CSE 4/521 Introduction to Operating Systems

Lecture 29 – Windows 7

(History, Design Principles, System Components, Programmer Interface)

Summer 2018

Overview

Objective:

- To explore the principles upon which Windows 7 is designed and the specific components involved in the system.
- To understand how Windows 7 can run programs for other operating systems.
- To cover the interface available to system and application programmers.

- History
- Design Principles
- System Components
- Programmer Interface

Overview

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History

- 32-bit preemptive multitasking operating system for Intel microprocessors
- Key goals for the system:
  - portability
  - security
  - POSIX compliance
  - multiprocessor support
  - extensibility
  - international support
  - compatibility with MS-DOS and MS-Windows applications.
- Uses a micro-kernel architecture
- Available in six client versions, Starter, Home Basic, Home Premium, Professional, Enterprise and Ultimate. With the exception of Starter edition (32-bit only) all are available in both 32-bit and 64-bit.

History

- In 1988, Microsoft decided to develop a "new technology" (NT) portable operating system that supported both the OS/2 and POSIX APIs
- Originally, NT was supposed to use the OS/2 API as its native environment but during development NT was changed to use the Win32 API, reflecting the popularity of Windows 3.0.

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Design Principles

- Extensibility — layered architecture
  - Executive, which runs in protected mode, provides the basic system services
  - On top of the executive, several server subsystems operate in user mode
  - Modular structure allows additional environmental subsystems to be added without affecting the executive
- Portability — Windows 7 can be moved from one hardware architecture to another with relatively few changes
  - Written in C and C++
  - Processor-specific portions are written in assembly language for a given processor architecture (small amount of such code).
  - Platform-dependent code is isolated in a dynamic link library (DLL) called the "hardware abstraction layer" (HAL)

Design Principles

- Reliability — Windows 7 uses hardware protection for virtual memory, and software protection mechanisms for operating system resources
- Compatibility — applications that follow the IEEE 1003.1 (POSIX) standard can be complied to run on 7 without changing the source code
- Performance — Windows 7 subsystems can communicate with one another via high-performance message passing
  - Preemption of low priority threads enables the system to respond quickly to external events
  - Designed for symmetrical multiprocessing
- International support — supports different locales via the national language support (NLS) API

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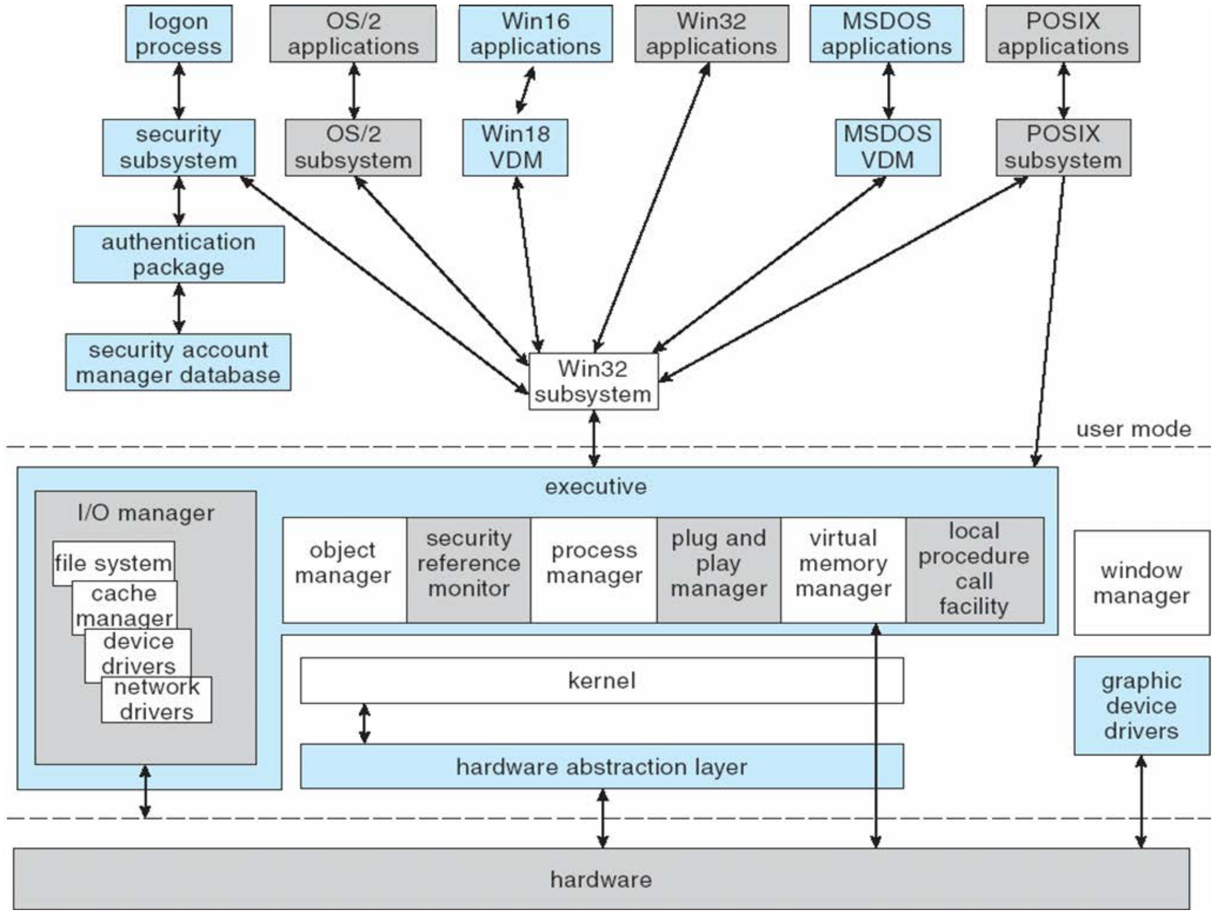
System Components: Windows 7 Architecture

