Mac OS X for UNIX Users

The power of UNIX with the simplicity of Macintosh.

Features

Open source, standards-based UNIX foundation
- Based on FreeBSD 5 and Mach 3.0
- Support for POSIX, Linux, and System V APIs
- High-performance math libraries, including vector/DSP and PowerPC G5 support
- Optimized X11 window server for UNIX GUIs
- Open source code available via the Darwin project
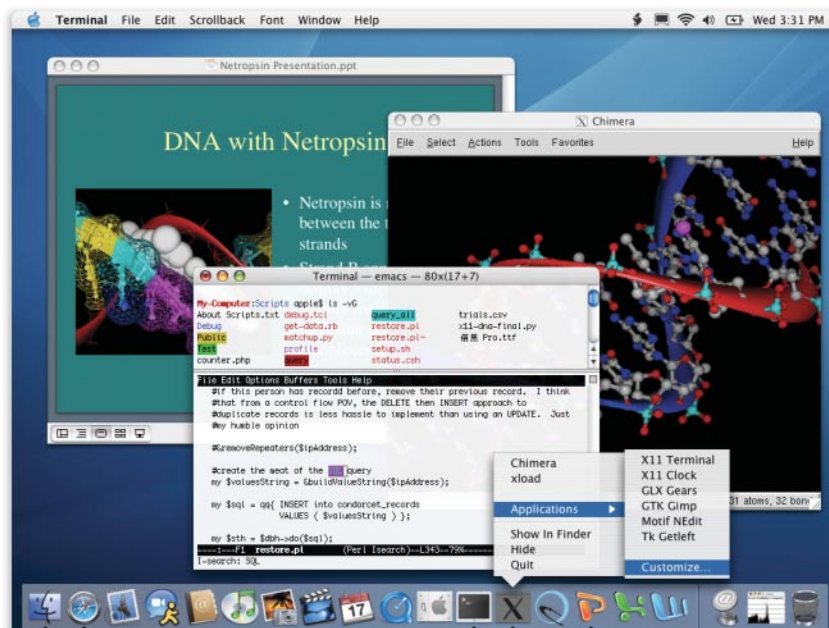
Standards-based networking
- Open source TCP/IP-based networking architecture, including IPv4, IPv6, and L2TP/IPSec
- Interoperability with NFS, AFP, and Windows (SMB/CIFS) file servers
- Powerful web server (Apache)
- Open Directory 2, an LDAP-based directory services architecture
- Single sign-on based on MIT Kerberos

Familiar UNIX environment
- Terminal emulation with full xterm-color functionality, including VT220 and Unicode support
- Terminal application featuring transparency and drag-and-drop
- Comprehensive set of UNIX/Linux utilities (including emacs, vim, gnutar)
- Comprehensive set of scripting languages (including bash, Perl, PHP, Python, tcl, Ruby)
- Bundled GCC 3.3 compiler for fast compilation and execution of C, C++, and Objective-C source
- Rich set of command-line C, Java, and UNIX build tools (including make and distcc)

Mac OS X version 10.3 "Panther" combines a robust and open UNIX-based foundation with the richness and usability of the Macintosh interface, bringing UNIX technology to the mass market. Apple has made open source and standards a key part of its strategy and delivers an operating system built on a powerful UNIX-based foundation that is innovative and easy to use.

There are over 8.5 million Mac OS X users, including scientists, animators, developers, and system administrators, 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. For notebook computer users, Mac OS X delivers full power management and mobility support for Apple's award-winning PowerBook G4.

| System Applications |
| User Interface |
| Application Frameworks |
| Graphics and Media |
| System Services |
| Operating System Foundation |

Apple and open source

The core of Mac OS X, Darwin, is an open source project, similar to projects like BSD, Linux, Sendmail, Apache, and Perl, which embody the spirit and power of the open source model. Apple is committed to working with Mac OS X developers and the open source community to enhance Darwin. By pooling its expertise with the open source development community, Apple improves the quality, performance, and feature set of Mac OS X software.

You can find the latest Darwin source code at developer.apple.com/darwin. This site also contains other open source projects from Apple, such as Rendezvous, CDSA, X11 for Mac OS X, and WebCore. In addition, developers can participate in the community-based OpenDarwin project at www.opendarwin.org.

Mac OS X Architecture

Mac OS X has a modular architecture built around four major components: the Aqua user interface, a diverse suite of application frameworks, standards-based graphics systems, and the Darwin foundation.

Aqua

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.

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 who have moved their applications from Mac OS 9 to Mac OS X.

- **Java 2 Standard Edition** v1.4.1 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

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 2D.** This high-performance graphics rendering library, based on Adobe's cross-platform Portable Document Format (PDF) standard, is the primary Mac OS X imaging model. Quartz 2D displays and prints high-quality, anti-aliased text and graphics and provides industry-leading support for OpenType, PostScript, and TrueType fonts.

- **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 enables high-end 3D graphics. Darwin boosts the performance of OpenGL on Mac OS X, making it the ideal platform for 3D animations and special effects.

- **QuickTime.** Apple's cutting-edge digital media software provides a fully standards-based environment for creating, playing, and delivering video (MPEG-4), audio (AAC, or Advanced Audio Coding), and images (JPEG 2000, GIF, Animated GIF, and many more formats).

