



Mac OS X for UNIX Users

The power of UNIX with the simplicity of Macintosh.

Features

Open source, UNIX-based foundation

- SMP-optimized kernel based on FreeBSD 5 and Mach 3.0
- 64-bit virtual memory based on the LP64 model
- Standard libraries and utilities for easy porting of Linux, UNIX, and POSIX source code
- Hand-tuned, standards-compliant scalar and vector math libraries
- UNIX GUI support via native toolkits and included X11 server
- Open source code available via the Darwin project

Standards-based networking

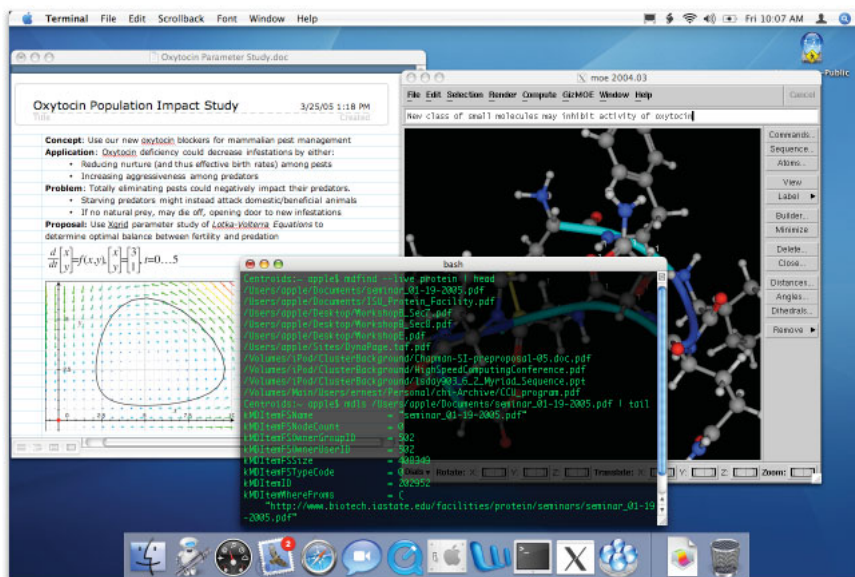
- Complete IP-based architecture supporting IPv4, IPv6, and L2TP/IPSec VPN
- Rich zero-configuration discovery and naming via Bonjour and Dynamic DNS
- Interoperable file serving via NFS, AFP, SMB/CIFS, and FTP
- Powerful Apache services (httpd, DAV, PHP)
- Open Directory services built on LDAP and Kerberos for single sign-on

Comprehensive UNIX user environment

- Standards-based graphics built on PDF (Quartz), OpenGL, H.264, and MPEG-4 (QuickTime)
- Xterm-compliant Terminal integrated with Aqua user interface
- Choice of shells (bash, ksh, csh) and scripting languages (Perl, Python, Tcl, Ruby)
- Enhanced with Spotlight searching, Xgrid queuing, and Automator workflows
- Comprehensive UNIX/Linux utilities (emacs, vim, gnutar, make)
- Xcode 2 developer tools with GCC 4.0 for optimized code generation and ISO/IEC 14882:2003 C++ support

Mac OS X version 10.4 Tiger combines a robust and open UNIX-based foundation with the richness and usability of the Mac interface, bringing UNIX technology and 64-bit power to the mass market. Apple has made open source and standards a key part of its strategy to deliver an industrial-strength operating system that is both innovative and easy to use.

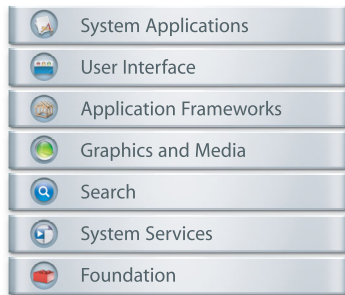
There are over 15 million Mac OS X users—scientists, animators, developers, system administrators, and more—making Mac OS X the most widely used UNIX-based desktop operating system. In addition, Mac OS X is the only UNIX-based environment that natively runs Microsoft Office, Adobe Photoshop, and thousands of other consumer applications—all side by side with traditional command-line, X11, and Java applications. Mac OS X is also the foundation for Mac OS X Server, which makes open source software easy to administer. Tight integration with Apple hardware, from the sleek PowerBook G4 to the award-winning Xserve G5, is making Mac OS X the platform of choice for an emerging generation of UNIX users.



Technology Brief

Mac OS X for UNIX Users

System architecture



Mac OS X: The desktop for open source

Since Apple first released the Darwin code in 1999, Mac OS X has been closely identified with the open source community. Apple worked with other pioneers to develop one of the first corporate open source licenses and has built ongoing relationships with key projects such as Apache, FreeBSD, Perl, and Python—many of whose committers are now devoted Mac OS X users. Today Apple is the largest single vendor of open source software such as GCC, PHP, Samba, SSH, and scores of other projects (see www.apple.com/opensource). Leading advocates from Java developer James Gosling to Slashdot founder Rob Malda are discovering that Mac OS X really is the ideal desktop for open source.

Mac OS X Architecture

The flexibility of Mac OS X derives from a modular architecture built around six major layers.

System applications

Mac OS X comes with more than three dozen high-quality graphical applications for file management, Internet access, system configuration, and much more.

Aqua user interface

Aqua provides the elegantly functional look and feel of Mac OS X. The entire interface—including icons, menus, windows, and controls—represents an innovative continuation of the legendary Mac ease of use, using color, transparency, and animation to enhance the usability and consistency of the system and applications. Developers can create Aqua user interfaces for Cocoa, Carbon, and Java applications, as well as with several scripting frameworks.

Application frameworks

Mac OS X includes a variety of rich application frameworks, built on top of the traditional UNIX APIs, to support developers in many different communities.

- **Cocoa** is a set of object-oriented frameworks designed for rapid application development, making it easy to add rich Aqua interfaces to existing UNIX software or to create entirely new applications.
- **Carbon** provides a gentle migration path for developers using C++ and procedural application frameworks.
- **Java 2 Standard Edition** on Mac OS X is fully compliant, highly optimized, and tightly integrated with the native look and feel, making it easy to run standards-based Java applications right out of the box.

Graphics and media

The Mac OS X graphics system combines 2D, 3D, and time-based media standards using an industry-leading compositing window system for a rich yet seamless user experience.

- **Quartz** is the high-performance imaging model in Mac OS X, based on Adobe's cross-platform Portable Document Format (PDF) standard. Quartz uses Core Image to leverage the graphics processor for efficient display and printing of high-quality, anti-aliased text and graphics.
- **OpenGL** is the industry standard for visualizing 3D shapes and textures. Mac OS X features a tightly integrated, highly optimized, and standards-compliant implementation that uses high-end 3D graphics cards to full advantage, for basic drawing primitives as well as real-time 3D modeling and rendering.
- **QuickTime**, Apple's cutting-edge digital media software, provides a fully standards-based environment for creating, playing, and delivering video (MPEG-4 and H.264), audio (AAC, or Advanced Audio Coding), and images (JPEG 2000, PNG, TIFF, and hundreds more).
- **Core Image** is a new system framework in Mac OS X Tiger for high-precision image processing that can utilize modern, high-performance graphics cards to provide real-time image processing capabilities using a systemwide API for image effects and transformations.