- Layered system of module
- Protected mode — hardware abstraction layer (HAL), kernel, executive
- User mode — collection of subsystems
  - Environmental subsystems emulate different operating systems
  - Protection subsystems provide security functions

System Components: Windows 7 Architecture



System Components: Kernel

- Foundation for the executive and the subsystems
- Never paged out of memory; execution is never preempted
- Four main responsibilities:
  - thread scheduling
  - interrupt and exception handling
  - low-level processor synchronization
  - recovery after a power failure
- Kernel is object-oriented, uses two sets of objects
  - dispatcher objects control dispatching and synchronization (events, mutants, mutexes, semaphores, threads and timers)
  - control objects (asynchronous procedure calls, interrupts, power notify, power status, process and profile objects)

System Components: Process and Threads

- The process has a virtual memory address space, information (such as a base priority), and an affinity for one or more processors.
- Threads are the unit of execution scheduled by the kernel's dispatcher.
- Each thread has its own state, including a priority, processor affinity, and accounting information.
- A thread can be one of six states: ready, standby, running, waiting, transition, and terminated.

System Components: Scheduling (1/2)

- The dispatcher uses a 32-level priority scheme to determine the order of thread execution.
  - Priorities are divided into two classes
    - The real-time class contains threads with priorities ranging from 16 to 31
    - The variable class contains threads having priorities from 0 to 15
- Characteristics of Windows 7’s priority strategy
  - Tends to give very good response times to interactive threads that are using the mouse and windows
  - Enables I/O-bound threads to keep the I/O devices busy

System Components: Scheduling (2/2)

- Scheduling can occur when a thread enters the ready or wait state, when a thread terminates, or when an application changes a thread's priority or processor affinity
- Real-time threads are given preferential access to the CPU; but 7 does not guarantee that a real-time thread will start to execute within any particular time limit .
  - This is known as soft realtime.

System Components: Windows 7 Interrupt Request Levels

interrupt levels	types of interrupts
31	machine check or bus error
30	power fail
29	interprocessor notification (request another processor to act; e.g., dispatch a process or update the TLB)
28	clock (used to keep track of time)
27	profile
3–26	traditional PC IRQ hardware interrupts
2	dispatch and deferred procedure call (DPC) (kernel)
1	asynchronous procedure call (APC)
0	passive

System Components: Kernel – Trap Handling

- The kernel provides trap handling when exceptions and interrupts are generated by hardware or software.
- Exceptions that cannot be handled by the trap handler are handled by the kernel's exception dispatcher.
- The interrupt dispatcher in the kernel handles interrupts by calling either an interrupt service routine (such as in a device driver) or an internal kernel routine.
- The kernel uses spin locks that reside in global memory to achieve multiprocessor mutual exclusion.

