

Read Me First

Welcome to *Take Control of Your 802.11n AirPort Network, Third Edition*, version 3.2, published in August 2013 by TidBITS Publishing Inc. This book was written by Glenn Fleishman and edited by Tonya Engst.

If you're setting up, extending, or retooling a Wi-Fi network with one or more 802.11n or 802.11ac base stations from Apple—the AirPort Extreme, AirPort Express, or Time Capsule—with AirPort Utility 6 or AirPort Utility in iOS, this book will help you get the fastest network with the least equipment and fewest roadblocks. This book has advice on connecting to a Wi-Fi network from iOS (Mac OS X 10.6 Lion and later, Windows 7 and 8, and from older versions of Mac OS X.

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Basics

Here are a few rules of the road that will help you read this book:

- **Path syntax:** I occasionally use a *path* to show the location of a file or folder in the Mac's file system. For example, AirPort Utility gets installed into the Utility folder, which is in the Applications folder. The path to AirPort Utility is [/Applications/Utilities/AirPort Utility](#).
- **Menus:** When I describe choosing a command from a menu in the menu bar, I use an abbreviated description. For example, the abbreviated description for the menu command that creates a new folder in the Mac OS X Finder is “File > New Folder.”

- **Big cats:** I often mention features specific to a particular version of Mac OS X, which Apple usually refers to by their “big cat” and “high surf” names:

 - ▶ Mavericks: 10.9
 - ▶ Mountain Lion: 10.8
 - ▶ Lion: 10.7
 - ▶ Snow Leopard: 10.6
 - ▶ Leopard: 10.5
- **Finding preference panes:** I sometimes refer to Mac OS X preferences, such as those in the Network preference pane. To reach a preference pane, open System Preferences by clicking its icon in the Dock or by choosing Apple  > System Preferences. Then, to open a preference pane, click its icon or choose it from the View menu.

For example, to see “the Network preference pane,” launch System Preferences and then click the Network icon or choose View > Network. To find the Wi-Fi view in the Network preference pane, you would click the Wi-Fi item in the list at the left of the pane.
- **Wi-Fi menu:** The Wi-Fi  status menu appears near the right side of the menu bar on a Macintosh. If yours isn’t showing, you can turn it on via a checkbox in the Network system preference pane, in the Wi-Fi view. To learn about the icons that may mark the top of this menu, see [Mac Wi-Fi Iconography](#).
- **Configuring a base station:** Throughout the book, I refer to using a program called AirPort Utility to configure a base station. In almost all cases, to configure a base station in AirPort Utility 6 on the Mac or in AirPort Utility in iOS (both versions are covered in the book), you select the base station in the AirPort Utility graphical display and then click or tap the Edit button that appears. (You may have to enter a password for the base station first.)

What’s New in Version 3.2

This update takes account of several changes that have occurred since version 3.1 of the ebook came out in 2012:

- **New AirPort Extreme and Time Capsule:** Introduced in June 2013, these new models feature *802.11ac*, a newer (still in progress) version of Wi-Fi that offers higher data transfer rates and better coverage. The shape of the base stations was also changed. *802.11ac* is now mentioned throughout the ebook, but see especially [Wi-Fi and AirPort Flavors](#).
- **More support for guest networks:** Guest networking can now be set up on all base stations in a network, due to a change in AirPort Utility and updated firmware released in early 2013. (See [Set Up Guest Networking](#).)
- **WPS for Wi-Fi printers:** A Wi-Fi-enabled printer can be simply added to a network without entering an encryption key, due to the same early 2013 firmware update. (See [Add a Wi-Fi Printer Using WPS](#)). This method of adding a printer relies on Wi-Fi Protected Setup (WPS), a no-entry

system for connecting devices to a Wi-Fi network. (Apple once included WPS to connect computers and some other devices, but removed it in an earlier release. The ability to connect printers is new.)


- **Wireless Diagnostics utility:** The Wi-Fi Diagnostics program found in the first release of OS X 10.08 Mountain Lion has been substantially changed yet again. (See [Run Wireless Diagnostics](#).)
- **Windows 8:** With Windows 8.1 expected in October 2013, I've inserted directions for adding a printer and connecting to a Wi-Fi network with Windows 8.1. See [Add a Shared Printer in Windows 8](#) and [Connect in Windows 8](#).

Note: 10.9 Mavericks has not yet shipped, but from the preview information that I've seen, I expect that its Wi-Fi settings will be identical to those in 10.8 Mountain Lion.

What Was New in Version 3.1

This update was inspired by three events that took place after version 3.0 of this ebook appeared in early 2012:

- **AirPort Utility update:** Apple restored configuration features for IPv6 networking and WPA2 Enterprise security in AirPort Utility 6.1 and a corresponding update to the iOS app. See [Configure IPv6 Networking](#) and [Turn On WPA/WPA2 or WPA2 Enterprise](#).
- **OS X 10.8 Mountain Lion:** When 10.8 Mountain Lion became available in July of 2012, it left most Wi-Fi features and options alone, but had one major change worth calling out. The software base station feature that lets you turn a Macintosh into the equivalent of a hardware Wi-Fi router like an AirPort Extreme finally included proper modern security. See [Software Base Station](#).
Apple also made the Wi-Fi Diagnostics app easier to launch and revised its interface. (Apple has subsequently changed the name of the app in Mountain Lion and made additional modifications.) Read [Run Wireless Diagnostics](#).
- **New AirPort Express:** The new [AirPort Express](#) has substantial changes in form but only minor changes in features, notably the addition of a second Ethernet port. Where it's important to note differences between it and the 2008 AirPort Express model, I refer to the new model as the 2012 Express.

I also added advice about troubleshooting your Wi-Fi connection if an exclamation-point  icon appears at the top of the Wi-Fi menu in the menu bar. See [Wi-Fi Network Won't Assign an IP Address](#).