Darwin

Beneath the easy-to-use interface and rich graphics of Mac OS X 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, networking, and command-line utilities described in the following pages.

UNIX enhancements in Panther

Kernel
- BSD environment updated to FreeBSD 5
- 64-bit support in the kernel for more than 4GB of physical memory
- New system notifications built around BSD kqueue/kevent

File systems
- UFS with DirPrefs support, for performance approaching that of HFS+
- Greatly improved NFS performance and stability (including lockd/statd)
- Samba 3.0, with internationalization support

Libraries
- Math libraries enhanced for image processing and PowerPC G5
- UNIX internationalization support (wchar_t, ICU, libiconv)
- Additional POSIX/Linux APIs (asynchronous I/O, poll, dlopen, libxml2)
- X11 window server with native performance, friendly GUI, and Aqua-compatible window manager

Networking
- IPv6 support throughout, including Safari, Preferences, and Cocoa/Carbon APIs
- New L2TP/IPSec VPN client
- Integrated NIS and Active Directory support in Open Directory
- Integrated MIT Kerberos for single sign-on, including Active Directory compatibility

Environment
- New utilities including vim, gnutar, and srm for secure deletion
- GIMP-Print drivers for even broader printer support
- Finder integration allowing double-click launch of utilities and X11 applications
- Enhanced Terminal application featuring function-key remapping and Connect To menu for Rendezvous and favorite servers
- New Activity Monitor for monitoring CPU, memory, network, and disk usage

Development
- Updated scripting languages (Perl 5.8.1, Python 2.3, tcl 8.4.2, PHP 4.2.3)
- Script-based access to Quartz using sips command-line tool and Python CoreGraphics bindings
- GCC updated to version 3.3, integrated with distcc for distributed builds

Kernel

The Mac OS X kernel at the heart of Darwin is based on FreeBSD and Mach 3.0. The open source FreeBSD (developed at the University of California, Berkeley) distribution is one of the most widely used UNIX implementations available today. This BSD implementation provides Mac OS X with the stability, performance, and compatibility associated with UNIX. Apple has enhanced BSD by adding Mach 3.0 technology based on the OSF/mk microkernel from the Open Software Foundation. Mach services for memory management, thread control, hardware abstraction, and interprocess communication enable the Mac OS X kernel to provide a number of advanced features, including:

- **Fine-grained multithreading.** The Mac OS X kernel provides superior thread management, for efficient handling of multithreaded applications whether the threads are running on one or multiple processors. It also provides precise control of real-time requirements. For example, when a user burns a DVD, the kernel thread-handling features ensure that the data-burning thread always has just enough cycles to keep the write buffer filled while the computer continues to perform other tasks. Mac OS X implements POSIX threads using true kernel threads rather than user threads, so each thread can be scheduled independently for maximum efficiency.

- **Support for symmetric multiprocessing (SMP).** Mac OS X automatically harnesses both processors in dual processor Macintosh systems, so all applications benefit from the higher performance added by the second processor. Complex tasks such as image transformations, video compression, and audio encoding operations can take a long time to complete when they're done consecutively. With both processors working in parallel, two tasks can be performed in little more than the time it takes to complete each task on a single processor. Because Mac OS X is multithreaded, users benefit from multiple processors even with applications that do not take advantage of the multiple threads.

- **A unified buffer cache** enables the file system and virtual memory subsystem to share kernel buffers. As with most UNIX systems, physical memory and on-disk files are both automatically mapped into 4GB of virtual memory per process. This design uses a single backing mechanism for both, minimizing disk access and the use of wired kernel memory.

- **64-bit kernel services.** Panther features a redesigned kernel and updated system software math libraries specifically for the 64-bit PowerPC G5 processor. The updated kernel delivers the most substantial benefits of 64-bit computing by breaking through the 4GB physical memory limit. The key functions of the system math and vector libraries have been tuned to take maximum advantage of new and faster math functions supported by the 64-bit G5. Moreover, unmodified applications that use the system math functions will get an automatic performance boost on the G5. The PowerPC chip was architected from the beginning to run both 32-bit and 64-bit applications without the need for emulation or translation software. This means that 32-bit applications that run on Mac OS X today will run natively on 64-bit PowerPC G5 processor–based Macintosh computers, without the need for recompiling or additional optimizations.

- **System notifications** are a comprehensive systemwide service ("notify.h") for communicating both kernel-to-application and application-to-application events. These incorporate the BSD kqueue/kevent mechanism, specifically the VNODE, PROC, SIGNAL, READ, and WRITE events. Kernel-based notifications provide the opportunity for significant performance gains, by 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.

- **The I/O Kit** is the device driver subsystem of Mac OS X. This powerful, object-oriented architecture helps device manufacturers rapidly create drivers that run safely in a multiprocessing, preemptive environment. It's specifically designed to support the dynamic plug-and-play capability expected by Mac users, as well as the low latencies required by video and audio applications. The I/O Kit provides a set of C++ classes implementing object-oriented 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 also allows developers to manipulate drivers from application code, which in many cases avoids the need to write kernel drivers.