System Components: Executive – Object Manager

- Windows 7 uses objects for all its services and entities; the object manger supervises the use of all the objects
  - Generates an object handle
  - Checks security
  - Keeps track of which processes are using each object
- Objects are manipulated by a standard set of methods, namely `create, open, close, delete, query name, parse` and `security`.

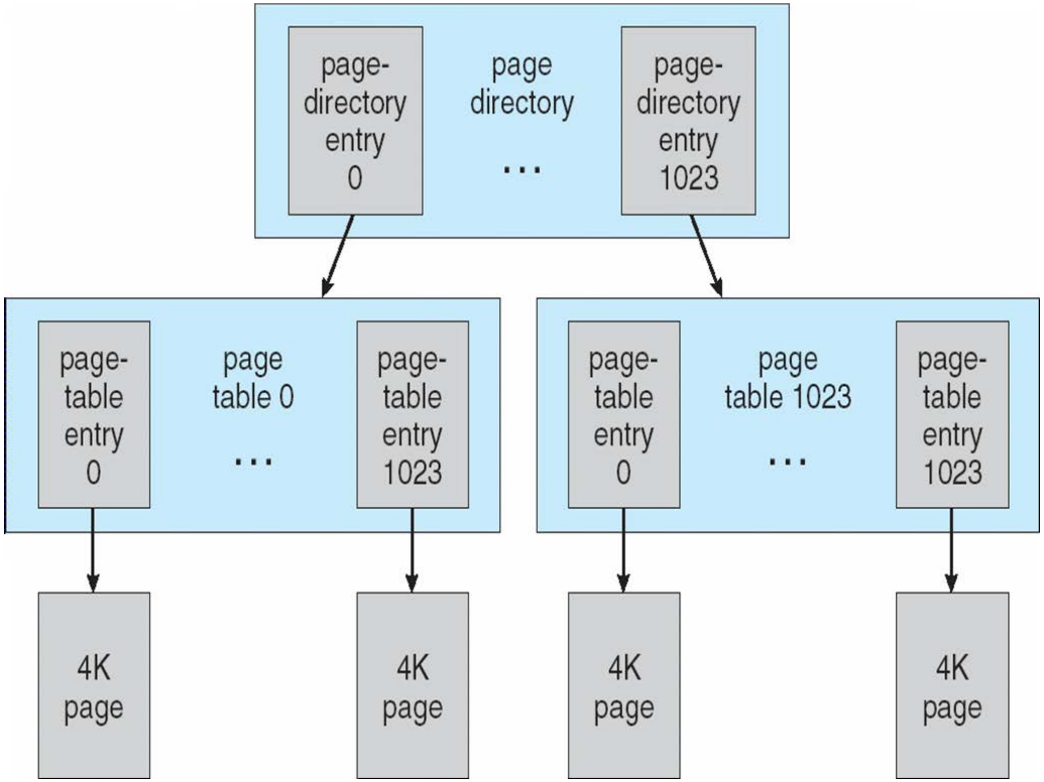
System Components: Executive – Naming Objects

- The Windows 7 executive allows almost any object to be given a name, which may be either permanent or temporary. Exceptions are process, thread and some others object types.
- Object names are structured like file path names in MS-DOS and UNIX.
- Windows 7 implements a symbolic link object, which is similar to *symbolic links* in UNIX that allow multiple nicknames or aliases to refer to the same file.
- A process gets an object handle by creating an object, by opening an existing one, by receiving a duplicated handle from another process, or by inheriting a handle from a parent process.