What Was New in Version 3.0

Version 3.0 of this ebook made a significant change: it replaced coverage of AirPort Utility 5 in favor of AirPort Utility 6, which was released in February 2012 and updated to version 6.1 in June 2012.

AirPort Utility 6 runs on 10.7 Lion and later; 10.6 Snow Leopard can run only version 5.

The big new feature in AirPort Utility 6 was a graphical depiction of the layout of an AirPort network.

This is terrific for visualizing how parts are connected and seeing where errors lie.

AirPort Utility 6 has many features that are described in previous editions of this ebook, but it omits several options for mixed 802.11g and 802.11n networks and it can't configure 802.11b and 802.11g AirPort base stations (any base station released from 1999 through 2006). Further, although AirPort Utility 6.1 can configure the 2012 AirPort Express, AirPort Utility 6.0 cannot.

This ebook also now discusses AirPort Utility for iOS, which has a similar approach to AirPort Utility 6, and makes it possible to configure and manage an Apple base station without a desktop computer. That's a first for Apple.

Older versions of AirPort Utility remain available:

- **Mac:** The latest releases of AirPort Utility 5 for the Mac are AirPort Utility 5.6.1 for Leopard and Snow Leopard and 5.6.0 for Lion and Mountain Lion. However, version 5.6.0 cannot configure a 2012 AirPort Express; only version 5.6.1 can, and 5.6.1 will not install under Lion or Mountain Lion.
- **Windows:** AirPort Utility 5.6.1 for Windows XP, Vista, and 7 is the latest version. Apple appears to have abandoned Windows support, but hasn't come out and said it.

***Free download:** If you need help with AirPort Utility 5, you can refer to the previous edition of this ebook—there's no extra charge. Follow the “access extras” link in [Ebook Extras](#), and look in the blo*

Introduction

Despite Apple's 14-year history with wireless networking and the general excellence of their software and support, setting up a wireless network isn't always a snap. This book helps you set up 802.11n and 802.11ac AirPort networks and offers tips to save time, improve security, extend range, and enjoy a technical edge when working with Wi-Fi.

Although this book focuses on using AirPort Utility 6 with 10.7 Lion and later and AirPort Utility for iOS to configure a network, I also cover compatibility and connections with older computer hardware and how to connect to Wi-Fi base stations via Mac OS X and Windows 7 and later. And, I provide some information to help you use Wi-Fi with 10.6 Snow Leopard and 10.5 Leopard.

I start with wireless basics, move through base station installation and configuration, explain how to share printers and hard disks, tell you how to connect to a Wi-Fi network, give advice on extending a network's range and quality, look at using an AirPort Express's unique features, and finish with how-to information on security for those who want their AirPort networks safe from freeloaders and intruders.

Free download: *If you need help with AirPort Utility 5, you can refer to the previous edition of this ebook—there's no extra charge. Follow the “access extras” link in [Ebook Extras](#), and look in the blo*

Quick Start to AirPort Networking

You can read this book from start to finish, and you'll find that it covers topics like learning about Wi-Fi, unpacking a base station, starting configuration, figuring out the network you want to build, and then configuring that network. More specific cases follow, such as how to add a printer, separating older and newer flavors of Wi-Fi into two separate networks, and securing a network.

Use this Quick Start to get an idea of how you might jump into the book if you are at a particular stage in working with your network, and to find more than one path through the material.

***Need a quick solution?** Flip ahead a few pages to the [Quick Troubleshooting Guide](#) or see [Light Reading](#) to learn what the light on your AirPort base station is trying to tell you. Also, you may especially wish to consult [Overcome Interference](#).*

Learn wireless basics:

- Get a quick grounding in [Learn Wireless Basics](#).
- Familiarize yourself with [Wi-Fi Gear from Apple](#).

Plan your network:

- For common configurations, see [Picture Your Scenario](#) and focus on the diagrams and description at the beginning of: [New Network, Single Base Station](#), [Extend a Network via Ethernet or Wi-Fi](#), and [Replace an Existing Base Station](#).
- For ideas on using the AirPort Express, skim [AirPort Express Extras](#).
- For more advanced possibilities, consult [Connect Multiple Base Stations](#) and pay special attention to the descriptions and diagrams at the start of [Add Access Points via Ethernet](#) and [Bridge Wirelessly](#). Also, note that Appendix C covers creating a [Software Base Station](#) and [Ad Hoc Networking](#).
- Although it's not necessary for a basic setup, you can consider the channels and bands that your Wi-Fi network will use in [Spectrum Trade-offs](#).

Set up your base station(s):

- Unpack your base station and start down the path of configuring it in [Plug In Your Base Station and Get Started](#). You'll likely continue in one of these sections:
 - ▶ Learn how to configure a new network with a single base station. See [New Network, Single Base Station](#).
 - ▶ For existing networks, find what you need to [Extend a Network via Ethernet or Wi-Fi](#) or [Replace an Existing Base Station](#).
 - ▶ When wireless is the way to go, learn what you need to extend a network using only Wi-Fi. See [Bridge Wirelessly](#).
 - ▶ Hook up a larger network with many base stations. See [Connect Multiple Base Stations](#) to build a network that spans a house or office connected wirelessly, or via electrical outlets or Ethernet.

- Further configure your network's LAN settings for fixed addresses or special cases. See [Advanced Networking](#).
- [Pick the Right Place and the Right Channel](#) for your base station, thus making sure your network reaches as far as you want with the bandwidth you need. For help with concepts used in that section, consult [Spectrum Trade-offs](#).
- Share a printer or a hard drive. See [Set Up a Shared Printer](#) or [Set Up a Shared USB Disk](#).
- Set up Time Machine backups with a Time Capsule base station. Read [Work with Time Capsule](#).