- **Mobility** includes sophisticated power management and the ability to respond to network status changes automatically. 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. This integration helps the system automat-ically reroute Internet traffic between wired and wireless connections when the user plugs in and unplugs the Ethernet cable. The system is also the first 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 either the GUI or the command line.

- **Loadable file systems** based on BSD's stackable virtual file system layer (vfs) allow Mac OS X to dynamically mount, read, and write to numerous local file systems, including:
  - **HFS+** (the default), case insensitive with support for fast Btree-based directory searches. HFS+ in Panther supports journaling to ensure that the disk is always in a consistent state, enabling rapid recovery after emergency shutdowns.
  - **UFS,** based on Berkeley FFS, with support for standard POSIX semantics. UFS in Panther includes BSD DirPrefs support and other enhancements for greatly improved performance, approaching that of HFS+.
  - **ISO 9660,** the standard CD-ROM format.
  - **UDF,** the Universal Disk Format for DVDs.
  - **FAT32,** the standard Windows interchange format.
  - **NTFS** (read-only), the high-end Microsoft file system format.

Libraries

Mac OS X provides a robust set of optimized libraries, making it easy to port your existing UNIX code.

Core libraries

- **A standard, multithreaded C library (libc)** that includes support for such capabilities as reentrant variants of standard functions (such as strtok_r), easing the porting of thread-aware applications to Mac OS X.

- **POSIX API support,** including POSIX thread signaling (such as pthread_kill, pthread_cancel) and I/O (such as pread/pwrite), for easy porting of POSIX applications. Panther includes an in-kernel implementation of the asynchronous input/output APIs (aio_*) defined in the POSIX.4 standard, which simplifies porting of applications that receive input and output on different threads. This is particularly important for high-performance applications such as databases.

System datatype sizes

char	1
short	2
int	4
long	4
long long	8[1]
float	4
double	8
long double	8[2]
void *	4
void (*)(void)	4
size_t	4
off_t	8

[1]Native long long operations can be enabled on the PowerPC G5 as described in the "Developer Tools" section.
[2]The size of long doubles may change in the future, so avoid code that relies on this assumption.

- **Internationalization.** The wide character datatypes (wchar_t and others) are a standard way for UNIX scripts and programs to support non-Roman character sets such as Unicode, which may contain more than 8 bits per character. GNU libiconv is an open source, cross-platform version of iconv (the standard UNIX function for converting between different local text encodings), which also supports converting to and from Unicode. This is especially important for open source applications like Samba that have added internationalization support. The International Components for Unicode (ICU) provide robust, full-featured services for analyzing, comparing, and transforming Unicode text strings. Together with iconv and wchar_t, ICU makes it easy to port internationalized versions of open source software to Mac OS X.

- **UNIX/Linux portability APIs,** including System V semaphores, make it easy to port applications from System V–based versions of UNIX such as Linux and Solaris. Panther emulates the System V *poll* system call on top of BSD's native *select* API, and the *dlopen/dlclose* dynamic library access routines—used with Executable and Linking Format (ELF) binaries on Linux, BSD, and other operating systems—on top of the native Mach-O format used on Mac OS X. With these routines available on Mac OS X, developers of cross-platform UNIX applications can port libraries and applications to Mac OS X with little or no change to their existing applications.

X11 windows can run side by side and overlap with Aqua windows.

- **X11 for Mac OS X** provides a complete X11 Window System as an optional installation for Panther, enabling Mac OS X to run UNIX GUI applications side by side with Cocoa, Carbon, and Java applications. X11 for Mac OS X is a complete X11R6.6 implementation corresponding to XFree86 4.3, the same open source project used for X11 on Linux, BSD, and other UNIX-based systems. Features include:
  - **Direct Quartz integration.** X11 runs directly on top of native CoreGraphics 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, for 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. Panther 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.** Provides Aqua title bars and buttons for X11 windows, including fully functional close, minimize to Dock (using Genie or Scale), 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 you view and pick any of the current X11 windows, as well as launch additional applications defined in the user-customizable Application menu, so you 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.

- **GLUT (OpenGL Utility Toolkit)** is a cross-platform toolkit for writing OpenGL programs that supports an Aqua-compatible look and feel on Mac OS X.

- **Extensive security APIs,** including common UNIX security APIs such as PAM, pkcs-11, and md5, make it possible to port and integrate secure versions of UNIX utilities into Mac OS X to improve system security.

- **The BSD SDK** contains popular UNIX libraries and headers (including Perl, Python, tcl, and libxml2) that help you compile many common UNIX applications right out of the box.

Numerical computing resources

Languages

- IBM's xlf FORTRAN compiler:
www.ibm.com/software/awdtools/fortran/xlfortran
- GNU g77 FORTRAN compiler:
hpc.sourceforge.net
- NAGWare f95 compiler:
www.nag.com/nagware.asp
- Absoft Pro Fortran:
www.absoft.com/newosxproductpage.html
- PSR/Veridian VAST Optimizer:
www.psrv.com
- Perl Data Language:
pdl.perl.org
- Numerical Python (NumPy):
numpy.sourceforge.net

Environments

- Mathematica:
www.wolfram.com/products/mathematica
- MATLAB:
www.mathworks.com
- LabVIEW:
www.ni.com/mac
- SPSS:
www.spss.com/spssbi/spss_mac
- JMP Discovery:
www.jmp.com
- The R Project:
cran.r-project.org
- Stata:
www.stata.com

Clustering/Grid computing

- Platform LSF:
www.platform.com/products/index.asp
- SGE (Sun's Grid Engine):
wwws.sun.com/software/gridware/sge.html
- Pooch (based on UCLA's AppleSeed):
www.daugerresearch.com
- MPICH (message-passing API standard):
www.sdsc.edu/~tkaiser/mac_stuff/mpi_osx.html
- OpenPBS:
www.openpbs.org

Numerical libraries

Mac OS X Panther is designed to support a wide range of numerical computation tools for desktop supercomputing, making it possible for developers to get optimal performance without using assembly language or platform-specific coding.