System Components: Executive - Virtual Memory Manager

- The design of the VM manager assumes that the underlying hardware supports virtual to physical mapping a paging mechanism, transparent cache coherence on multiprocessor systems, and virtual addressing aliasing.
- The VM manager in Windows 7 uses a page-based management scheme with a page size of 4 KB.
- The Windows 7 VM manager uses a two step process to allocate memory
    - The first step reserves a portion of the process's address space
    - The second step commits the allocation by assigning space in the system's paging file(s)

System Components: Executive – Virtual Memory Layout

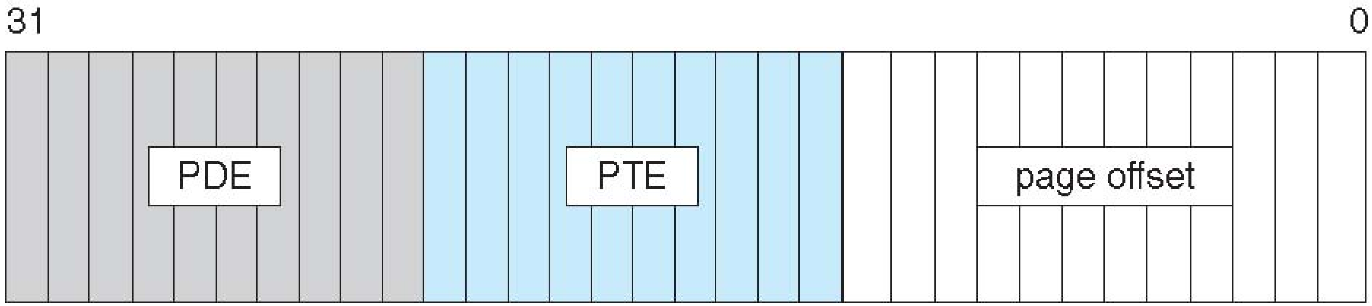


System Components: Virtual Memory Manager

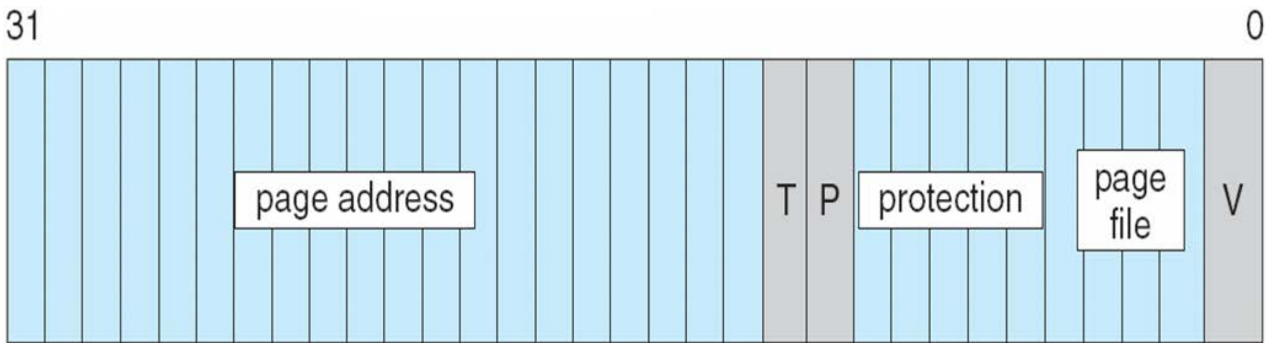
- The virtual address translation in Windows 7 uses several data structures
  - Each process has a page directory that contains 1024 page directory entries of size 4 bytes.
  - Each page directory entry points to a page table which contains 1024 page table entries (PTEs) of size 4 bytes.
  - Each PTE points to a 4 KB page frame in physical memory.
- A 10-bit integer can represent all the values form 0 to 1023, therefore, can select any entry in the page directory, or in a page table.
- This property is used when translating a virtual address pointer to a byte address in physical memory.
- A page can be in one of six states: valid, zeroed, free, standby, modified and bad.

System Components: Virtual-to-Physical Address Translation

10 bits for page directory entry, 20 bits for page table entry, and 12 bits for byte offset in page



System Components: Page File Page-Table Entry



5 bits for page protection,
20 bits for page frame address,
4 bits to select a paging file,
3 bits that describe the page state.
V = 0

System Components: Executive – Process Manager

- Provides services for creating, deleting, and using threads and processes
- Issues such as parent/child relationships or process hierarchies are left to the particular environmental subsystem that owns the process.