Connect to your base station:

- Find out how to connect Macs, iOS devices, and Windows systems to a base station in [Connect Your Devices](#).
- Access your network when you're not physically on it. See [Reach Your Network Remotely](#).
- Access your base station with the Back to My Mac service in iCloud. See [Access a Base Station via iCloud](#).

Add music and video:

- Stream music through AirPlay. See [Stream Audio with AirPlay](#) and [Share with Airfoil](#).
- Get jiggy with a video- and audio-streaming set-top box, the Apple TV. See [Appendix A: Apple TV and Wi-Fi](#).

Connect between Macs:

- Understand the AirDrop peer-to-peer file-transfer feature, and see if your hardware and situation are a good fit to use it. Read [Share Files with AirDrop](#).

Secure your network:

- Avoid security tricks that don't work. Consult [Simple Tricks That Don't Work](#).
- Apply encryption using the best—and often simplest—method. See [Use Built-In Encryption](#).
- With a 2009 or later AirPort Extreme or Time Capsule or a 2012 AirPort Express, you can [Set Up Guest Networking](#).

Learn still more advanced topics:

- Stop pulling your hair out over a problem with new firmware you install that doesn't work. See [Revert to Older Firmware](#).
- Make a brief acquaintance with IPv6 and learn how to configure it with AirPort Utility in [Configure IPv6 Networking](#).
- Get a few details about saving and re-using an AirPort base station's settings in [Appendix B: Configuration Files](#).

Quick Troubleshooting Guide

If you need quick help, here's the starting point. I first look at handling a locked-up base station and then give tips for solving a variety of common problems.

Note: [Light Reading](#), a few pages ahead, helps you learn about a problem by decoding a base station's LED status light.

Reset a Locked-up Base Station

If an AirPort Extreme Base Station, AirPort Express, or Time Capsule appears neither in the Wi-Fi menu as an available network nor in AirPort Utility as an available base station, or AirPort Utility identifies it as missing, try these steps in order:

1. **Check a local connection:** Make sure that the computer running AirPort Utility is on the same local network as the base station. Try connecting the computer via Ethernet to one of the base station's LAN ports. Try AirPort Utility again.
2. **Failing a direct Ethernet connection, try power cycling:**

Warning! *You might damage the data on the internal drive by unplugging a Time Capsule. Make sure Time Machine backups or other transfers aren't in progress before you power cycle a Time Capsule—for each computer on your network that uses the Time Capsule, eject any mounted Time Capsule volumes and halt Time Machine backups. The easiest way is via the Time Machine system preference pane: flip On to Off. After you power cycle the Time Capsule, you can flip Time Machine back on for each computer.*

Remove the power adapter's plug from the wall socket or remove the end that plugs into the base station. Wait 10 seconds. Plug the base station back in, and see if it appears in AirPort Utility. Everything may be back to normal.

3. **Failing power cycling, try a factory reset:** This step erases any custom settings you've made (I recommend backing up these settings; see [Appendix B: Configuration Files](#)).

To reset any Apple base station, straighten an end of a paperclip, and with the base station plugged into power, hold down the base station's reset button with the paperclip end. The reset button is found in different places on different models:

- ▶ 2007–2012 AirPort Extreme and Time Capsule: The reset button is recessed at the rear right. The reset label, a white triangle reversed out of a gray circle, is above the button (**Figure 1**, left).
- ▶ 2012 AirPort Express: The reset button is above the audio jack.
- ▶ 2013 AirPort Extreme and Time Capsule: The reset button is to the right of the power jack and has a gray triangle printed on it (**Figure 1**, right).

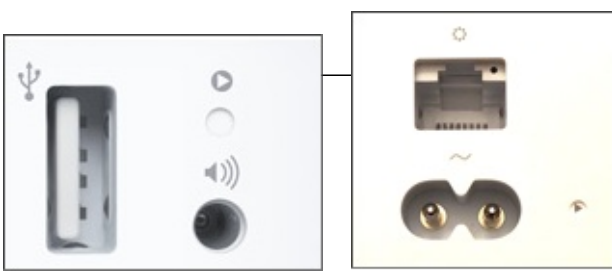



Figure 1: On the 2007–2012 models, the reset button is located below the reversed-out white triangle; at left, it's shown above the audio port of an AirPort Express. On the 2013 models, a gray triangle is printed on the reset button (right).

4. **Failing a factory reset, try another method to reset the base station:** Unplug the base station from power, push in the reset button and hold it down, plug the base station into power, and keep the reset button pressed for at least 20 seconds.
5. **Failing all the above:** Call Apple for return instructions if the unit is under warranty. If not, it may be time to invest in a new one.

Wi-Fi Network Won't Assign an IP Address

When connecting a Mac to a Wi-Fi network, you may sometimes see the oscillating waves in the Wi-Fi menu icon continue for several seconds, and then resolve with this icon: . That means that while the Mac's Wi-Fi radio could make a *physical* connection to the network, negotiating wireless standards, the underlying *logical* network server never responded to the computer's request to assign an IP address to access the local network and, by extension, the Internet.

First, try running Network Diagnostics. From the Wi-Fi menu, choose Alert: No Internet Connection. Or, open the Network preference pane and click Assist Me at the bottom. Follow the steps provided.

If that doesn't work, try renewing the DHCP lease:

1. Open the Network preference pane.
2. Select your Wi-Fi adapter in the list at the left (or select AirPort in 10.5 Leopard or 10.6 Snow Leopard). At the right, you should see a message about how the IP address is either missing or begins with **169**, a so-called self-assigned address that a Mac may use when a network doesn't provide one.
3. Click the Advanced button, and then the TCP/IP button.
4. Click the Renew DHCP Lease button. This sends out a new signal to the network's DHCP server that you want an address.