Panther includes a robust suite of hand-optimized standard math libraries, plus high-performance, state-of-the-art libraries for digital signal processing and large number operations. While the libraries work on every Macintosh, they are optimized to take advantage of the 64-bit PowerPC G5 and the Velocity Engine wherever appropriate. Best of all, unlike the costly comparable solutions for other platforms, these libraries are included free with every copy of Mac OS X. They include the following:

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

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

- **Vector image processing (vImage).** A built-in collection of basic image processing filters such as Convolution, Morphological, and Geometric transforms is included. Alpha compositing and histogram operations are also supported.

- **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 you to perform standard, cross-platform vector and matrix mathematics with optimal performance, 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 on Mac OS X, using the Velocity Engine where possible.

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

- **vBigNum.** These basic arithmetic operations for manipulating large integers enable you to perform math operations on 128-bit integers, which is especially useful in applications such as cryptography.

Networking

Panther supports popular networking and file system standards, allowing Macintosh computers to fit easily into any computing environment.

TCP/IP

Networking in Panther is based primarily on Internet standard TCP/IP protocols. Specifically, Panther networking is built on a full BSD TCP/IP stack—the same networking technology the Internet is built on.

Important networking capabilities in Mac OS X include the following:
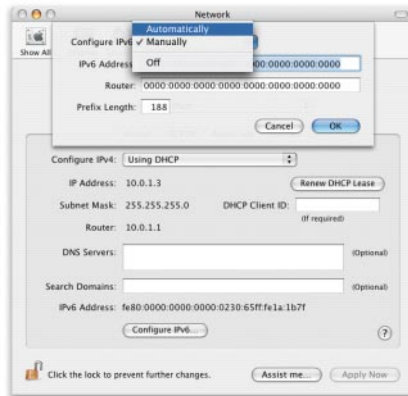
Inspect and manage 128-bit IPv6 addresses.

- **IPv6,** 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. Although IPv6 nodes automatically self-configure, the Network pane of System Preferences enables you to both inspect and manage the IPv6 address and router. Apple's low-level CFNetwork API seamlessly supports both IPv4 (today's Internet standard) and IPv6 addresses, which means that high-level applications like Safari can easily access hosts on an IPv6 network.

- **DNS** (Domain Name Services), the standard Internet service for mapping host names to IP addresses. Mac OS X implements DNS services using BIND 9, the Berkeley Internet Name Daemon.

- **DHCP.** Support for the Network Address Translation (NAT) protocol and the Dynamic Host Configuration Protocol (DHCP) allows multiple computers to connect to the Internet through a single Macintosh system.

- **inetd.** This Internet "super-server" listens for connections on certain sockets. When a connection occurs, inetd decides which service the socket corresponds to and invokes the appropriate program to service the request. inetd reduces system loads by eliminating the need to have many different daemons running to detect incoming requests.

- **Rendezvous** is a powerful, standards-based protocol developed by Apple that makes it easy to find systems and services on a local network without requiring a network administrator. Rendezvous 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 (Internet Engineering Task Force) standard protocols such as DNS service discovery and is designed to fit seamlessly into today's IP-based networks. Rendezvous is part of the IETF's ongoing standardization work; Apple has submitted Rendezvous as a Working Draft to the IETF's Zeroconf Working Group and released it both as an open standard and as open source for use on other platforms.

File sharing

Mac OS X enables Macintosh systems to seamlessly share file systems with heterogeneous networks of UNIX, Windows, and other Macintosh computers. Mac OS X can act as either a client or a server for the following file system protocols.

- **NFS (Network File System)** is the dominant file sharing protocol among UNIX variants. The Panther 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. The current version features reduced process counts (especially when idle) and 16K read/write buffers for greater throughput, for performance comparable to that of other UNIX clients. Directory-based NFS share points (including those from NIS) even show up under /Network in the Finder.
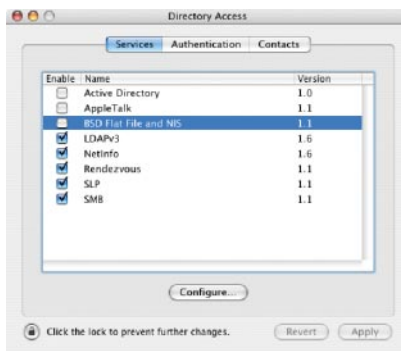
Enable file and Internet sharing with a single click.