Top New Features for UNIX Users

- **64-bit processes.** Tiger sports a complete 64-bit virtual memory system while natively running 32-bit processes. Processes have 16 exabytes of address space, more than enough for today's (and tomorrow's) biological and engineering data sets.
- **Spotlight.** The `mdfind` command-line tool makes it trivial for scripts and web services to search the Spotlight metadata store and quickly find relevant images, email, documents, and other files.
- **Automator.** Automator is not just a great graphical tool for integrating shell scripts and AppleScript scripts into complex workflows; those workflows can be scheduled (à la cron) or saved as their own applications.
- **Xgrid.** The Xgrid command-line tool makes it easy to run an arbitrary program across an ad hoc network with different inputs, for scientific computation or content creation.
- **GCC 4.0.** GCC 4.0 features global optimization based on Single Static Assignment; a new C++ front end designed for ISO/IEC 14882:2003 conformance; and support for both Macintosh computers with the 64-bit PowerPC G5 with Velocity Engine, and the new Intel-based Macintosh computers with SSE.
- **Remappable modifiers.** The Keyboard pane in System Preferences allows arbitrary remapping of modifiers (such as Ctrl and Caps Lock) on any keyboard.
- **Enhanced kernel.** Robust kernel programming interfaces (KPIs) enabled a reengineered kernel with optimized SMP locking, higher I/O throughput, native poll system calls, and less use of wired memory.
- **Access control lists.** Kernel-level checks for read, write, and execute permissions of arbitrary user lists are fully compatible with UNIX and Windows standards.
- **HFS+ command-line support.** Utilities (`cp`, `mv`, `tar`, `rsync`) properly handle resource forks, using the same standard APIs as Spotlight and ACLs.
- **Tk/Aqua.** The Tcl/Tk framework runs natively (no X11) on Quartz and is also accessible from Python.
- **Quartz for Python.** Users can convert Word files and other rich documents to PDF and tap into the full power of Quartz drawing, QuickTime imaging, and Cocoa text.
- **vForce.** All-new Accelerate APIs maximize throughput for common forms of numerical computing while preserving accuracy.
- **Korn shell.** AT&T's `ksh` is included, making it much easier to run scripts written for Solaris and similar systems.

Search

The ability to search for information—using filenames, metadata, or the contents of files—is an integral part of the Mac OS X architecture. The user interface, system applications, file system, and interprocess communication all work together to ensure that users get up-to-date information about documents, messages, applications, and other resources on the system.

System services

Beneath the easy-to-use interface and rich graphics are powerful system services for directories, mobility, and security. Together, these services ensure that Mac OS X functions consistently, compatibly, and securely wherever users go.

Darwin foundation

Powering all these capabilities is Darwin, an open source, UNIX-based foundation built on technologies such as FreeBSD, Mach, Apache, and GCC. Darwin provides a complete UNIX environment, with X11 and POSIX services comparable to Linux or FreeBSD, including the familiar kernel, libraries, network services, and command-line environment described in the following pages.

State-of-the-Art Foundation

The Mac OS X kernel at the heart of Darwin is based on FreeBSD 5 and Mach 3.0. The Berkeley Standard Distribution (BSD, first developed at the University of California, Berkeley) is one of the most widely respected UNIX implementations. BSD provides Mac OS X with the stability, performance, and compatibility for which UNIX is justly famous. Apple has enhanced BSD by adding Mach 3.0 technology based on the OSF/mk microkernel from the Open Software Foundation, providing memory management, thread control, hardware abstraction, and interprocess communication services.

Apple has built on top of this rich Mach/BSD heritage with a number of powerful innovations, including well-defined, future-proof kernel programming interfaces (KPIs) supporting dynamically loadable file systems, network extensions, and packet filters, as well as I/O Kit drivers. Such innovations enable Mac OS X to provide a wide range of services, which include the following.

Process management

Optimized symmetric multiprocessing (SMP)

Mac OS X has always provided full SMP support for user applications as well as within the Mach subsystems. Tiger includes optimized kernel resource locking at the level of individual interfaces and buffers, minimizing the chance of threads on different processors having to block for each other. This allows users to get maximum performance from multiprocessor systems such as the Xserve G5 or Power Mac G5.

Efficient kernel threads

The Mac OS X kernel directly implements the pthreads API (from the POSIX 1003.1c standard) for efficiently handling multithreaded applications on one or more processors. Each thread is individually scheduled and migrated by the kernel, without the overhead of user-level thread libraries, minimizing CPU and memory overhead. Tiger includes full support for POSIX threads, including cancellation and synchronization.

User-level real-time support

Each thread, even an unprivileged one, can specify its exact real-time requirements. For example, a thread can request 30 out of every 200 cycles to ensure that the write buffer is always full for maximum-speed DVD burning. The kernel then monitors threads to ensure that they stay within their stated allotment, enabling the system to safely perform normal tasks during time-sensitive operations.

Semaphores

Tiger fully supports both POSIX (1003.1b) and SysV semaphores for managing resource sharing between threads and tasks, including message queues and semctl. Tiger also provides POSIX, Mach, and SysV shared memory APIs, as well as the ipcs and ipcrm command-line tools. Together, these features make it much easier to port certain classes of software from Linux or Solaris to Mac OS X.

I/O blocking

The modern kqueue/kevent APIs from FreeBSD 5 provide a scalable and flexible architecture for implementing the synchronous BSD select and SysV poll APIs, as well as the asynchronous aio APIs from POSIX.4. Mac OS X supports VNODE, PROC, SIGNAL, READ, WRITE, and now MACHPORT, and FS events, eliminating the need for time-consuming polling and making it easy for tools and services to find out about such items as changed files and network disconnects.

Virtual video RAM

To support numerous GPU integration features, Tiger maps video RAM (VRAM) onto main memory. This gives normal applications easy access to data such as textures, which are automatically mapped back into VRAM for use by the GPU. Mapping VRAM into system memory also simplifies the use of data sets larger than physical VRAM.

System data type sizes (in bytes)

Type	32-bit size	64-bit size
char	1	1
short	2	2
int	4	4
long	4	8
long long	8 ¹	8 ¹
float	4	4
double	8	8
long double	16 ²	16 ²
void *	4	8
void (*)(void)	4	8
size_t	4	8
off_t	8	8

¹Native long long operations can be enabled (from 32-bit or 64-bit mode) on the PowerPC G5.

²In Tiger, long double always defaults to 16 bytes (128-bit head-tail), compared with 8 bytes in Mac OS X Panther and earlier versions.

64-bit services

Tiger features an upgraded kernel tuned specifically for 64-bit computing and the PowerPC G5 processor.

Full 32-bit compatibility

The PowerPC chip is designed to run both 32-bit and 64-bit programs in the same instruction mode, maximizing both compatibility and performance. In addition, a 32-bit application can exchange data with a 64-bit process using sockets and shared memory for interprocess communication. A single binary can even contain both 32-bit ppc and 64-bit ppc64 binaries, so a command-line utility shared over NFS would run as 32-bit on a PowerBook G4 but 64-bit on an Xserve G5.

Full 64-bit memory addressing

Tiger processes have the option of using full 64-bit pointers for addressing virtual memory; that's equivalent to 16 exabytes, more than enough to individually address each square centimeter of Earth's surface. This is particularly useful for scientific computing and multimedia applications that need to access huge data sets.

64-bit system libraries

The standard C runtime libraries, along with other components of the system framework, have been recompiled to support 64-bit pointers. This makes it easy to build cross-platform UNIX and open source code for Mac OS X.

Optimized math

All math and vector libraries have been tuned to take maximum advantage of the new and faster math functions supported by the 64-bit G5, as well as to use multiple processors or the Velocity Engine. In addition, portions of the Accelerate framework have been extended to accept 64-bit as well as 32-bit pointers. See "Numerical libraries" on page 14 for more details.

Hardware I/O

I/O Kit is the device driver subsystem of Mac OS X. This powerful, object-oriented architecture in embedded C++ helps device manufacturers rapidly create drivers that run safely in a multiprocessing, preemptive environment. I/O Kit is specifically designed to support the dynamic plug-and-play capabilities expected by Mac users, as well as the low latencies required by video and audio applications. The driver model provides classes implementing abstractions common to all drivers, as well as specific high-level families such as IONetworkController and IOBlockStorageDevice. This makes it easy to implement SMP/real-time-safe drivers with a minimum of device-specific code. The I/O Kit user clients allow developers to manipulate drivers from application code, which in many cases avoids the need to write kernel drivers.

Key device families supported by I/O Kit include the following.

USB

Apple's groundbreaking iMac jump-started the market for plug-and-play USB peripherals in 1998. Today Mac OS X leads the industry with built-in support for USB disk drives, digital cameras, gamepads and joysticks, speakers and microphones, MIDI keyboards, and numerous inkjet printers. Thanks to this support, users may never need to download another driver.