Now, if the IPv4 Address field contains a legitimate address and you can access the Internet, you're done. (You may have to revisit this, because a flaky network often doesn't heal itself that fast.) But, if the IPv4 Address field remains empty or it fills with an address starting with **169**, read on.

Typical reasons why a network doesn't assign an address boil down to misconfiguration, capacity, and distance:

- **Misconfiguration:** A network may be set up correctly and nothing you can do will mitigate the problem. A router in a café or a back-end DHCP server on a large conference center network may


need to be rebooted. Find the staffer or the “help” number for the network to see if you can get them to take action. (I’ve had to ask baristas to restart routers more times than I can recall.)

- **Capacity:** Poorly configured networks may run out of network addresses to assign over Wi-Fi. This happened particularly often when the iPhone first shipped, because networks set to handle, say, 50 computers were suddenly inundated with dozens of iPhones. You can’t solve this problem on your end. You need a router or server to be restarted or even reconfigured.
- **Distance:** Your Mac may appear to see and connect to a Wi-Fi network, but fail to get an address because it is at the edge of a usable signal and can’t reliably exchange network traffic. Try moving closer, using the tips in [Testing from Client to Base Station](#) for measuring signal strength.

Other Troubleshooting

Can’t see base station’s network from a device

Did you set an 802.11n base station to allow only 802.11n connections in 2.4 GHz? The device may be too old to support 802.11n. Late 2006 and later Macs have 802.11n built in, and the iPhone and iPod touch added it in 2010. It’s supported in all iPad models. For more help, read [Pick the Right Place and the Right Channel](#). (802.11ac base station models can’t be set to limit connection types.)

Further, computers can sometimes temporarily lose their capability to find Wi-Fi networks—and don’t ask me why! It’s a mystery of many years. Try turning the adapter off and back on—on a Mac, choose Turn Wi-Fi Off from the Wi-Fi  menu, and then choose Turn Wi-Fi On. Another common fix is to restart the computer.

Can’t connect to base station network; get an error instead

If you can see its network name, try either of these fixes:

- Did you inadvertently set an 802.11n base station to allow only 802.11n connections in the 2.4 GHz band? See [Connect Your Devices](#) (look for the first Warning in the chapter).
- Interference from other networks may be the problem. Consult [Overcome Interference](#).

Error occurs after connecting to a base station with the correct encryption key

You might be using a Mac with the older AirPort Card with a base station set up with WPA2 encryption. See [Turn On WPA/WPA2 or WPA2 Personal](#).

Can’t connect to a base station via Ethernet in AirPort Utility after selecting it and seeing the summary screen

You might have hit an unusual bug. If you’ve changed the minimum transmission unit (MTU) for your Ethernet adapter to anything but the standard 1,500-byte setting, you need to change it back; or, you can turn off IPv6 networking. This is rather obscure; Jumbo frames are used to speed network data transfers on gigabit Ethernet networks, but for it to work properly, all devices must support Jumbo frames automatically. Apple’s base stations apparently do not support them. In the Network System Preferences pane, select your Ethernet adapter, then click Advanced. In the Hardware view, choose Manually from the Configure pop-up menu and then Standard (1500) from the MTU pop-up menu. Now, click OK, and then click Apply.

Firmware update makes base station act erratically

Try to [Revert to Older Firmware](#).

Network works erratically

Another network might be interfering with yours. See [Overcome Interference](#).

Conflicting signals seem to cause network problems

Read [Overcome Interference](#).

Mac Wi-Fi Iconography

The Wi-Fi menu—located on the system menu bar—reveals what kind of connection is in progress on your computer. Knowing what the icons mean can help you troubleshoot problems. This icon is always at the top of the Wi-Fi menu.



A gray fan indicates an active Wi-Fi network adapter that isn't currently connected to a network. Read [Connect Your Devices](#).



A full fan with one or more black bars—the bars represent current strength—indicates a current Wi-Fi connection to either a base station or a network created through the Sharing preference pane's Internet Sharing service. (An animation of each wave turning black in turn occurs while the connection is underway.) For more information, consult [Connect Your Devices](#) and [Appendix C: Setting Up a Software Base Station](#).



iOS devices may share a cellular connection via Wi-Fi using the Personal Hotspot feature. When a Mac connects to such a network, the fan icon is overlaid with interlinked loops. Apple also uses this symbol in iOS to indicate a tethered connection of this kind.



A fan showing an up arrow indicates that the Internet Sharing service is active on this computer. See [Software Base Station](#).



A fan containing a computer shows that the Mac has created an *ad hoc network*, a method of handling Wi-Fi communication among multiple computers without a base station—not even the “software” base station that's created by Internet Sharing. See [Ad Hoc Networking](#), in Appendix C.



A fan containing an exclamation point indicates an error in setting up the network part of the Wi-Fi connection. While the computer has connected wirelessly to the base station, it was unable to obtain a network address. See [Wi-Fi Network Won't Assign an IP Address](#).



An empty fan outline indicates that either there's no Wi-Fi adapter in the computer, or the Wi-Fi adapter is off. To turn it on, choose Turn Wi-Fi On from the menu. If the Wi-Fi icon still looks like an empty fan or an error says that there's no card or it can't be turned on, you may have a hardware problem.



The Eye of Sauron appears in its unblinking form that sees all and knows all when you use a monitoring mode in Wi-Fi Diagnostics, a hidden tool that can help you sort through problems. See [Run Wireless Diagnostics](#) for more details.

Light Reading

The light on the front of any Apple Wi-Fi base station indicates what the base station is up to: handling data correctly, hitting an error, or in a special mode. The guide below helps you decipher the meaning.