- **AFP (Apple File Protocol),** running over TCP/IP, remains the principal file sharing protocol for Macintosh systems.
- **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 bundles Samba, the popular open source SMB implementation, to enable Windows users to access files on Macintosh computers. In addition, the BSD-based SMB client support in Mac OS X gives Macintosh users the ability to browse and connect to Windows file servers and volumes.

Internet sharing

With its powerful Apache web server and other essential Internet services, Mac OS X is the platform of choice for developing and serving Internet content.

- **HTTP.** Apache is the world's most popular web server, providing reliable, high-performance delivery of both static and dynamically generated web content. Mac OS X includes a fully native port of the standard Apache (httpd) server, providing Apache performance better than or equal to that of any other system in its class. Users can configure a basic Apache server with a single click in Sharing preferences, or they can edit the configuration files using a text editor, similar to 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.
- **WebDAV.** Web Distributed Authoring and Versioning (WebDAV) allows users to collaboratively edit and manage files on remote web servers via the HTTP protocol. Mac OS X includes the Apache mod_dav module, enabling it to act as a WebDAV server; and a WebDAV file system, allowing it to mount other WebDAV servers on the desktop.
- **FTP (File Transfer Protocol).** FTP is the standard protocol used to move files between computers on TCP/IP networks. An FTP server can be activated on 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.

Open Directory

Open Directory is Apple's directory services architecture built around LDAP, the IETF standard Lightweight Directory Access Protocol. Open Directory enables a computer running Mac OS X to authenticate users, find their home directories on the network, and provide file and print services using a centralized directory server. The Open Directory client is designed to use LDAP v2/3 and can be extended to work with legacy directories, allowing it to access data from services such as:

Easily configure access to multiple directory services.

- **OpenLDAP** (the open source LDAP server)
- 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 **NetInfo**

These services can be manipulated using the Directory Services command line, dscl. Apple also 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 over either LDAP or NetInfo protocols.

Network security

Mac OS X is the first operating system designed for the Internet. Apple has built proven security techniques into the core operating system from the start, where they can protect both client and server systems. As a result, users need not be security experts to run a secure system.

· **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 (and potentially other authorized users) authenticates into the Administrator role, which allows the user to perform one specific privileged operation at a time.

· **Network services turned off by default.** Unlike many systems, Mac computers are shipped with all ports closed (sometimes called "prehardened"). This approach avoids unnecessary exposure resulting from open network ports, while allowing authorized users to enable the services they need with a single click.

· **Fast, reliable software updates.** To ensure that Mac OS X users are always running the most secure systems possible, most services are turned off by default. However, in the event that a security patch is necessary, Apple provides rapid-response software updates to address CERT/FIRST alerts and other security concerns. The user is prompted to install these updates after connecting to the Internet.

Securely access Virtual Private Networks.

· **VPN via L2TP/IPSec or PPTP.** Panther 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.

· **Kerberos single sign-on.** Kerberos is a network authentication protocol designed to provide strong authentication for client/server applications by using encryption keys. With Kerberos, authorized users can securely access multiple network services without repeatedly typing in their passwords. A full implementation of the MIT Kerberos client authentication services allows Mac OS X to participate on secure networks protected by Kerberos v4 and v5 servers. In addition to a kerberized login, Mac OS X includes kerberized applications such as Samba, Mail, ftp, ssh, telnet, and the AFP client. The Kerberos clients in Mac OS X are compatible with those in Microsoft Active Directory and Mac OS X Server.

· **Firewall.** The built-in firewall in Mac OS X, based on FreeBSD's ipfw, protects a Macintosh system from Internet hackers by sealing off its vulnerabilities. To provide a high level of security right out of the box, the firewall closes all ports by default. Ports that are subsequently opened can be filtered by the firewall to ensure that the system is not compromised. The firewall is easy to use; it has simple on/off checkboxes and human-readable names and can be managed in System Preferences.

Protect your computer via the built-in firewall.

· **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).

The Common Data Security Architecture is the open standard for cryptography.
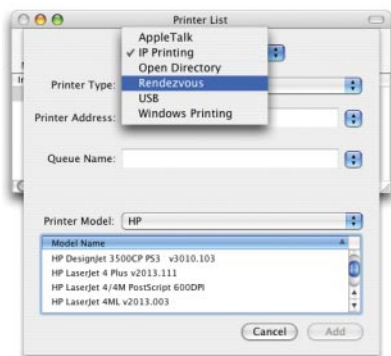
- **CDSA.** Mac OS X uses the Common Data Security Architecture (CDSA), an open standard from the Open Group, to provide a foundation for strong cryptography and a public key infrastructure. Apple created the first industrial-strength open source implementation of CDSA, and Mac OS X is one of the first major operating systems with CDSA built in. CDSA provides a layered set of security services, as well as a cryptographic framework for creating security-enabled applications, including support for Secure Sockets Layer (SSL) v2/v3 and Transport Layer Security (TLS) v1. Apple also includes OpenSSL, a security library for use by legacy open source applications.

- **PAM.** Mac OS X integrates the Linux Pluggable Authentication Modules (PAM) into Apple's CDSA architecture, allowing UNIX applications to access CDSA services through a PAM API.