FireWire

FireWire, based on Apple-developed technology, is an industry standard (IEEE 1394) for connecting peripheral devices to a computer or each other. By providing a high-bandwidth, easy-to-use I/O technology, FireWire inspired a new generation of portable devices such as DV camcorders, external disk drives, and digital music players like the Apple iPod. Now even faster at up to 800 megabits per second (Mbps), FireWire is also a boon to professional audio and video production. Mac OS X provides drivers that take full advantage of the hot pluggability, daisy chaining, and power management capabilities of FireWire, so most devices just work right out of the box.

Ethernet

Apple was the first personal computer company to incorporate Ethernet in all its systems and continues to aggressively adopt new Ethernet technology. Mac OS X supports Gigabit (1000BASE-T) Ethernet as well as 10BASE-T and 100BASE-T Ethernet—and even 10 Gigabit Ethernet with the appropriate card—and negotiates to the highest link speed and duplex that can be used on a given connection. Gigabit Ethernet can also make use of jumbo frames on supported cards, such as the Ethernet implementation built into the Xserve G5. Mac OS X now supports IEEE 802.3ad Link Aggregation, which combines multiple links for higher performance or interface failover.

AirPort

AirPort, Apple's innovative implementation of the 802.11 wireless networking technology, is easy to set up and use and offers unique capabilities like USB printer sharing and music streaming.* While fully interoperable with any Wi-Fi network, Apple's autoconfiguring software, easy-to-use management tools, and built-in antennas on most computers make wireless networking simple.

All of Apple's AirPort base stations are Wi-Fi Certified, supporting the high-speed IEEE 802.11g standard at up to 54 Mbps, as well as the 802.11b protocol, which provides throughput of up to 11 Mbps. All AirPort base stations offer built-in WPA and 128-bit security, as well as compatibility with RADIUS and 802.1X solutions, ensuring that only authorized users can connect with the wireless network.



Apple's AirPort technology brought Wi-Fi to the mass market.

Bluetooth

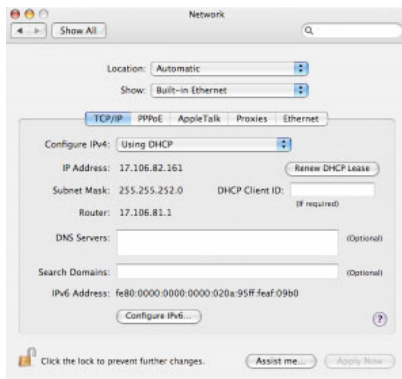
Mac OS X includes built-in support for Bluetooth devices. Bluetooth is a short-range, low-power wireless technology designed for automatic discovery of and easy access to peripherals such as the Apple Wireless Keyboard and Mouse, as well as handheld devices such as mobile phones and PDAs. It is integrated closely with Sync Services in Tiger for seamlessly sharing information between devices and one or more Mac systems.

Fibre Channel

Mac OS X provides built-in support for Apple's Fibre Channel cards, the technology of choice for high-performance storage, enabling connection to Apple's industry-leading Xserve RAID.

TCP/IP networking

Networking in Mac OS X is built entirely around industry-standard TCP/IP (Transmission Control Protocol/Internet Protocol). In addition to a robust and efficient low-level TCP/IP implementation based on the original BSD sockets code, Mac OS X provides a wide range of IP-based services.



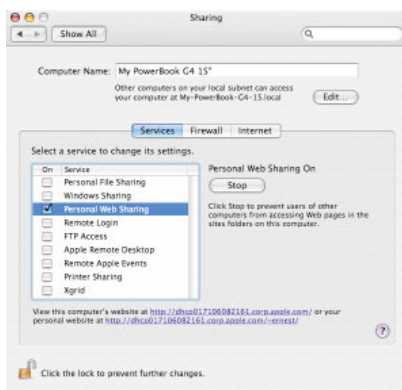
Automatic handling of both IPv4 and IPv6 addresses

IPv6

IPv6 is the next-generation, 128-bit Internet Protocol. Apple's implementation is based on the KAME open source project for BSD, ensuring that it can interoperate freely with other IPv6 hosts and routers used on cutting-edge research networks. Though IPv6 nodes automatically self-configure, the Network pane of System Preferences also gives users the option to manually inspect and manage the IPv6 address and router. Apple's low-level CFNetwork API seamlessly supports both IPv4 (today's 32-bit Internet standard) and IPv6 addresses, making it easy for developers and applications (such as Safari) to transparently support both.

Internet sharing

Support for Network Address Translation (NAT) and the Dynamic Host Configuration Protocol (DHCP) allows multiple computers to connect to the Internet through a single Mac system. This enables single-click Internet sharing of, for example, an Ethernet connection over a wireless network.



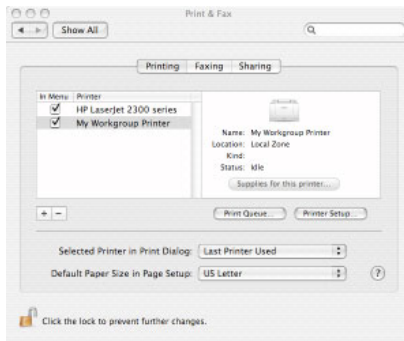
File and Internet sharing with a single click

Daemon management

Network services in Mac OS X are managed by launchd, a next-generation process launcher that replaces init, mach_init, StartupItems, and inetd/xinetd. This Apple-developed open source project provides a unified API for developers to register daemons, which can then be launched based on activity from a socket or Mach port. This approach also simplifies configuration, management, and monitoring of system and network services.

Apache HTTP

Apache is the world's most popular web server, providing reliable, high-performance delivery of both static and dynamically generated web content. Users can configure a basic Apache httpd server with a single click in Sharing preferences, or they can edit the configuration files using a text editor, as in other UNIX implementations of Apache. Both mod_perl and the PHP server-side scripting language are included with Mac OS X for easy creation of dynamic web pages and Common Gateway Interface (CGI) scripts.



Simple interface to manage comprehensive, standards-based printing capabilities

SAN file system for Mac OS X

Xsan is a high-performance, enterprise-class 64-bit cluster file system available for Mac OS X. With Xsan, users can set up a file system across one or more external storage devices, such as Apple's Xserve RAID. The file system can be shared concurrently by more than 60 Mac OS X systems using a high-speed Fibre Channel network. Each system—Power Mac or Xserve—has direct block-level access to shared storage and can access the file system as if it were its own internal disk drive. High-availability features such as metadata controller failover and Fibre Channel multipathing are built in. Easy to set up and maintain, Xsan includes powerful volume management and monitoring tools that support email and pager notifications.

Designed to support all Mac OS X and Mac OS X Server applications, Xsan can be easily integrated into managed environments that use a standard LDAPv3 directory service or Microsoft's Active Directory. It can be deployed using any Fibre Channel SCSI 3 storage supported by Mac OS X. Apple has qualified Xsan with Apple's Fibre Channel card, Xserve RAID, and Fibre Channel switches from major manufacturers including Brocade, Emulex, and QLogic. Xsan is completely interoperable with ADIC's StorNext File System so that Windows, Linux, and other UNIX systems running StorNext File System can be added to an Xsan environment.

Xsan is ideal for high-bandwidth video editing workflows, storage consolidation, and NAS replacement projects and is an affordable alternative for data management in computational clusters.

CUPS printing

Mac OS X uses a PDF-based printing architecture built entirely around the open source Common UNIX Printing System (CUPS). CUPS provides full compatibility with existing UNIX tools (lpr, lpstat) as well as secure printing via the IETF's HTTP-based Internet Printing Protocol (IPP), making it safe and easy for Windows and UNIX systems to share Mac printers and vice versa. Mac OS X not only includes hundreds of built-in, vendor-supplied raster drivers and PostScript Printer Description (PPD) files, but also works with hundreds more legacy printers thanks to the open source GIMP-Print printer driver project. The included raster image processor (RIP) even allows a Mac to export a local inkjet printer as a network PostScript printer for use by Windows computers.

File system architecture

Dynamically loaded file systems based on BSD's stackable virtual file system layer (vfs), as well as new kernel programming interfaces (KPIs), allow Mac OS X to dynamically mount, read, and write to numerous local and remote file systems, including heterogeneous networks of UNIX, Windows, and other Mac computers.