- **Off:** There's no power! Plug in the base station. If it is plugged in, check the outlet or power strip, and the places where the cord plugs into other cords or into the base station. If juice is flowing and the cord looks correct, you have a defunct base station or a bad cord.
- **Blinking green:** The base station light blinks or flashes green in two cases:
 - **Startup:** The light flashes green on and off for 1 second.
 - **Reset:** This happens after you press the recessed reset button for long enough to trigger a reset.
- **Solid green:** The base station is configured correctly, has no updates available, and is connected to the Internet.
- **Solid amber:** The base station is still powering up and hasn't loaded all its settings and connected to the network.
- **Blinking amber:** A blinking amber light has several meanings:
 - The base station has a configuration problem, has lost its network connection, or is suffering from another problem. Use AirPort Utility to troubleshoot the problem.
 - A Time Capsule may have a [Disk Integrity](#) problem.

Learn Wireless Basics

Let's quickly run through some basics to set the stage for what follows.

Adapters and Access Points

Wi-Fi networks need two connected parts: a wireless adapter and an access point. The wireless adapter is part of a computer or mobile device, while the *access point* connects both to wireless adapters and to a broader network, such as the Internet via a broadband modem. An access point that's coupled with a router is called a *wireless gateway*; Apple calls its wireless gateway a *base station*.

Apple's line-up of base stations includes the AirPort Extreme, the AirPort Express, and the Time Capsule. When I talk about "AirPort equipment," I mean all Apple base stations, including Time Capsules. An *AirPort network* is a Wi-Fi network with some Apple extras that may work only with Apple software—under Mac OS X or Windows—or in conjunction with other AirPort equipment. Examples of such features include streaming audio, certain forms of hard-drive file sharing, and base station-to-base-station connections.

What's Wi-Fi?

The name *Wi-Fi* is a certification guarantee for which The Wi-Fi Alliance trade group owns the rights and controls the testing. *Wi-Fi* doesn't stand for anything—it's a made-up name—but it loosely connotes *wireless fidelity*, in the sense of *faithfulness*: devices with Wi-Fi stamped on them work with other Wi-Fi devices following the same standards, or are faithful to one another.

The wireless adapter uses client software on the computer or handheld device to connect to a specific base station (or set of affiliated base stations) after a user selects a network name from a list or manually enters the network's name. Mac OS X allows network selection from the Wi-Fi menu in the menu bar and the Wi-Fi view in the Network system preference pane.

When a wireless adapter connects—technically, *associates*—with a base station, the device to which the adapter is attached can send data to and from the base station. If the base station has encryption enabled, then an encryption key must be provided before the base station allows the device access to any networks to which it connects. The key, which consists of a series of characters, may need to be entered exactly as it was entered on the base station, although a stored key can be sent without a person having to re-enter it.

Once an adapter connects to a base station and the encryption key is accepted, the computer's operating system can carry out the next steps, such as automatically requesting an Internet protocol (IP) address using DHCP and sending data over the wireless network.

With newer adapters, a connection may be made directly to another device with peer-to-peer networking at the same time that an adapter is connected to a regular Wi-Fi network. AirDrop, which was introduced with 10.7 Lion, is an example. AirDrop is an Apple-only version of a more general standard called *Wi-Fi Direct* (see [Share Files with AirDrop](#)).

The Spectrum Part of Wi-Fi

Wi-Fi networks use *unlicensed spectrum*, so called because regulatory agencies allow license-free use of those airwaves by everyone in a given country. In contrast, cellular telephone companies pay huge amounts for the exclusive geographic rights to certain frequencies.

Licenses in a few places: *In some developing nations, inexpensive or free licenses are required for outdoor use but not indoor use, or by businesses but not individuals. In the United States, Australia, Japan, South Korea, and most of Europe, no licenses are required.*

Spectrum *bands*—specified ranges of frequencies—are divided into smaller portions called *channels* which allow many devices to use the same band within “hearing” distance of each other, but without overlapping any or all the frequencies they employ. However, unlicensed bands are intended for broad use by individuals and businesses, and there’s no guarantee that you won’t encounter interfering signals, reducing the speeds you can achieve.

The rule is that in these unlicensed bands, devices use extremely low signal power, but they also must be quite robust in order to cope with lots of interference.

In the United States and in most countries, two bands are available for use, the 2.4 GHz (gigahertz) band and the 5 GHz band. (The 900 MHz [megahertz] band is also unlicensed in the United States, but it is not employed for wireless LANs. The 1.9 GHz band is used by newer home cordless telephones.) The precise frequencies and channels vary enormously by country.

When it comes to the way AirPort gear handles bands, there are three approaches:

- **One band only:** Older AirPort equipment from 1999–2006 works only in the 2.4 GHz band.

Previous edition: *You can download the previous edition of this ebook at no cost to learn how to make older and newer AirPort equipment work together. See [Ebook Extras](#) (once you reach the Take Control site, look for the ebook’s Blog).*

- **Dual band:** All 2007 and 2008 Apple base stations can use either the 2.4 or the 5 GHz band, but you must choose one before starting or restarting, and use that one until a change is made and the unit is restarted again.
- **Simultaneous dual band:** The AirPort Extreme and Time Capsule models released starting in 2006 and the AirPort Express from 2012 can use both bands at once.

For more on the differences between 2.4 and 5 GHz, see [Spectrum Trade-offs](#).

Warning! *Many manufacturers, including Apple, sell specific hardware for each country or regulatory domain in which they do business. Because laws vary by country and regulatory body, it’s crucial that you don’t take a base station from, say, the United States to France and turn it on. You could wind up facing fines and jail time.*

Wi-Fi and AirPort Flavors

AirPort hardware has gone through many transformations since its original 1999 introduction. Each major flavor of Wi-Fi that Apple has built into AirPort gear relies on industry standards created by the IEEE, the Institute of Electrical and Electronics Engineers. The IEEE has groups that work on many different kinds of standards. Their 802 group handles local area networks (LANs), and a working group in that area, numbered 11, covers wireless LANs (WLANs). This is called the 802.11 Working Group.