CUPS printing

Mac OS X features a comprehensive, standards-compliant printing architecture based on the open source Common UNIX Printing System (CUPS v1.1)—making it easy to render documents faithfully on a wide range of printers. CUPS is also the standard API for new printer drivers on Mac OS X. Features include:

- **PDF printing.** Mac OS X applications can print directly to PDF, which is based on the same imaging model as PostScript. This ensures that what users see on the screen is what they get on the printed page.

- **Internet Printing Protocol (IPP).** CUPS uses the IETF's Internet Printing Protocol, based on HTTP, to provide remote print spooling services. Mac OS X systems can print to any IPP-enabled print spool, and they provide IPP spooling on port 631 to local printers when Printer Sharing is selected in Sharing preferences.

Mac OS X features comprehensive, standards-based printing.

- **UNIX compatibility.** In addition to full GUI-based printing services, CUPS allows users to print files using traditional BSD (lpr, lprm, lpc) and SysV (lp, cancel, lpmove, lpstat) commands. It also accepts lpd print spooling requests.

- **Broad printer support.** Panther includes hundreds of built-in, vendor-supplied raster drivers and PostScript Printer Description (PPD) files, supporting the most popular printers from manufacturers including Brother, Canon, Epson, HP, Lexmark, and Xerox. In addition, Panther includes the open source GIMP-Print (v4.2.5) printer driver project, which supports hundreds of devices not supported on Mac OS X by their vendors.

Communications

Mac OS X provides connectivity to both wired and wireless networks through Ethernet, AirPort, and Bluetooth.

- **Ethernet.** Mac OS X supports Gigabit (1000BASE-T) Ethernet as well as 10BASE-T and 100BASE-T Ethernet. It determines and defaults to the highest speed that can be used on a given connection. It also supports Jumbo frames for Gigabit Ethernet on PCI cards.

- **AirPort.** AirPort, Apple's implementation of the 802.11 wireless networking technology, is easy to set up, easy to use, and inexpensive. It lets users get on the Internet from almost anywhere in their home, school, or office—without cables, additional phone lines, or complicated networking hardware. AirPort enables wireless communications within a radius of approximately 150 feet from a base station. Apple's AirPort Extreme Base Stations support both the widely used Wi-Fi Certified 802.11b protocol, providing data transfer at up to 11 megabits per second (Mbps), and the cutting-edge IEEE 802.11g standard at up to 54 Mbps. Best of all, since 802.11g is compatible with 802.11b, AirPort Extreme–enabled Mac systems automatically use whichever version is available.*

· **Bluetooth.** Panther includes support for Bluetooth software and hardware. Bluetooth is a short-range, low-power wireless technology designed for automatic discovery of and easy access to handheld devices such as mobile phones and PDAs.

Command-Line Environment

UNIX users will quickly recognize the robust UNIX environment that underlies Mac OS X. That environment is accessible at any time from the Terminal application, which ships in the /Applications/Utilities folder with every copy of Mac OS X. You can also run commands that don't require arguments (such as top) by double-clicking them in the Finder (use "defaults write com.apple.finder AppleShowAllFiles –boolean yes" to show the hidden UNIX folders). With the thousands of man pages included in Mac OS X, you can quickly find all your favorite UNIX tools.

UNIX utilities and scripting languages

All of the standard UNIX utilities and scripting languages are included in Mac OS X: editors such as emacs, vim, and pico; file management tools such as cp, mv, ls, and gnutar; shell scripts including bash (the default shell), tcsh (csh), and zsh; and scripting languages such as Perl, PHP, tcl, Ruby, and Python.

Quartz for UNIX

Panther includes a number of powerful services to make the industry-leading graphics support in the Mac accessible to UNIX tools, including:

· **pstopdf,** which converts complex PostScript documents to easily viewable and fully portable PDF. pstopdf provides command-line access to the built-in Adobe Raster Image Processor (RIP), which converts PostScript and EPS files to PDF.

· **sips,** a command-line tool for manipulating color profiles. sips is a front-end to the AppleScript Scriptable Image Processing Server, which manipulates International Color Consortium (ICC) profiles for ColorSync. It also supports basic image manipulation, such as rotate, scale, crop, and more.
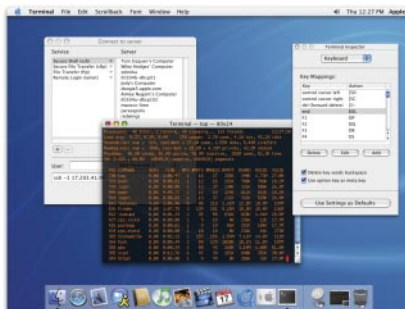
In addition, Panther provides CoreGraphics bindings for Python—a new approach for command-line scripts and server processes to manipulate graphics. This rich set of Python bindings was created using the open source WIG interface compiler (Simplified Wrapper and Interface Generator, for creating scriptable APIs from C functions). It can access the PDF-based Quartz graphics engine and QuickTime image formats (such as PNG, JPEG, TIFF, GIF), as well as some Cocoa renderings. The scripts can perform complex manipulations on PDF and images, such as:

· Render PDF, HTML, and RTF documents into a bitmap (implicitly using the Cocoa NSText and WebKit) that could be streamed from the server to the client (for example, new images for different zoom levels—useful for maps).

· Add content to a specific page in a PDF document.

· Use HTML forms that feed their input through Python to generate a PDF, for a receipt or invoice of the entered data.