Disk file systems

Mac OS X supports a wide range of local file systems, making it easy to share files and devices with other platforms.

- **HFS+** (the default), case insensitive with support for fast Btree-based directory searches. HFS+ in Mac OS X defaults to journaling to ensure that the disk is always in a consistent state, enabling rapid recovery after emergency shutdowns. Mac OS X Server provides an option for a case-sensitive version of HFS+ to support NFS file sharing (note that use of this version may affect desktop Mac OS X applications that rely on case insensitivity).
- **UFS**, based on Berkeley FFS, with support for standard POSIX semantics and BSD DirPrefs.
- **ISO 9660**, the standard CD-ROM format.
- **UDF 2.5**, the Universal Disk Format for DVDs and DVD-ROMs.
- **FAT32**, the standard Windows interchange format.
- **NTFS** (read-only), the high-end Microsoft file system format.

Network file systems

Mac OS X includes all the most popular network file systems, making it easy to connect to virtually any server.

- **NFS** (Network File System) is the dominant file sharing protocol among UNIX variants. The Mac OS X implementation is based on FreeBSD's NFSv3 and includes lockd/statd file locking to prevent overwrites, as well as mobility support for graceful unmounting on network disconnect.
- **AFP** (Apple File Protocol), running over TCP/IP, remains the principal file sharing protocol for Mac systems due to its robust security and metadata support.
- **SMB/CIFS**, Microsoft's proprietary Server Message Block/Common Internet File System file service, is the primary file sharing protocol for Windows. Mac OS X includes Samba, the popular open source SMB server, to enable Windows users to access files on Mac computers. In addition, BSD-based SMB client support in Mac OS X gives Mac users the ability to browse and connect to Windows file servers and volumes.
- **FTP** (File Transfer Protocol) is the standard protocol used to move files between computers on TCP/IP networks. An FTP server can be activated in Mac OS X with a single click. In addition, FTP servers can be mounted as Mac OS X file systems, where they can be accessed from either the Finder or the command line.

- **DAV** (Web Distributed Authoring and Versioning) allows users to collaboratively edit and manage files on remote web servers via HTTP. Mac OS X includes the Apache `mod_dav` module, enabling it to act as a DAV server. The DAV file system, which mounts DAV servers on the desktop, has been completely rewritten to use CFNetwork and now supports SSL authentication. Tiger also provides a new API that developers can use to access .Mac iDisk volumes using DAV for storage, sharing, or syncing.

File system features

Mac OS X provides an advanced file system infrastructure designed to provide the security, scalability, and richness expected by modern applications.

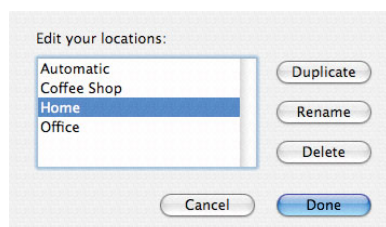
- **Extended attributes.** Tiger introduces a new level of file system sophistication with vfs-level support for extended attributes, inspired by the POSIX.2e proposal. These include `*xattr` routines to read, write, list, and delete extended attributes. Extended attributes are stored natively on HFS+ as forks and emulated on other file systems via the AppleDouble format (that is, “`._filename`”). This provides a consistent, Darwin-level API for managing resource forks, metadata, security information, properties, and other attributes.
- **Access control lists (ACLs).** The new `kauth` subsystem in Tiger provides fine-grained control of access control entries (ACEs) as first-class kernel objects, eliminating the need for uid/gid checking in favor of usage-based credential verification. System administrators can dynamically assign fine-grained access to virtually any resource (typically folders) on a user-by-user basis, rather than having to use static UNIX groups. This granularity covers permissions to:
 - Read/write/execute/append either data or extended attributes.
 - Read/write (regular) attributes.
 - Read/write security settings or change ownership.
 - Add/delete files, directories, or children.
 - Search/list directories.
- **File locking.** Mac OS X now provides unified file locking across AFP, CIFS (SMB), and NFS volumes, simplifying resharing and reducing the risk of data corruption.
- **Network home directories.** Tiger supports AFP, SMB, and NFS network home directories. Mac OS X Server now enables home folder syncing, which allows portable computers to automatically back up or update a network home directory for use even when the computer is disconnected from the network.
- **RAID.** In addition to striping (RAID 0) and mirroring (RAID 1), Apple’s built-in software RAID now supports combined 0+1 and 1+0 levels when using four or more disks, providing great fault tolerance and higher performance. Disk Utility and `diskutil(8)` also support concatenation (JBOD) and faster mirror rebuilds.

System Services

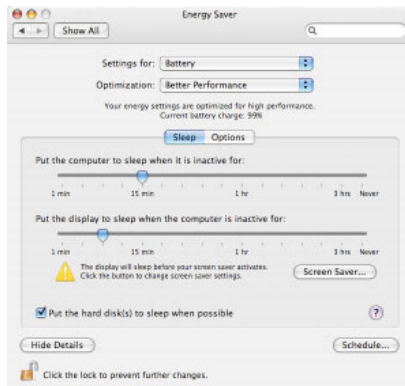
Mac OS X is designed to bring the openness and flexibility of UNIX to the mass market while ensuring a secure, user-friendly environment. Apple accomplishes this by ensuring that mobility, directory, and security features are integrated throughout the operating system, rather than being bolted on as an afterthought. The following sections describe how the new, open Mac OS X leverages industry standards to make it easier than ever to connect safely with anyone, anywhere.

Mobility

The ability to deal with constantly changing physical and network environments is one of the key features that distinguishes Mac OS X from other UNIX systems. Beneath the friendly interface for configuring and switching networks lies some very powerful infrastructure.



Easy management of multiple network locations



Self-configuring power management

Open Directory data stores

- Mac OS X Server
- OpenLDAP (LDAPv2, LDAPv3)
- Sun's SunOne Directory Server (formerly iPlanet)
- Microsoft's Active Directory
- Novell's eDirectory (formerly NDS)
- Sun's Network Information System (NIS)
- Traditional BSD configuration files (such as /etc/passwd)
- Apple's legacy NetInfo directory service

Notifications

notify is a comprehensive systemwide service for communicating both kernel-to-application and application-to-application events, which can help reduce reliance on signals and other legacy UNIX mechanisms sometimes used for this purpose. It uses the kqueue mechanism to track network and device changes.

Configuration

The unique configuration daemon configd uses notifications to help the system automatically reroute Internet traffic between wired and wireless connections whenever the user plugs in or unplugs the Ethernet cable, as well as reset other daemons as needed.

Power management

Because Mac OS X is tightly integrated with the underlying hardware, it is the first UNIX-based system in which instant sleep/wake and power minimization always "just work," without the need for manual configuration or determining which chipset is being used.

Safe disconnect

Mac OS X is the first system to gracefully mount and unmount NFS, DAV, and SMB/CIFS volumes based on changes to network status or available directory services, providing an uninterrupted experience from the GUI or the command line.

Directory services

Tiger is designed to minimize configuration effort by pulling information from a variety of sources.

Open Directory

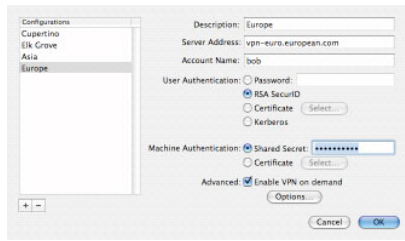
Open Directory is an extensible framework for managing authorization and configuration information for users and systems. While designed primarily for use with LDAPv2/v3 (the IETF standard Lightweight Directory Access Protocol), Open Directory is flexible enough to handle stand-alone desktop systems as well as legacy systems (see sidebar). These services can be managed using the graphical Directory Access application or the directory services command line (dscl). Apple provides an Open Directory server as part of Mac OS X Server, which uses Berkeley DB as its back end and can provide directory services to LDAP, SMB, or NetInfo clients.