System Components: Executive – Local Procedure Call Facility

- The LPC passes requests and results between client and server processes within a single machine.
- In particular, it is used to request services from the various Windows 7 subsystems.
- When a LPC channel is created, one of three types of message passing techniques must be specified.
  - First type is suitable for small messages, up to 256 bytes; port's message queue is used as intermediate storage, and the messages are copied from one process to the other.
  - Second type avoids copying large messages by pointing to a shared memory section object created for the channel.
  - Third method, called quick LPC was used by graphical display portions of the Win32 subsystem.

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Programmer Interface: Access to Kernel Object

- A process gains access to a kernel object named XXX by calling the `CreateXXX` function to open a *handle* to XXX; the handle is unique to that process.
- A handle can be closed by calling the `CloseHandle` function; the system may delete the object if the count of processes using the object drops to 0.
- Windows 7 provides three ways to share objects between processes
  - A child process inherits a handle to the object
  - One process gives the object a name when it is created and the second process opens that name
  - `DuplicateHandle` function:
    - Given a handle to process and the handle's value a second process can get a handle to the same object, and thus share it

Programmer Interface: Process Management

- Process is started via the `CreateProcess` routine which loads any dynamic link libraries that are used by the process, and creates a primary thread.
- Additional threads can be created by the `CreateThread` function.
- Every dynamic link library or executable file that is loaded into the address space of a process is identified by an instance handle.

Programmer Interface: Process Management

- Scheduling in Win32 utilizes four priority classes:
  1. `IDLE_PRIORITY_CLASS` (priority level 4)
  2. `NORMAL_PRIORITY_CLASS` (level8 — typical for most processes
  3. `HIGH_PRIORITY_CLASS` (level 13)
  4. `REALTIME_PRIORITY_CLASS` (level 24)
- To provide performance levels needed for interactive programs, 7 has a special scheduling rule for processes in the `NORMAL_PRIORITY_CLASS`
  - 7 distinguishes between the foreground process that is currently selected on the screen, and the background processes that are not currently selected.
  - When a process moves into the foreground, 7 increases the scheduling quantum by some factor, typically 3.

Programmer Interface: Process Management

- The kernel dynamically adjusts the priority of a thread depending on whether it is I/O-bound or CPU-bound.
- To synchronize the concurrent access to shared objects by threads, the kernel provides synchronization objects, such as semaphores and mutexes
  - In addition, threads can synchronize by using the `WaitForSingleObject` or `WaitForMultipleObjects` functions.
  - Another method of synchronization in the Win32 API is the critical section.

Programmer Interface: Process Management

- A fiber is user-mode code that gets scheduled according to a user-defined scheduling algorithm.
  - Only one fiber at a time is permitted to execute, even on multiprocessor hardware.
  - Windows 7 includes fibers to facilitate the porting of legacy UNIX applications that are written for a fiber execution model.
- Windows 7 also introduced user-mode scheduling for 64-bit systems which allows finer grained control of scheduling work without requiring kernel transitions.

Programmer Interface: Interprocess Communication

- Win32 applications can have interprocess communication by sharing kernel objects.
- An alternate means of interprocess communications is message passing, which is particularly popular for Windows GUI applications
- Every Win32 thread has its own input queue from which the thread receives messages.

Programmer Interface: Memory Management

- Virtual memory:
  - `VirtualAlloc` reserves or commits virtual memory
  - `VirtualFree` decommits or releases the memory
  - These functions enable the application to determine the virtual address at which the memory is allocated
- An application can use memory by memory mapping a file into its address space
  - Multistage process
  - Two processes share memory by mapping the same file into their virtual memory

Programmer Interface: Memory Management

- A heap in the Win32 environment is a region of reserved address space
  - A Win 32 process is created with a 1 MB default heap
  - Access is synchronized to protect the heap's space allocation data structures from damage by concurrent updates by multiple threads
- Because functions that rely on global or static data typically fail to work properly in a multithreaded environment, the thread-local storage mechanism allocates global storage on a per-thread basis
  - The mechanism provides both dynamic and static methods of creating thread-local storage

Credits for slides

Silberschatz, Galvin and Gagne