· Generate an n-up printed preview of a multipage PDF document.

· Create a single image or a PDF document as an index print from multiple original images.

· Remove or add color profiles to images (like sips).

· Soft-proof images by applying an ICC profile.

Terminal emulation functionality

Mac OS X terminal emulation is equivalent to xterm-color, the most popular UNIX terminal. Mac OS X includes support for:

· **VT100/VT220 emulation** for cursor control, animation, and drawing.

· **Unicode (UTF-8) and VT220 fonts** to enable the display of multiple languages and special characters, including tall and wide characters.

· Input and display of **multibyte and bidirectional fonts.**

· **Standard escape sequences** that set ISO-6429 colors, highlighting, and blinking.

· **Color-enabled utilities,** for example, "ls –G" for color-coded file listings.

Terminal application

This terminal emulation functionality is implemented in the Mac OS X Terminal application, which makes the command line more versatile than ever. With Mac OS X, command-line users can enjoy a rich Aqua experience through these and other features:

· **Connect To Server menu** (in the File menu) lets you browse and connect to servers for ssh, sftp, ftp, telnet, and additional user-defined protocols. Terminal displays Rendezvous-enabled services on the local network, and you can store your own favorite network services for easy access.

· **Function-key remapping** uses the Keyboard Inspector to redefine the character codes emitted by function keys (F10, Home, Enter). There are also checkboxes to map Del to Backspace and to use Option as the meta-key, making it more convenient to access older applications and servers.

· **Drag-and-drop copying** enables you to drag text from one window into a clip file, another window, or a different application—without having to touch the keyboard. You can even drag files onto a Terminal window from the Finder and have the pathnames properly quoted.

· **Color support** enables you to set the default color of the background, text, selection, or cursor, for optimum readability. You can also set a background image, or even make the background transparent so you can watch other applications behind it while working at the command line.

· **Split-view scrollback** lets you view the entire history of the terminal session while entering new text.

· **Fine-grained font control** allows you to turn anti-aliasing on and off and adjust character and line spacing for optimum readability.

Terminal provides advanced connectivity options.

New Activity Monitor application

The new Activity Monitor in /Applications/Utilities monitors CPU activity, system memory, disk activity and capacity, and network statistics, so you can easily see all processes on your system. Activity Monitor provides a far more comprehensive process view than ever before available:

· The **table view** shows application icons, the number of threads, and the real memory used, with the optional hierarchical view showing processing ownership.

· An **Inspector** shows additional memory and resources statistics, including open files.

· The **customizable toolbar** sports a dynamic search filter, with additional pop-ups for focusing on windowed, active, and inactive processes.

Monitor CPU, disk, and network activity.

In addition, Activity Monitor provides features such as:

· **Dynamic Dock icon.** Use the Dock icon to show CPU, disk, memory, or network usage, to keep an eye on important system attributes.

· **CPU usage monitor.** Graphically display current CPU usage, either in its own window or as a floating bar, for all the CPUs on your system.

· **CPU history monitor.** Graphically display a scrolling view of CPU history in a resizable window, so you can track how CPU usage varies over time as you perform tasks.

· **Process sampling.** Sample an application to determine in which routines each thread is spending its time. For developers, this provides an easy way to find out where your application is spending its time and what needs to be optimized or restructured, to guide further investigation using the Developer Performance Tools.
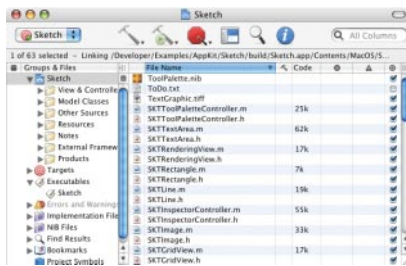
Developer Tools

Mac OS X Panther includes Xcode, a suite of developer tools enabling users to create high-performance Mac OS X native applications.

Graphical applications

· **Xcode** is Apple's new integrated development environment (IDE) for Mac OS X. It is designed to fully support all of the major platform initiatives of Mac OS X, such as the Carbon and Cocoa frameworks, Java, and the new application packaging mechanisms. It provides project editing, search and navigation, file editing, project building, and debugging facilities for all types of Mac OS X software projects, including applications, tools, frameworks, libraries, plug-in bundles, kernel extensions, and device drivers. It supports the use of C, C++, Objective-C, Objective-C++, and Java.

· **Interface Builder** is the graphical editor for designing user interface components for both Carbon and Cocoa applications. Interface Builder makes creating an application's user interface easier by allowing developers to use its graphical editing environment to manage every aspect of creating a user interface that adheres to the Aqua guidelines.

Command-line tools

These GUI applications are all built on the standard command-line developer tools familiar to the UNIX community, including:

· **GNU Compiler Collection 3.3** (GCC 3.3), including performance enhancements and support for the Power Mac G5 and 64-bit arithmetic. GCC 3.3 can generate optimal code for the G5 machine model, as well as code that executes efficiently on G5, G4, and G3 systems. This allows developers to build and qualify a single version of their applications for both 32-bit and 64-bit Mac hardware.

· **distcc,** a front-end to GCC that distributes builds of C, C++, Objective-C, or Objective-C++ code across several computers on a network.