Bonjour

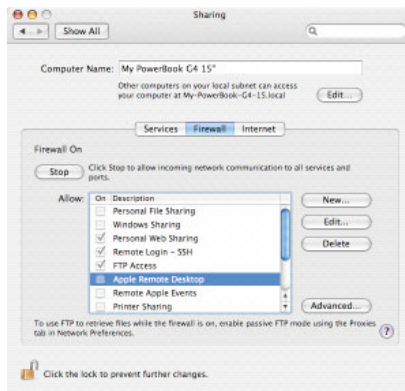
Bonjour is Apple's new name for open, zero-configuration networking standards built around multicast DNS. Bonjour makes it easy to find systems and services on a local network without requiring a network administrator. It is supported by a wide range of devices (such as printers and webcams), servers (such as Apache and ftpd), and other network-enabled services (such as ssh). It leverages existing IETF standard protocols such as DNS service discovery and is part of the IETF's ongoing standardization work via the Zeroconf Working Group. It is also available for numerous platforms as open source.

DNS (Domain Name Services)

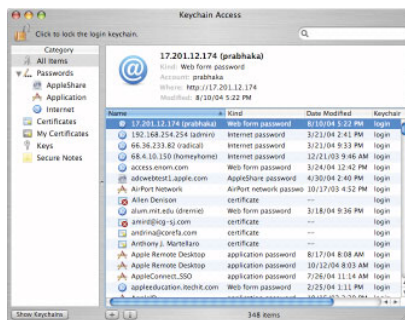
Mac OS X uses BIND 9 (Berkeley Internet Name Daemon), the standard Internet name service, for mapping DNS host names to IP addresses. Tiger and Tiger Server support Dynamic DNS updating, which uses Bonjour technology to ensure that a public host-name always resolves to a given computer no matter what physical network and IP address it may be using, as well as Secure DNS to ensure trustworthy name servers (to prevent spoofing).



Secure access to virtual private networks over L2TP/IPSec or PPTP



Protecting computers via the built-in firewall



Single place to manage passwords, certificates, and smart cards

Secure networking

To help ensure privacy and system integrity, Mac OS X delivers numerous state-of-the-art services for protecting network security.

VPN via L2TP/IPSec or PPTP

Mac OS X includes a virtual private network (VPN) client that supports the Internet standard Layer 2 Tunnel Protocol (L2TP) over IPSec (the secure version of IPv4), as well as the older Point-to-Point Tunneling Protocol (PPTP). This allows users to connect to Cisco, Microsoft, or other standards-based servers to create a secure, encrypted connection from the public Internet to a private network, such as those used in corporations and educational institutions. Tiger adds peer-based “site-to-site” VPN, avoiding the need for a centralized server when directly connecting two gateways.

SSH (Secure Shell)

Mac OS X uses OpenSSH as its default protocol for secure command-line access between computers. SSH encrypts remote command-line traffic (including passwords) to effectively eliminate eavesdropping, connection hijacking, and other network-level attacks to which rlogin and telnet are susceptible. Mac OS X includes the full suite of OpenSSH client and server functionality, including ssh (command execution), sftp (file transfer), and scp (file copies).

Built-in firewall

The built-in IP firewall, based on FreeBSD’s ipfw2, protects Mac systems from Internet hackers by closing all ports to incoming traffic—except those explicitly authorized by the user or enabled via the friendly interface in System Preferences. ipfw2 also improves auditing by logging traffic across the firewall.

Authentication

Tiger provides a state-of-the-art security infrastructure, based on modern, standards-based technologies for authenticating users and authorizing what they can do. Key technologies include the following.

Systemwide keychains

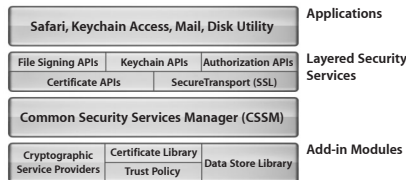
In Mac OS X, certificates and user passwords (such as those for mail accounts and websites) are stored in a secure keychain, which provides them only to verified, preauthorized applications. Keychains can be securely synced from computer to computer, and organizations can even specify a site-specific master password to ensure recoverability.

Certificates

Public key infrastructure (PKI) authentication is now integrated throughout Mac OS X. PKI keys and other X.509 certificates can be stored in smart cards, keychains, Address Book, or LDAP directories and used for iChat, IPSec-based VPN, S/MIME, document signing, and numerous other services. There’s even a lightweight Certificate Authority in Mac OS X so workgroups can establish their own local web of trust, as well as full certificate management in Mac OS X Server.

Unified authentication service

A single security daemon (securityd) processes authentication requests from both GUI and command-line applications, simplifying implementation, adoption, and auditing of new forms of authentication.



The Common Data Security Architecture is the open standard for cryptography.

Comprehensive smart card support

A new token daemon works with securityd to access smart cards and similar devices, allowing them to seamlessly participate in system and application authentication activities. Token handlers are provided for the U.S. government Common Access Cards, MUSCLE PC/SC, and pkcs-11. Tiger also supports the Government Smart Card–Interoperability Specification (GSC-IS).

Advanced cryptography technology

Mac OS X is the first and only system to integrate the Common Data Security Architecture (CDSA) standard for flexibly and safely managing strong cryptography (such as AES-128), public key infrastructure (such as OCSP, the Online Certificate Status Protocol), and secure transport (such as SSLv2/v3 and TLSv1) and user interaction (for example, approving new root certificates). Apple’s robust open source implementation is integrated with Linux Pluggable Authentication Modules (PAM) for easy two-way interoperability. Mac OS X also includes the OpenSSL security library for use by legacy open source applications, and it supports NTLMv1/v2 and NTM2 for Windows compatibility.

Kerberos single sign-on

Apple has adopted the MIT-developed, IETF-specified Kerberos protocol (v4/v5) for systemwide single sign-on—allowing users to authenticate against multiple services without retyping passwords or sending them over the network. The Kerberos clients in Mac OS X are fully compatible with Microsoft Active Directory as well as Mac OS X Server and other standards-compliant implementations.

System security

Because Internet security was a critical concern when designing Mac OS X, Apple leveraged its strengths in user experience to maximize the security of the system, while minimizing the inconvenience to, or expertise required of, ordinary users. The greatest security technology in the world is useless if users don’t understand how to use it, or worse, actively bypass it in order to get their work done. Apple works with the open source and security research communities to continue innovating in this area, so the growing Mac OS X customer base can continue enjoying its security advantage. Key features in Mac OS X Tiger include the following.

Role-based administration

Mac OS X does not require users to use the Administrator or root account to manage the system. Instead, the initial user (or other authorized user) can authenticate into the Administrator role, which allows one specific privileged operation at a time.

Network services off by default

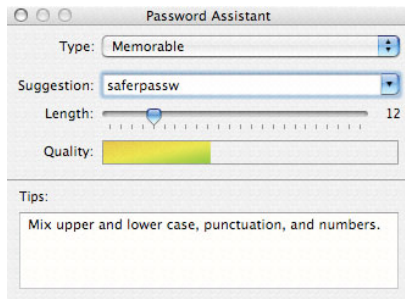
Unlike many systems, Mac OS X comes with no open ports (what is sometimes called “prehardened”). This approach avoids unnecessary exposure, yet authorized users can enable precisely the services they need with a single click.

Secure launch services

To minimize the risk of invisibly activating rogue software, Mac OS X warns users before opening mail attachments, adding new Safari handlers, downloading executables, or opening an application for the first time.

Fast user switching

As a multiuser operating system, UNIX has long made it possible to give each user his or her own account, with appropriate privileges for each user and strict separation between accounts. Mac OS X makes it convenient for any family to do the same, by making it easy to set up individual user accounts on shared computers, then quickly and safely switch between them.



Password Assistant makes it easy to discover whether new passwords are secure.

Password Assistant

To further reduce the risk of compromised accounts, Mac OS X now warns users about choosing an easily guessed password and encourages stronger alternatives.

FileVault

Users who are worried about sensitive data on their laptops can enable FileVault, which encrypts all or part of the user's home directory with government-grade AES-128 encryption. The password is securely stored in the user's keychain, which can be unlocked only by the user's personal password or a site-specific master password. In Tiger, users can even encrypt information paged out from main memory (that is, the swap file) to prevent possible data theft.

