History (Timeline from www.cgonline.com)

10/81 — IBM PC (“Personal Computer”) and PC-DOS 1.0

3/83 — Microsoft MS-DOS 2.0 (hard disk, file system)

11/83 — Windows announced (vaporware!)

11/84 — MS-DOS 3.1

11/85 — Windows 1.0 (tiled windows, doesn’t do well in market)

4/87 — IBM & Microsoft OS/2 1.0 (next generation, DOS-like command lines)

12/87 — Windows/386 (uses 80386’s virtual memory to allow safe “preemptive” multitasking)

History (cont.)

10/88 — OS/2 1.1 (Windows-like GUI, end of collaboration when IBM gets upset with Microsoft for improving Windows)

5/90 — Windows 3.0 (big success!)

4/92 — Windows 3.1 (bug fixes etc.)

10/92 — Windows for Workgroups 3.1 (adds networking, but fails in market)

5/93 — Windows NT 3.1 (visually like Windows 3.1, but stable 32-bit platform)

11/93 — Windows for Workgroups 3.11 (precursor to Windows 95)

5/94 — MS-DOS 6.22 (DOS final version)

9/94 — Windows NT 3.5
6/95 — Windows NT 3.51 (faster)

History (cont.)

8/95 — Windows 95 (originally Windows 4.0) (long file names, plug and play hardware, taskbar and Start menu, HUGE success in market!)

7/96 — Windows NT 4.0 (Windows 95 GUI, first successful version of NT)

6/98 — Windows 98 (Windows 95 + Internet Explorer 4.0, success in market)

2/00 — Windows 2000 (Windows NT 4.0 + plug and play, DirectX, USB, etc.)

9/00 — Windows Me (Millennium Edition) (Windows 98 + IE 5.0, media support, last version in Windows 9x line)

9/01 — Windows XP (combines Windows 2000 and ME, but based on NT/2000)

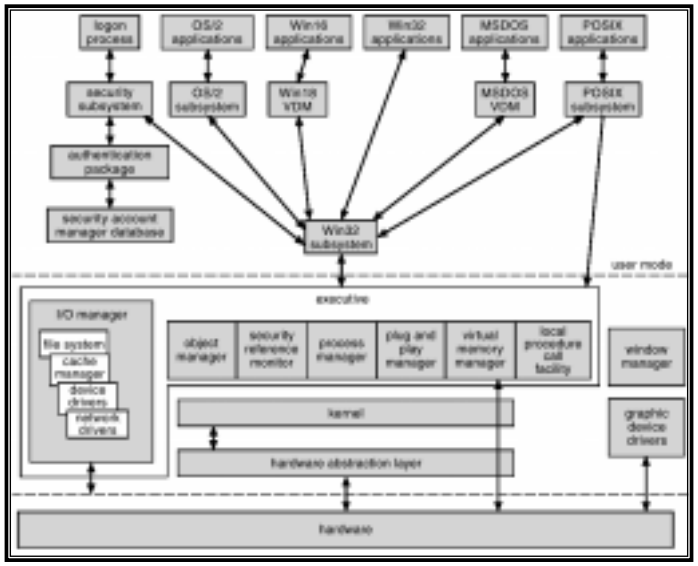
What is Windows 2000?

- 32-bit preemptive multitasking operating system for Intel microprocessors
- Key goals
  - extensibility
  - portability
  - reliability
  - POSIX compliance & compatibility with MS-DOS and MS-Windows applications
  - performance
  - multiprocessor support
  - international support
- Uses a micro-kernel architecture
- Four versions: Professional, Server, Advanced Server, Datacenter Server

Windows 2000 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
    - Emulate different OSs to run programs written for MS-DOS, Windows, and POSIX
- Portability — Windows 2000 can be moved from one Intel hardware architecture to another with few changes
  - Processor-dependent code is isolated in a dynamic link library (DLL) called the "hardware abstraction layer" (HAL)

Windows 2000 Block Diagram



Windows 2000 Design Principles (cont.)

- Reliability —hardware protection for virtual memory, FTFS file system that recovers automatically from many errors
- Compatibility — applications that follow the IEEE 1003.1 (POSIX) standard can be complied to run on 2000 without changing the source code
- Performance — high-performance message passing for communication between subsystems
  - 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

Windows 2000 Organization

- Micro-kernel based system
- In protected (kernel mode):
  - Executive — object management, process management, virtual memory management, local procedure calls, plug and play I/O, and security
  - (Micro) Kernel — never paged out of memory, never preempted, does thread scheduling, synchronization, interrupts;
  - Hardware Abstraction Layer (HAL) — hides hardware differences from upper layers; supports multiprocessors
- In user mode:
  - environmental subsystems (support code written for different platforms)
  - other non-kernel parts of OS
  - user programs

Windows 2000 Kernel

- Thread scheduling, interrupt & exception handling, processor synchronization
- Events, threads, semaphores, interrupts, etc. are all objects
- Threads have 6 states
  - Ready, standby, running, terminated
    - Standby is next one to run (more than one if multiple processors)
  - Waiting — I/O wait
  - Transition — waiting for resources
- CPU scheduler with 32-level priority feedback queues divided into 2 classes
  - real-time (16-31)
  - variable (0-15)

Windows 2000 Executive

- Object Manager
  - Objects for all services and entities
  - Standard methods of access
  - Security provided via access control list
- Virtual Memory Manager
  - Demand paging with a page size of 4 KB
  - 32-bit virtual address => 4 GB space
    - Each process has a *page directory* that contains 1024 *page directory entries* (PDEs) of size 4 bytes
    - Each PDE 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
  - Per-process page replacement
    - Working set starts at 30 pages per process, is adjusted as processes run

Windows 2000 Executive (cont.)

- Process Manager
  - Services for creating, deleting, and using threads and processes
- Local Procedure Call Facilty
  - Passes requests and results between client and server processes within a single machine (RPC optimized for message-passing within one system)
- I/O Manager
  - Responsible for file system, cache management, device drivers and network drivers
  - Centralized cache management, rather than one system for file system caching, etc. (as in UNIX)
- Security Reference Manager
  - Checks access to objects against the object's access control list

Windows 2000 Environmental Systems

- User-mode processes allow programs developed for other OSs to run
- Win32 subsystem is the main operating environment and is used to start all processes
  - Also provides all the keyboard, mouse and graphical display capabilities
- Virtual DOS Machine (VDM) supports DOS applications
  - Translates 16-bit DOS addresses to 32-bit Windows addresses, emulates MS-DOS BIOS, Intel 486 instructions (if Windows is running on a different architecture), etc.
- POSIX subsystem
  - Runs applications that follow the POSIX.1 standard (based on the UNIX model)

Windows 2000 File System (NT File System = NTFS)

- Files are treated as objects
- File volumes are based on disk partitions, but can span disks if desired
- NTFS uses clusters as the underlying unit of disk allocation
  - A cluster is a number of disk sectors that is a power of two (4 KB for volumes greater than 4 GB)
  - Because the cluster size is smaller than for the 16-bit FAT file system, the amount of internal fragmentation is reduced
- All file system data structure updates are performed inside transactions, to keep file system consistent after a crash
  - Before a data structure is altered, the transaction writes a log record that contains redo and undo information