· A full suite of **Java** compilation and debugging tools (javac, rmic, java, and jdb) based on JDK 1.4.1.

· Two versions of **make** (the default GNU make as well as BSD make).

· Parsing tools (**lex, flex, yacc,** and **bison**).

· **CVS** and **RCS,** the standard UNIX source code management tools.

Xcode is Apple's new integrated development environment.

GCC compiler options for the PowerPC G5

· -mcpu=970
This allows the compiler to use instructions available only on the G5 (also known as 970) processor.

· -mtune=970
This tells the compiler to tune code as optimally as it can for the G5. This flag can be safely used by itself on code that may run on processors other than the G5, because code compatibility is not changed.

· -mpowerpc64
In combination with the flags above, this flag tells the compiler to enable the G5's native 64-bit long long support for greatly enhanced performance when working with long longs. The "-force_cpusubtype_ALL" flag may also be needed.

Solutions resources
- Mathematic and gridMathematica (Wolfram):
  www.wolfram.com
- MATLAB (MathWorks):
  www.mathworks.com
- Oracle 10g:
  otn.oracle.com/products/database/oracle10g/
  content.html
- Sybase Adaptive Server:
  www.sybase.com/mac
- OpenOffice:
  porting.openoffice.org/mac
- TeX:
  www.rna.nl/tex-org.html
- The Metapkg Alliance:
  www.metapkg.org
- DarwinPorts Ports Collection:
  opendarwin.org/projects/darwinports
- Fink package management:
  fink.sourceforge.net
- Gentoo Portage for Mac OS X:
  www.gentoo.org
- Macintosh Products Guide:
  www.apple.com/guide
- Mac OS X Downloads page:
  www.apple.com/downloads/macosx
- BSD Mall:
  www.bsdmall.com/darwin.html
- OpenOSX:
  www.openosx.com

Other Sources of UNIX Software

Most popular open source software has already been ported to Mac OS X. For example, you can easily find such favorite command-line utilities as a pine mail client, trn news reader, lynx web browser, and the TeX formatting package. In addition, there are both native and X11 ports of major open source applications such as OpenOffice, the GIMP, and Mozilla.

Popular commercial UNIX applications are also available for Mac OS X:

- **MATLAB** from MathWorks joins Wolfram's **Mathematica** to provide advanced analytical tools for Mac users.

- **Sybase** has shipped its Adaptive Server for Mac OS X, and **Oracle** has released a developer preview of its Oracle database and other developer tools.

- Many other key commercial applications are already available or in development. See the **Macintosh Products Guide** at www.apple.com/guide for details.

To find out about these and the thousands of other applications available for Mac OS X, you can visit one of the following sites:

- The **Mac OS X Downloads page** (www.apple.com/downloads/macosx) offers a wealth of links to open source and commercial Mac OS X applications.

- The **Metapkg Alliance** (www.metapkg.org) includes the three major Ports Collections on Mac OS X (Fink, Gentoo, and DarwinPorts). A Ports Collection tracks all the dependencies of source code, libraries, and binaries, encapsulating the information needed to download, build, and install thousands of open source UNIX applications. There are also graphical interfaces (Fink Commander and DarwinPorts Manager) that allow you to do all this with a single click, rather than typing on the command line.

- **Prepackaged open source software** is available on compilation CDs for Mac OS X. BSD Mall offers a collection of UNIX utilities for Mac OS X, and OpenOSX provides user-friendly Mac OS X versions of UNIX solutions for databases, graphics, and word processing.

Mac OS X by the numbers
- More than 50 built-in, easy-to-use graphical applications
- Over two dozen bundled 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

Power Mac G5 resources
- Optimizing for the Power Mac G5: developer.apple.com/performance/g5optimization.html
- Tuning for the G5—A Practical Guide: developer.apple.com/technotes/tn/tn2086.html
- PowerPC G5 Performance Primer: developer.apple.com/technotes/tn/tn2087.html
- Driver Tuning on Panther for G5 (if you have written a device driver): developer.apple.com/technotes/tn/tn2090.html
- Power Mac G5 Performance White Paper (PDF): www.apple.com/powermac/pdf/PowerMacG5_Perf_WP_071503.pdf

For More Information

Now that you've had an introduction to the robust UNIX functionality of Mac OS X, visit these Apple web pages to find out more about specific topics.

- UNIX features in Mac OS X: www.apple.com/macosx/panther/unix.html
- Mac OS X in general: www.apple.com/macosx
- The Power Mac G5, the world's first 64-bit personal computer: www.apple.com/powermac
- The PowerBook G4, the world's best portable UNIX workstation: www.apple.com/powerbook
- Xserve, Apple's 1U rackmount server: www.apple.com/xserve
- Other Apple hardware products: www.apple.com/hardware
- Developer resources: developer.apple.com
- Open source code releases: developer.apple.com/darwin
- Web development: developer.apple.com/internet

Mac OS X Version 10.3 "Panther": Power of UNIX, Simplicity of Macintosh

Mac OS X Panther combines a robust and open UNIX-based foundation with the richness and usability of the Macintosh interface. In addition, Panther offers more than 150 new features and innovations, including iChat AV for personal video conferencing, Exposé for instantly finding any window, and a new Finder for easy access to every-thing you need. It's like having an all-new Mac.