Each successive update to the standard produced by the 802.11 group is lettered and defines a particular set of codified ideas:

- **802.11b:** The original popular flavor of Wi-Fi from 1999.
- **802.11g:** Released in 2003, this somewhat faster version of Wi-Fi was coupled with a security improvement.
- **802.11n:** Much faster than 802.11b and g, this version appeared widely in 2007.
- **802.11ac:** This, the latest, fastest version of Wi-Fi, appeared in 2012 and first showed up in Apple's equipment in 2013. (It is still in draft form, but it is effectively finished.)

The Wi-Fi Alliance, a trade group, takes those IEEE standards and builds tests that allow different makers to ensure that they are creating equipment that works with all the other manufacturers' equipment and that carries out a common set of tasks in the same way.

Since the original AirPort, Apple has released four major versions of the AirPort hardware, three of which were related to major revisions of the IEEE 802.11 standards. Every older version can be used with even the newest models, so long as the newer base station has a legacy or compatibility mode enabled.

What about 802.11a?

The 802.11a protocol was approved in 1999 even before 802.11b. 802.11a may use only the 5 GHz band, and it never quite caught on because it wasn't backward compatible with 802.11b or 802.11g, which relied on the 2.4 GHz band. Building an affordable single adapter or base station with both bands that could work at once wasn't possible until about 2009.

Apple shipped some early Intel-based Macs with 802.11a quietly enabled because it was built into the chips that Apple used for Wi-Fi. It still works in Macs today for compatibility's sake.

802.11n Technology (2007)

802.11n can be ten or more times faster than its predecessor, 802.11g, in typical circumstances when measuring real data passed over a network. 802.11n devices typically have several antennas, with at least two receiving and two transmitting data (called 2x2), as well as multiple radios.

Having more radios allows signals to go farther, and it allows multiple simultaneous data streams—each radio sending a unique set of data at the same time that bounces across slightly different paths through space using the same frequencies! Think of this like pool balls on a pool table. A sending base station is the equivalent of two pool players shooting a series of balls that uniquely ricochet across the table (sometimes striking and passing through each other in a ghostly fashion) until they sink into different holes at the other end.

Each incoming signal is “heard” by two or more antennas, making it easier to pick up more distant

transmissions and to tease out the wheat (data) from lots of chaff (other, interfering signals and background noise).

These techniques allow 802.11n to have a raw data rate of 75–450 Mbps (megabits per second) in current versions and up to 600 Mbps in advanced versions used in corporate campuses. Apple’s last generation of AirPort Extreme and Time Capsule released in 2012 used three data streams for a maximum raw rate of 450 Mbps with a 3x3 antenna array. And, the most advanced 802.11n Mac hardware shipped with a 3x3 Wi-Fi radio system installed, allowing for the greatest range and speed.

802.11n was the greatest thing since sliced bread when it was introduced, and Apple’s version gradually improved over the years. But in 2013, Apple upped the ante by joining other firms in offering the newest greatest thing: 802.11ac, explained next.

Single-stream Radios

A form of 802.11n and 802.11ac called *single stream* uses one or two antennas and a single data stream, which limits a device to raw rates of 75 Mbps in 2.4 GHz (802.11n only) and 150, 300, or 433 Mbps in 5 GHz, depending on the flavor of 802.11n or 802.11ac.

While these rates seems contrary to the advantages of 802.11n and ac, they are still a huge boost over 802.11g—from double to several times that data rate. 802.11ac adds the further advantage of allowing a base station to use *multiple-user MIMO* and send separate data streams at the same time to devices that have fewer radios than the base station’s maximum number of streams. Thus, a four-radio 802.11ac base station could simultaneously send data to two one-stream devices and one two-stream device; previously, it would have had to send those successively, wasting network throughput.

Apple has included single-stream 802.11n in all iPhone models introduced starting in 2010 (iPhone 4) and all iPod touch models since 2009 (4th-generation). The iPad has included single-stream 802.11n from its first model. The iPad, iPhone 5, and 5th-generation iPod touch handle both 2.4 and 5 GHz networking.

802.11ac Networking (2013)

While 802.11n brought extreme improvements in raw speed, net throughput, and range, there was still more performance to eke out, which led to 802.11ac. Although the standard is still in progress, it is essentially finished. It started shipping in gear from manufacturers other than Apple in 2012. Apple shipped its first laptop, a revised MacBook Air, and its first base stations, updated AirPort Extreme and Time Capsule models, in June 2013.

The 802.11ac standard uses only the 5 GHz band, but “802.11ac” routers include backward-compatibility support for 802.11a, g, and n to make sure other devices can still connect. Apple’s version of 802.11ac has a raw top rate of 1.3 Gbps, although it will rarely achieve that performance because of practical considerations of having enough spectrum available in the vicinity and having a client device close enough to achieve maximum throughput. (See [Throughput](#) for more detail.)

However, with an 802.11ac router swapped in place of an older 802.11n router, you should generally see faster transfer rates, and areas of dead, slow, or poor coverage with 802.11n should have improved reception.

Compatibility among 802.11 Flavors

While each 802.11 evolution brings unique elements to the table, all 802.11 versions designed for the same band can work together. Newer versions are designed to not trample on all older versions, and base stations can be set to allow all, some, or no backward compatibility.

With Apple gear, for instance, the original AirPort handled just 802.11b, and the AirPort Extreme 2003 added 802.11g, which can talk to “B” devices with full support. Likewise, Apple’s 802.11n base stations handle the older 802.11a/b/g standards, and its 802.11ac models support all four previous standards.

