Every time the SRM finishes processing an ACE in the DACL, the granted access mask (0001) is compared to the requested access mask (0001). They are equal and hence **access is granted**.

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### Mandatory access control


- Windows **integrity mechanism** is an extension of Windows security architecture.
- Adds integrity level to the security access token, and a mandatory label access control entry to the system ACL (SACL) in the security descriptor.
- This can be used to enforce a type of **mandatory access control**.

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The Windows **integrity mechanism** is an extension of the Windows security architecture.

It adds an integrity level to the security access token, and a mandatory label access control entry to the system ACL (SACL) in the security descriptor. This can be used to enforce a type of mandatory access control.

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## User Account Control (UAC)

- **User Account Control (UAC)** was introduced in Windows Vista/Server 2008; more refined version in newer versions.
- Goal to limit apps to standard privileges, even when user logged in as an admin.
- If admin privileges needed, then must be explicitly authorised by the user.
- So only apps trusted by user will get admin privileges, limiting ability of malware to compromise the OS.

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**User Account Control (UAC)** was introduced in Windows Vista and Windows Server 2008; a more refined version is present in subsequent versions of Windows. The goal of UAC is to improve security by limiting applications to standard user privileges even when a user is logged in as an administrator. If admin privileges are required then this must be explicitly authorised by the user. As a result, only applications trusted by the user will enjoy administrative privileges, and this will limit the ability of malware to compromise the OS.

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## UAC operation

- When admin user logs in, 2 access tokens created:
  - one contains admin privileges;
  - other is a **restricted token**, without admin privileges.
- All applications are associated with restricted token.
- When application tries to do something needing admin privileges, or if user runs application 'as administrator', UAC prompts:
  - a 'standard' user to enter the credentials of an Administrator account, or
  - an Administrator to confirm and, if agrees, continues/starts process using unrestricted token.

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When a user in the Administrators group logs in, two separate access tokens are created. The first token contains all the privileges typically given to an administrator, and the second is a **restricted token**, somewhat similar to that which a non-administrator (standard) user would receive. All applications run by the user, including the Windows desktop, are associated with the restricted token. When an application tries to do something requiring administrator privileges, or when a user indicates it wishes to run an application 'as administrator', UAC will prompt either:

- a 'standard' user to enter the credentials of an Administrator account, or
- an Administrator for confirmation and, if consent is given, continue or start the process using an unrestricted token.




## Agenda

- Introduction
- Active directory
- Domains
- Windows subjects and objects
- Access rights
- Authentication
- Access control
- Security management
- Resources

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We conclude by briefly introducing some of the functions Windows provides to support security management across a domain.



## Security management

- Deploying security policies to widely distributed machines causes many administrative problems.
- Creating a domain forest and organisational units can simplify management of security policies by using Active Directory and inheritance of ACLs.
- Windows also provides **Security Configuration Tool Set (SCTS)** and **Group Policy objects** to simplify security management & administration.

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The deployment of security policies to widely distributed machines causes many administrative problems in modern enterprises.

Creating a domain forest and suitable organisational units can simplify the management of security policies by exploiting the features of Active Directory and the inheritance of ACLs.

Windows also provides the **Security Configuration Tool Set (SCTS)** and **Group Policy objects** to simplify the management and administration of security.



## SCTS I

- SCTS allows a security administrator to define security policies and automatically deploy them across the enterprise.
- SCTS can also be used to analyse the performance of a system configuration, and compare it with requirements of the enterprise security policy.

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SCTS allows a security administrator to define one or more security policies and automatically deploy them across the enterprise.

SCTS can also be used to analyse the performance of a particular system configuration and compare it with the requirements of the enterprise security policy.




## SCTS II

- SCTS allows configuration and analysis of many security features including:
  - policies for passwords and account lockout;
  - audit policies and audit logs;
  - privilege assignment;
  - assignment of users to groups;
  - security settings for:
    - system services;
    - file volumes;
    - directory trees;
    - registry keys.

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  - system services;
  - file volumes;
  - directory trees;
  - registry keys.



## Group Policy objects I

- Security policy settings are stored in **Group Policy objects (GPOs)**, which are Active Directory objects.
- Policy settings applied by changing entries in Windows registry, and include:
  - software policies;
  - startup and shutdown scripts;
  - user documents and settings;
  - security settings.


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Security policy settings are stored in Group Policy objects (GPOs):

- GPOs are Active Directory objects.

Policy settings are applied by changing entries in the Windows registry and include:

- software policies;
- startup and shutdown scripts;
- user documents and settings;
- security settings.



## Group Policy objects II

- Every computer has a local GPO.
- GPOs can be linked to:
  - organisational units; or
  - domains.
- OU policy overrides domain policy.
- Domain policy overrides local policy.

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Every computer has a local GPO.

GPOs can also be linked to:

- organisational units; or to
- domains.

An OU policy overrides any domain policy.

A domain policy overrides any local policy.




## Security settings

- **Password policy.**
- **Account lockout policy** (e.g. following a certain number of failed logon attempts):
  - who can unlock the account;
  - when can the account be unlocked.
- **Kerberos policy:**
  - duration of tickets;
  - acceptable limits on clock synchronisation.