Fast, reliable security updates

While all network services are disabled by default, Apple is committed to providing rapid-response software updates to address theoretical vulnerabilities identified by CERT/FIRST or other groups. Users are periodically prompted to install these updates, which with Tiger Server can be limited to updates that are preapproved at their site. Administrators can also use Apple Remote Desktop to proactively push essential updates onto systems.

Compatible, Optimized Libraries

Mac OS X includes a robust set of standard, optimized libraries, making it easy for developers to port most existing UNIX code (POSIX, SysV, Linux, BSD, and more) to the Mac platform. In addition to the supported libraries, headers for several common open source toolkits (Tcl/Tk, OpenSSL) are available via the BSD SDK for greater compatibility. Mac OS X provides a number of enhanced APIs compared with those of traditional UNIX systems, including the following.

Application libraries

Standard C library

In addition to supporting traditional POSIX APIs, the C library provides thread-safe versions of standard I/O functions ("stdio.h"), including special reentrant versions (such as "strtok_r") where needed, providing full support for multithreaded C applications.

Internationalization

Mac OS X uses a 32-bit `wchar_t` for maximum flexibility in representing Unicode data strings, along with GNU `libiconv` for converting between different character sets. The string handling APIs now also support UNIX (POSIX) locales.

Cursor control

`ncurses` provides complete compatibility with the latest UNIX standards for cursor control, which is particularly important for editors and other full-screen applications.

Markup language processing

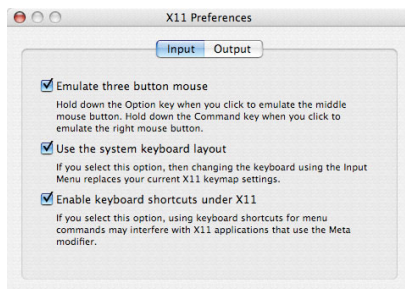
XML/HTML processing is supported via GNOME's `libxml2` and `libxslt`, which along with `libtidy` form the basis of the Cocoa NSXML APIs. The KDE project's `khtml` and `kjs` similarly form the basis of Apple's open source WebCore framework and the Cocoa WebKit, which now supports HTML editing and scriptable plug-ins. This technology also undergirds support for RSS feeds in Safari, which works with various versions of RSS, RDF, and the Atom API.



SQLite powers Core Data and several key applications.



Bundled and optimized version of XFree86



X11 integrates with the native input system, including support or emulation of multi-button mice.

SQLite

SQLite, the embedded, public domain SQL database, is now available as a framework for developers, as well as being part of the new Core Data framework in Cocoa for data modeling and automatic persistence.

Apple System Logger (ASL)

ASL, a next-generation implementation of syslog introduced in Tiger, is a unified, network-aware facility for managing the multitude of log files generated by applications and services. While providing a richer yet backward-compatible API for developers, ASL gives administrators a unified means of collecting and monitoring both local and remote logs.

Graphics libraries

Core Image

Core Image is a new graphics library from Apple designed to maximize use of the powerful graphics processing units (GPUs) on today's video cards. This library is used to provide hardware acceleration facilities for Apple's Quartz graphics on capable cards, as well as being available to applications. Core Image takes advantage of the open source libjpeg, libpng, and libgd libraries to speed up the import of very large data files in a variety of formats.

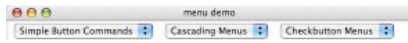
X Window System

X11 for Mac OS X includes a complete, smoothly integrated X11 Window System, enabling Mac OS X to run UNIX GUI applications side by side with Cocoa, Carbon, and Java applications. X11 for Mac OS X is primarily based on XFree86 and shares the bulk of its code with X11 on Linux, BSD, and other UNIX-based systems. Features include the following.

- **Direct Quartz integration.** X11 runs directly on top of native Core Graphics APIs and is tied directly into the native event system, for minimal overhead (reducing memory and CPU usage) and Quartz hardware acceleration (including Quartz Extreme and Exposé).
- **High-performance OpenGL.** X11 GLX applications have direct access to OpenGL direct rendering, enabling the same high-speed performance as native OpenGL applications.
- **Both rootless and full-screen mode.** Rootless mode allows X11 windows to run on the same desktop as native Aqua windows, making it easy to work with both at the same time. X11.app also provides a full-screen option that runs all X11 windows on a separate screen with an X11 root window in the background, using a hot key to switch back and forth.
- **Quartz window manager.** The Quartz window manager provides Aqua title bars and buttons for X11 windows, including fully functional close, minimize to Dock (using the Genie or Scale effect), and maximize buttons. Users can optionally install and use standard X11 window managers instead.
- **Dock menu.** The menu available from the X11 Dock icon lets users view and pick any of the current X11 windows, as well as launch additional applications defined in the user-customizable Application menu, so they can easily bring up a new or existing X11 window directly from the Dock.
- **Finder integration.** Launch Services recognizes X11 and other UNIX binaries, so double-clicking one in the Finder automatically runs the application and launches X11 if necessary.

OpenGL Utility Toolkit (GLUT)

GLUT is a cross-platform toolkit for writing OpenGL programs that supports an Aqua-compatible look and feel in Mac OS X.



Tk scripts now run natively on Mac OS X with an Aqua look and feel.

Tcl/Tk

Tk/Aqua is a native Mac OS X implementation of the most popular UNIX GUI toolkit. It enables developers to write cross-platform GUI applications using Tcl or Python that will run directly under Quartz without requiring X11 to be installed or active.

WxWidgets

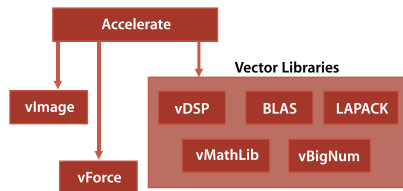
WxWidgets is a native port of the popular cross-platform GUI toolkit, including Python, Perl, and C++ bindings.

Numerical libraries

Mac OS X Tiger is designed to support a wide range of numerical computation tools for desktop and cluster supercomputing, making it possible for developers to get optimal performance without using assembly language or platform-specific coding. Tiger includes a robust suite of hand-optimized standard math libraries, as well as high-performance, state-of-the-art libraries for digital signal processing and large number operations.

While the libraries work on every Mac, they are optimized to take advantage of the 64-bit PowerPC G5 with Velocity Engine, as well as Streaming SIMD Extensions (SSE) on the new Intel-based Macintosh computers, wherever appropriate. In particular, all of the math libraries (except the low-level vDSP) accept 64-bit pointers, even with float, double, complex float and double, and long double.

Best of all, unlike the costly comparable solutions for other platforms, these libraries are included free with Mac OS X. They include the following.



Accelerate makes it easy for math-intensive code to take full advantage of modern hardware.

Optimized, C99-compliant math

The C math library in Mac OS X (integrated into libSystem) is compliant with C99 and IEEE 754, providing the fastest performance ever on the Mac for transcendental functions (including sin, cos, exp, and log), even when using standard cross-platform C code.

Extended data types

In addition to the traditional single- and double-precision libraries, Tiger supports long double and complex double functions via an extended math library (“-l mx”).

vForce

vForce is a brand-new component of the Accelerate framework designed to wring optimal efficiency from modern hardware. By specifying multiple operands at once, using computations rather than table lookups, and allowing only default IEEE exception handling, vForce maximizes CPU efficiency and minimizes data path stalling while providing data as accurate as that of traditional libraries.

Vectorized digital signal processing (vDSP)

Built-in double- and single-precision operations accelerate Fast Fourier Transforms (FFTs), convolutions, and squares. These functions allow the use of high-performance routines to manipulate audio and other signal data, without the need to write Velocity Engine assembly code or distinguish between single and double precision.