See **Table 1** to visualize which protocols support which bands.

Table 1: Protocols and Bands		
	2.4 GHz	5 GHz
802.11a		●
802.11b	●	
802.11g	●	
802.11n*	●	●
802.11ac		●

* 802.11n devices may support either or both bands.

Transfer speeds between an adapter and a base station running different 802.11 standards can’t exceed the speed supported by the slower of the two 802.11 flavors that both devices share. For example, any B device connecting to an N base station communicates at B speeds, meaning that each packet of data a B device pushes through the network occupies the equivalent of 10–30 N packets.

While most of the loss in throughput happens only while older devices are taking up airtime (and newer devices are cooling their heels), enabling backward compatibility shaves at least 10 percent of a network’s maximum throughput. This is because each packet of data begins with a special message—a *preamble*—that’s encoded at a backward compatible speed so the slowest devices can understand it.

With 802.11n base stations, you can increase the speed of networks by setting minimum levels of backward compatibility, as described in [Compatibility](#). (This option is not available in 802.11ac base stations.) By eliminating slower speeds or B adapters, you can speed up a network. Apple’s simultaneous dual-band base stations avoid this problem largely by allowing N devices to work mostly in the 5 GHz band, leaving 2.4 GHz for slower B and G adapters.

Upcoming: 802.11ad

The IEEE has a newer standard on the horizon for personal area wireless networks: 802.11ad, which will use spectrum way up the dial at 60 GHz for rates as high as 7 Gbps over very short distances, such as within a room. Devices are planned that will incorporate 802.11ad alongside older 802.11n and 802.11ac in a single package.

Wi-Fi Gear from Apple

A long history with Wi-Fi has led to three devices in Apple's current lineup of base stations, each with a distinct set of features. Let's look first at how Apple has chosen to work with 802.11n and 802.11ac and then at Apple's current [AirPort Base Station Models](#) and the options for [Adapters in Macs and iOS Devices](#).

At the end of this chapter, you should better understand the gear that you have, or be in a better position to shop for new equipment.

802.11n, 802.11ac, and Apple's Choices

Although Apple has made distinct choices when implementing Wi-Fi, all three of Apple's current base stations can handle both the 2.4 band and the 5 GHz band. All current base stations can manage networks on both bands at the same time.

Note: Despite the AirPort Express being called an 802.11n base station and the 2013 models of the AirPort Extreme and Time Capsule's being labeled 802.11ac, these are really "multi-protocol" devices. That is, the Express can handle a, b, g, and n in any combination; the 2013 Extreme and Time Capsule handle a, b, g, and n while *also* adding ac.

For the 5 GHz band, Apple enables just 8 of the 23 possible channels in the United States for use in a base station. This is because of a compromise among the radio equipment industry, the military, government agencies, and the FCC. This compromise protects 15 of the possible 23 channels so that base station signals don't cause even the slightest interference with weather-sensing and military radar, but it also makes it more difficult to use those channels for home networks. Apple has chosen not to support those 15 channels in its base stations. The company doesn't think that they would be consistently available in a way that would be useful to most consumers and small offices who would buy AirPort gear.

Note: The adapters in a Mac can, in fact, connect to all the 23 legal channels in the United States. Some companies may deploy Wi-Fi networks using non-Apple base stations that allow the use of all 23 channels, as they're more likely to be available inside buildings without hitting military and weather radar rules.

Apple also chose to limit 802.11n's wide channels to the 5 GHz band. *Wide channels* are an 802.11n feature that uses two adjacent channels at once—this doubles the raw bandwidth. Apple's choice was an option under the Wi-Fi Alliance's certification rules, but some vendors offer wide channels in 2.4 GHz.

In practice, 2.4 GHz wide channels don't work well, because 802.11n devices tread lightly to avoid interfering with other networks. In a real-world situation, you would likely see an improvement in throughput with 2.4 GHz wide channels only if no other Wi-Fi networks were nearby.

Even wider channels are possible in 802.11ac: the equivalent of four and eight normal channels in 5 GHz, the only band in which 802.11ac functions. Apple supports only the four-channel-wide flavor, which makes sense as there aren't eight adjacent channels available for consistent use in 5 GHz.

AirPort Base Station Models

Apple's current Wi-Fi base stations are the [AirPort Extreme](#), a solid offering for home networks and small offices; the [Time Capsule](#), a backup system coupled with Extreme features; and the [AirPort Express](#), a compact router with most of the AirPort Extreme's features but portable enough for travel. **Table 2** (ahead shortly) summarizes the differences between these devices, and I discuss each device in the pages ahead.

Field Guide to Base Stations

Within its 802.11n and ac line, Apple has kept the same name for six generations of AirPort Extreme, five generations of Time Capsule, and two generations of AirPort Express. The dates for the Extreme and Time Capsule generations were 2007 (Extreme only), 2008, early 2009, late 2009, second-quarter (June) 2011, and June 2013. The AirPort Express comes in 2008 and 2012 models. This can make it difficult to figure out which unit you own.

However, in AirPort Utility 6, you can see a unit's model information by clicking its name in the graphical view and then hovering over its name in the popover. The names shown in **Table 2**, in the bullet items that begin with AU, correspond to those shown in AirPort Utility 5.6.1 and 6.3.