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The following policies can be set using security settings:

- The Password policy (discussed on next slide).
- The Account lockout policy (which applies, for example, following a certain number of failed logon attempts), covering:
  - who can unlock the account;
  - when can the account be unlocked.
- The Kerberos policy, covering:
  - the duration of tickets;
  - acceptable limits on clock synchronisation.



## Example – password policies

- Restrictions on lifetime and structure of passwords often form part of an enterprise security policy.
- Windows provides number of policies that can be used to deploy such restrictions.
- Password policies can be defined in a Group Policy object.

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Restrictions on the lifetime and structure of passwords often form an important part of an enterprise security policy. Windows provides a number of policies that can be used to define and deploy such restrictions.

Password policies can be defined in a Group Policy object.

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### Example – password policies

Policy Name	Range	Default
Enforce password history	0–24	1
Maximum password age	1–999 (days)	42
Minimum password age	0–999 (days)	0
Minimum password length	0–14	0
Passwords must meet complexity requirements	Not applicable	Disabled

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Examples of predefined password policy settings are shown.

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### Audit

- Auditing serves three main purposes:
  - detect behaviour violating the security policy;
  - analyse security breaches;
  - provide evidence for action against individuals (internal/external) violating security policy.
- Remember:
  - auditing has overhead, and can substantially affect overall system performance;
  - auditing generates (lots of) information that must be stored securely.

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Auditing serves three main purposes:

- to detect behaviour that violates the security policy;
  - to analyse security breaches;
  - to provide evidence for possible actions against individuals (internally or externally) who violate security policy.
- Remember:
- auditing always incurs overheads and can substantially affect overall system performance;
  - auditing generates (potentially large quantities of) information that needs to be stored securely.

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## Audit events

- Types of events most commonly audited are:
  - access to objects (such as files and folders);
  - management of user accounts and group accounts:
    - user account or group created, changed, or deleted;
    - user account renamed, disabled, or enabled;
    - password set or changed.
  - users logging on to and logging off from the system:
    - logon succeeds;
    - logon fails;
    - Kerberos TGT issued.

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The types of events which are most commonly audited are:

- access to objects (such as files and folders);
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## Auditing object access

- Windows provides fine-grained audit capabilities through use of system ACLs.
- Object's SACL determines which access requests for the object should be audited:
  - if a principal can access an object then that access can be audited;
  - a SACL contains system-audit ACEs.

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Windows provides fine-grained audit capabilities through the use of system ACLs. An object's SACL determines which access requests for the object should be audited:

- if a principal can access an object then that access can be audited;
- a SACL contains system-audit ACEs.



## System-audit ACEs

- ACEs contain two audit flags (only used in system-audit ACEs):
  - `FAILED_ACCESS_ACE_FLAG`
    - the access mask in the ACE specifies operations that should be logged when they fail;
  - `SUCCESSFUL_ACCESS_ACE_FLAG`
    - the access mask specifies operations that should be logged when they succeed.

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ACEs contain two audit flags (that are only used in system-audit ACEs):

`FAILED_ACCESS_ACE_FLAG`

the access mask in the ACE specifies the operations that should be logged when they fail;

`SUCCESSFUL_ACCESS_ACE_FLAG`

the access mask specifies the operations that should be logged when they succeed.




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There are a wide variety of helpful resources on the topic of Windows security.



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## Supplementary reading I

- The most useful Microsoft resource is the TechNet site  
<http://technet.microsoft.com/en-us/windows/default.aspx>
- Windows client security and control:  
<http://technet.microsoft.com/en-us/windows/aa905062.aspx>
- Overview of authentication in Windows:  
<https://technet.microsoft.com/en-us/library/hh831472.aspx>
- Overview of identity management and access control in Windows Vista:  
[http://technet.microsoft.com/en-us/library/cc749433\(WS.10\).aspx](http://technet.microsoft.com/en-us/library/cc749433(WS.10).aspx)

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## Supplementary reading II

- Windows Server Security (this link provides access to a large library of useful material):  
<http://technet.microsoft.com/en-gb/windowsserver/windows-server-security.aspx>
- Active Directory:  
<http://technet.microsoft.com/en-us/library/bb878028.aspx>  
[http://technet.microsoft.com/en-gb/library/dd578336\(WS.10\).aspx](http://technet.microsoft.com/en-gb/library/dd578336(WS.10).aspx)
- Chapter 8 of D. Gollmann (3rd edition) contains an overview of Windows security.

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The most useful Microsoft resource is the TechNet site

<http://technet.microsoft.com/en-us/windows/default.aspx>

Windows client security and control:

<http://technet.microsoft.com/en-us/windows/aa905062.aspx>

Overview of authentication in Windows:

<https://technet.microsoft.com/en-us/library/hh831472.aspx>

Overview of identity management and access control in Windows Vista:

[http://technet.microsoft.com/en-us/library/cc749433\(WS.10\).aspx](http://technet.microsoft.com/en-us/library/cc749433(WS.10).aspx)

Windows Server Security (this link provides access to a large library of useful material):

<http://technet.microsoft.com/en-gb/windowsserver/windows-server-security.aspx>

Active Directory:

<http://technet.microsoft.com/en-us/library/bb878028.aspx>

[http://technet.microsoft.com/en-gb/library/dd578336\(WS.10\).aspx](http://technet.microsoft.com/en-gb/library/dd578336(WS.10).aspx)

Chapter 8 of D. Gollmann's *Computer Security* (3rd edition) contains an overview of Windows security.