Vector image processing (vImage)

Tiger features dramatically enhanced image manipulation routines, which take advantage of the Velocity Engine wherever possible. Improvements include:

- Greatly improved general-purpose Convolution speed, with new support for special high-performance kernels
- Massively faster gamma correction
- Color space transformations (using matrix multiplication)

Vector data type sizes

C or C++ type	Count	Size	Range
vector unsigned char	16	8	0 to 255
vector signed char	16	8	-128 to 127
vector unsigned short	8	16	0 to 65,535
vector signed short	8	16	-32,768 to 32,767
vector unsigned int	4	32	0 to 4,294,967,295
vector signed int	4	32	-32,768 to 32,767
vector bool char	16	8	0 or 255 (0xFF)
vector bool short	8	16	0 or 65,535 (0xFFFF)
vector bool int	4	32	0 or 0xFFFFFFFF
vector float	4	32	IEEE ¹
vector pixel	8	16	ARGB: 1/5/5/5

¹See PowerPC Numerics at developer.apple.com/documentation/macos8/Utilities/PowerPCNumerics/powerpcnumerics.html.

UNIX environment resources

- Mac OS X Intro for UNIX Developers: developer.apple.com/unix
- Darwin open source projects: developer.apple.com/darwin
- OpenDarwin community site: www.opendarwin.org
- Terminal basics for Mac users: homepage.mac.com/rgriff/termguide.html
- OS X FAQ—Mac OS X UNIX Tutorial: www.osxfaq.com/Tutorials/LearningCenter

- Enhanced support for new image data types (16-bit signed/unsigned integer, 1555 ARGB 16-bit/pixel, 565 RGB 16-bit/pixel, 888 RGB 24-bit/pixel, 16-bit OpenEXR floating point)
- Improved Alpha compositing modes, including limited RGBA support (in addition to the existing ARGB)
- Improved memory management capabilities
- Acceptance of images that are more than 4 billion pixels wide or tall (in addition to allowing 64-bit pointers)

BLAS (Basic Linear Algebra Subprograms) Levels I, II, and III

These high-quality “building block” routines for performing basic vector and matrix operations include Level 1 BLAS for vector-vector operations, Level 2 BLAS for matrix-vector operations, and Level 3 BLAS for matrix-matrix operations. They enable optimal performance of standard, cross-platform vector and matrix mathematics, taking advantage of the Velocity Engine where possible.

LAPACK (Linear Algebra Package)

Written on top of BLAS, LAPACK provides routines for solving systems of simultaneous linear equations, least-squares solutions of linear systems of equations, eigenvalue problems, and singular-value problems. Cross-platform FORTRAN and C routines written to industry-standard LAPACK run at full native performance in Mac OS X, using the Velocity Engine where possible. In Tiger, LAPACK itself has been further tuned for float, complex float, and complex double, beyond the usual double-precision calculations.

vMathLib

These basic vectorized transcendental functions provide a version of libm optimized for the Velocity Engine, enabling users to perform standard math functions on many operands at once.

vBigNum

These basic arithmetic operations for manipulating large integers enable users to perform math operations on 128-bit integers, which is especially useful in applications such as number theory and cryptography.

Beyond the UNIX User Interface

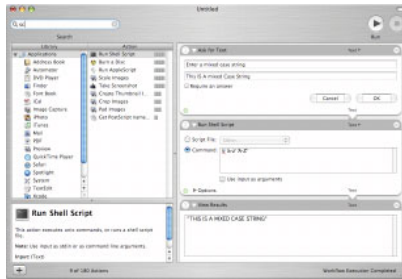
UNIX users will quickly recognize the full BSD command-line environment in Mac OS X, with the usual editors (emacs, vim, pico/nano), utilities (ls, cp, gnutar), and shells (bash (sh), tcsh (csh), zsh, and now ksh). But there’s much more to Mac OS X—not just friendly applications for productivity and the digital lifestyle, but powerful services, utilities, and tools that will improve the workflow of any command-line user.

Next-generation services

Mac OS X includes several breakthrough technologies that promise to dramatically expand the capabilities of the UNIX command line.

Spotlight

Spotlight is a radically new and lightning-fast way to find virtually anything on a computer—documents, email, images—based on their metadata (such as keywords and properties). The command-line tool `mdfind` returns a list of pathnames whose metadata matches a given string, rather like a systemwide `grep`, while `mdls` displays metadata associated with a file.



Automator is the easiest way to reuse and combine UNIX scripts, AppleScript scripts, and custom code.

Automator

Automator, an innovative graphical assistant for creating and running automated tasks, does with a GUI what the UNIX shell did for the command line. Users drag predefined tasks (which can wrap Cocoa objects, AppleScript scripts, or shell scripts) into a visual pipeline, which can be executed, saved, or shared with others. It's never been easier to reuse, combine, or publish shell scripts as graphical applications.

Xgrid

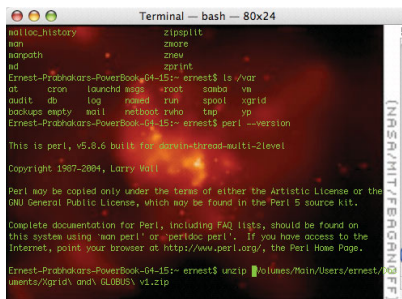
Xgrid makes it easy to run virtually any command-line program (such as a scientific computation or a multimedia renderer) on an ad hoc grid of Mac computers, using Bonjour networking and the BEEP (Blocks Extensible Exchange Protocol) open standard. Jobs can be submitted directly using the Xgrid command-line tool, or from applications using the new Cocoa API. There's also a friendly `xgridctl` for managing individual agents (which do the work) or the central controller (which manages the queues).

Quartz for Python

Quartz for Python makes the advanced power of Quartz, Apple's PDF-based graphics API, accessible directly from Python. This allows scripters to create and manipulate PDF documents and to translate between QuickTime image formats (TIFF, GIF, JPEG, and hundreds more) as well as from Cocoa document types (ASCII, RTF, HTML, DOC, WordML).

Terminal

Terminal.app in Mac OS X combines full xterm-color compatibility and VT100/VT220 terminal emulation with an innovative Aqua user interface. Terminal windows accept (and automatically escape) pathnames dragged from the Finder or the desktop, and they can use a variety of color schemes—even transparency and background pictures. Users get one-click connections to their favorite services (SSH, FTP, and so on), as well as new ones discovered by Bonjour. Terminal also supports accessibility and VoiceOver to better serve visually challenged users.

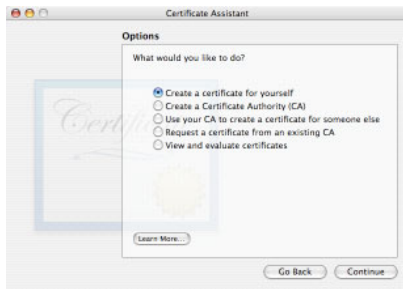


Terminal leverages Quartz and VoiceOver to provide rich access to traditional command-line tools.

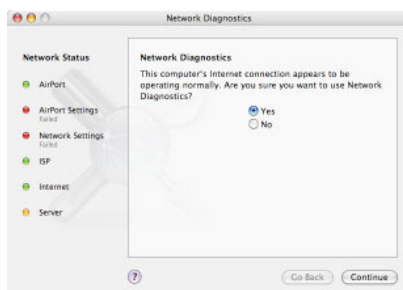
Utility applications

In addition to the dozens of rich GUI applications for end users, Mac OS X ships with several advanced applications (typically in `/Applications/Utilities`) of particular interest to developers, administrators, and UNIX enthusiasts. These applications include the following.

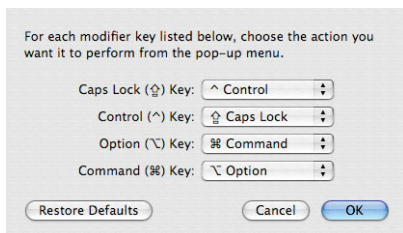
- **Activity Monitor**, which monitors CPU activity, system memory, disk activity and capacity, and network statistics, so users can easily see the impact of all the processes on the system. Activity Monitor provides a variety of different views, including transparent overlays and icon drawing, and allows users to inspect, kill, sample, and search for processes.
- **Console**, a friendly front end integrating access to the tty console, system log files, and application crash logs. Console makes it easy to view, search, and save important debugging or auditing information, without having to dig through obscure log files.
- **Disk Utility**, a simple graphical tool for creating and repairing volumes, partitions, and disk images.
- **Grapher**, a rich environment for visualizing 2D and 3D mathematical functions.



Certificate Assistant lets users create and manage a personal web of trust.



Network Diagnostics helps identify and resolve Internet connectivity issues.



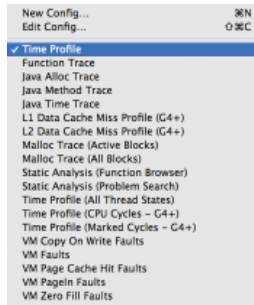
Modifier keys can be remapped to match muscle memory.

- **Keychain Access**, for managing passwords and securely storing notes, account numbers, and other confidential information. It now includes a complete Certificate Assistant, enabling easy creation of certificates for the user or an entire trusted workgroup.
- **Network Utility**, a unified graphical front end to several common diagnostic tools—netstat, ping, lookup, traceroute, whois, and more.
- **System Preferences**, for secure, user-friendly configuration of personal and system preferences. System Preferences includes location-based network services, remappable modifier keys, and hardware settings. From the Networking pane, users can access Network Diagnostics, which helps identify how the system is (or is not) connecting to the Internet and suggests possible workarounds.

Enhanced command-line tools

Mac OS X adds or improves a number of command-line tools—complete with man(1) pages—for the convenience of UNIX users. Examples include the following.

- **authopen**. Secure file opening services using the system authorization services.
- **bles**, **disklabel**, **disktool**, **diskutil**, **drutil**, **fsck**, **hdiutil**, **pdisk**. Create, identify, manage, and fix Mac OS X disks, file systems, and disk images.
- **cp**, **mv**, **scp**, **emacs**, **vim**, **pico**. Properly handle HFS+ resource forks using the new extended attribute APIs, as do archivers such as tar, rsync, gzip, bzip2, and cpio.
- **createhomedir**, **mnthome**. Create and manage home directories.
- **defaults**, **plutil**. Read and modify application defaults or other property list files in ASCII, XML, or binary format.
- **dscl**, **dsconfigad**, **dsconfigldap**, **dseditgroup**, **dsidentify**. Directory services command-line tools to manipulate Open Directory data stores.
- **fs_usage**, **latency**, **sar**, **sc_usage**. Display various system usage statistics.
- **ioreg**, **kextstat**. Show device drivers and other kernel extensions in use.
- **kadmin**, **kdb5_util**, **ktutil**. Manage Kerberos tickets, along with kinit, klist, and kdestroy and the new sso_util for single sign-on.
- **kerberosautoconfig**, **slapconfig**, **kdcsetup**. Configure the Kerberos server.
- **installer**, **packagemaker**, **softwareupdate**. Create and use Mac OS X install packages.
- **mDNS**. Diagnostic tool for testing Bonjour service discovery.
- **nvr**, **pmset**. Manage Open Firmware and power management settings.
- **open**. Invoke launch services on an arbitrary document or application, equivalent to double-clicking it in the Finder.
- **open-x11**. Explicitly set up and invoke X11.app before running a script or binary (since normal Terminal windows are not part of an X11 environment and don't have DISPLAY set).
- **osacompile**, **osalang**, **osascript**. Compile, describe, and execute any OSA-compliant script (such as AppleScript).
- **pbcopy**, **pbpaste**. Move data between stdin/stdout and the Mac OS X pasteboard.



Shark gives developers the inside scoop on what's slowing down their programs—and how to fix it.

Open source software

- Mac OS X downloads:
www.apple.com/downloads/macosx/unix_open_source
- BSD Mall:
www.bsdmall.com/darwin.html
- OpenOSX:
www.openosx.com
- DarwinPorts Ports Collection:
opendarwin.org/projects/darwinports
- Fink package management:
fink.sourceforge.net
- Gentoo Portage for Mac OS X:
www.metadistribution.org/macosx
- High Performance Computing:
hpc.sourceforge.net
- OpenOffice:
www.neooffice.org
- TeX:
www.rna.nl/tex.html
- GIMP:
www.gimp.org/macintosh

Mac OS X by the numbers

- More than 50 built-in, easy-to-use graphical applications and utilities
- More than two dozen included professional-quality GUI developer tools
- More than 1000 command-line utilities
- More than 350 Perl modules
- More than 800 Python modules
- More than 3500 man pages
- More than 3000 open source projects ported

Performance tools

Shark is the easiest way ever to profile and optimize code. It provides a rich, source-level view of application hot spots, with friendly advice on how to tune applications for optimum processor performance. Shark works like an Apple optimization expert, pointing out cache misses and inefficient execution paths and suggesting workarounds. Other performance tools enable monitoring of hardware performance counters, memory usage, drawing performance, thread contention, and resource consumption.

GNU Compiler Collection (GCC) 4.0

Debuting in Tiger, GCC 4.0 is a radically revamped implementation of the famed GNU tool suite. Working with IBM and other members of the GCC community via the publicly viewable, FSF-hosted `apple-ppc-branch`, Apple helped drive the adoption of modern compiler optimizations such as Single Static Assignment (SSA) and autovectorization, drastically improving performance while maintaining the compatibility, standards compliance, and portability for which GCC is famous. In particular, GCC 4.0 supports ISO/IEC 14882:2003 conformant C++ parsing, the LP64 data model (long and pointer are 64-bit; int is 32-bit), and 128-bit long doubles.

Distributed compilation

`distcc` is a front end to GCC that distributes building of C, C++, Objective-C, or Objective-C++ code across several computers on a network. It is integrated with Xcode and Bonjour, enabling easy distributed builds across multiple computers.

Dynamic linker

`dyld` is the dynamic link editor for loading and linking dynamic libraries written in Apple's native MACH-O format. It has been completely rewritten for more consistent handling of C++ initialization, as well as greater efficiency—largely eliminating the need for time-consuming prebinding. `dyld` now provides integrated compatibility APIs for `dlopen/dlclose` (as used on ELF systems) and supports 64-bit binaries (as does `gdb`).

Java

Xcode includes the full suite of Java compilation and debugging tools (`javac`, `rmic`, `java`, and `jdb`). Java in Mac OS X includes support for Java Advanced Imaging (JAI) and Java 3D. It also takes advantage of Quartz drawing for incredibly fast 2D drawing performance, as well as improved Xcode name completion and ant integration.

Build tools

Mac OS X ships with two versions of `make` (the default GNU `make` as well as BSD `make`), `ant` for Java projects, and the usual parsing tools (`lex`, `flex`, `yacc`, and `bison`).

For More Information

Now that you've had an introduction to the robust UNIX functionality of Mac OS X, here are several of the best web pages for finding out more about specific topics.

- Mac OS X overview: www.apple.com/macosx
- UNIX features: www.apple.com/macosx/features/unix
- Open source projects: www.apple.com/opensource
- Power Mac G5, the 64-bit professional dream machine: www.apple.com/powermac
- PowerBook G4, the world's best portable UNIX workstation: www.apple.com/powerbook
- Xserve G5, Apple's 1U rackmount server: www.apple.com/xserve
- Apple Workgroup Cluster: www.apple.com/xserve/workgroupcluster
- UNIX developer resources: developer.apple.com/unix
- Open source code releases: developer.apple.com/opensource

Mac OS X Version 10.4 Tiger: Power of UNIX, Simplicity of Macintosh

Mac OS X Tiger keeps up Apple's blazing pace of innovation with more than 200 breakthrough new features, including Spotlight, a revolutionary new way to find files and information on personal computers; Safari RSS, a new version of Apple's innovative web browser that provides instant access to the most current RSS information on the web; Dashboard, a dazzling new way to quickly get in and out of a collection of new all-purpose "widgets"; and iChat AV multiway video and audio conferencing, the industry's first consumer solution with a stunning 3D interface.

For More Information

For more information about Mac OS X Tiger, visit www.apple.com/macosx.

*Wireless Internet access requires an AirPort Card or AirPort Extreme Card, base station or other wireless access point, and Internet access (fees may apply). Some ISPs are not currently compatible with AirPort. Range may vary with site conditions. Achieving data rates up to 54 Mbps requires that all users have an 802.11g-enabled computer and connect to an 802.11g access point. Actual speed will vary based on range, connection rate, site conditions, size of network, and other factors.

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