Table 2: Current Apple Wi-Fi Hardware, June 2013 Refresh		
<i>(AU is the AirPort Utility description)</i>		
Name	Features	Price
AirPort Extreme (June 2013)	<ul style="list-style-type: none">• Four gigabit Ethernet ports (three LAN, one WAN).• USB disk and printer sharing (any number of each).• Simultaneous dual-band networking using two separate radio systems.• Three-stream (1.3 Gbps) 802.11ac.• AU shows "AirPort Extreme 802.11ac".	\$199
Time Capsule (June 2013)	<ul style="list-style-type: none">• All AirPort Extreme features.• Built-in 2 TB or 3 TB hard drive for network-attached storage or Time Machine networked backup.• AU shows "Time Capsule 802.11ac".	\$299 (2 TB), \$399 (3 TB)
AirPort Express (June 2012)	<p>All AirPort Extreme features except:</p> <ul style="list-style-type: none">• Two 10/100 Mbps Ethernet ports (LAN and WAN).• Audio streaming.• USB printer sharing (one printer).• Two-stream (300 Mbps) 802.11n.• AU shows "AirPort Express 802.11n (2nd Generation)".	\$99

AirPort Extreme

Over the years, Apple has enhanced the wide range of features now available in the AirPort Extreme:

- **Simultaneous dual-band networking:** With two internal radio systems, the early 2009 and later models of the Extreme can operate a 2.4 GHz (802.11b/g/n) and a 5 GHz (802.11a/n/ac) network simultaneously and independently, allowing the fastest devices to connect to the best network.
- **Ethernet:** The Extreme base station has four gigabit Ethernet ports, three for the LAN and one for the WAN (**Figure 2**).



Figure 2: The three-quarter front view (left) and straight-on back view (right) of the 2013 AirPort Extreme Base Station. The back ports are, top to bottom, three LAN Ethernet, USB, WAN Ethernet, and power. The tiny reset button is to the right of the power jack.

Note: Why so tall, Paul? The 2013 AirPort Extreme has a few inches of empty air inside. It's form factor is identical to the Time Capsule, which fills that empty space with a hard drive. Apple claims the signal carries better with a "higher platform," but I suspect it's a desire to have a unified appearance.

- **Guest networking:** Starting with the early 2009 model of the Extreme, you can set up a separately named Guest Network in addition to the network that you normally access. This feature broadcasts a *virtual* network that shares the same networking hardware, but appears as a unique name in the Wi-Fi menu. You can set separate security options, too. Guests who connect have no access to local network traffic or peripherals, like printers or file sharing.
- **1.3 Gbps throughput:** Starting with the June 2013 model of the Extreme base station, it can pump out up to 1.3 Gbps of raw data via 802.11ac in the 5 GHz band by bonding four channels (80 MHz of channels) and sending three separate 433 Mbps spatial streams. In practice, this keeps data rate consistent over longer distances from the base station rather than providing overall faster throughput. In 2.4 GHz, the base station relies on 802.11n as it's fastest flavor, topping out at 225 Mbps in a single-width channel.

Fastest method: *If you need speed, gigabit Ethernet is far faster and simpler than Wi-Fi, with the only downside being the requirement for wires. Ethernet switches can consistently deliver a few times the real throughput of 802.11ac between any two connected gigabit Ethernet devices in both directions. In contrast, Wi-Fi is limited to half its maximum speed when transmitting data between two Wi-Fi devices on the same network.*

Note: All four ports on an Extreme (or Time Capsule) can be used as switched LAN ports if the base station is set to bridging mode. In this mode, the Extreme just passes through traffic from the network to which it's connected. See [Passthrough and Bridging](#).

- **USB:** All Extreme models have a single USB port, which can be used to share a printer or hard drive across a network or the Internet; by attaching a powered USB hub, you can attach one or more printers or hard drives.
- **Power:** AC power is supplied through a nearly 6.5 foot/2 meter long cable that plugs directly into the base station.

Time Capsule

The Time Capsule is a backup appliance with all the technical characteristics and external ports found in an Extreme, but with the addition of an internal 2 TB or 3 TB drive. It looks identical to an AirPort Extreme Base Station.

Apple designed the Time Capsule to pair with Mac OS X's Time Machine feature for making network backups. Any computer with 10.5 Leopard or later installed can back up files over Wi-Fi or Ethernet to a Time Machine's internal drive or an externally connected drive.

Extra options for the internal drive: In AirPort Utility, you can erase the internal drive in a Time Capsule.

AirPort Express

Apple upgraded the AirPort Express to 802.11n in 2008 and refreshed it completely in 2012. The 2012 Express is identical in dimensions to an Apple TV (3.9 by 3.9 by 0.9 inch/98 by 98 by 23 mm), although it weighs slightly less at 8.5 ounces/240 grams. The 2012 Express sports a 6.5-foot/2-meter long cord that plugs into an integral power supply.

The Express is quite similar to the AirPort Extreme, but with three exceptions and one important addition. The exceptions are:

- The Express has two 10/100 Mbps Ethernet ports (one for WAN and one for LAN). The lack of gigabit Ethernet is a shame, because that puts a top end on the speed of 802.11n traffic that can pass between it and Ethernet.
- The Express has a USB port for sharing a single printer, but, unlike its two big brothers, it cannot share multiple printers nor even a single hard drive.
- From a wireless throughput standpoint, the Express has just a “2x2” radio setup, allowing a maximum of 300 Mbps of raw speed in 5 GHz and half that in 2.4 GHz, compared to the “3x3” in the 2009–2012 802.11n Extreme and Time Capsule models.

The Express has a unique extra, though, that makes it a must-have network add-on for some people: audio output via AirPlay. The unit has a special mini-stereo port that allows both analog output and digital optical (Toslink) output, depending on the jack and cord you use to route audio from the Express to a stereo.

Its small size and low weight makes it perfect to tuck into a bag for a trip, where it can be plugged into Ethernet in a hotel room to share an Internet connection via Wi-Fi.

Adapters in Macs and iOS Devices

Starting around the end of the third quarter of 2006, Apple began introducing new Mac models that secretly included 802.11n wireless chips. Apple didn't tell customers or enable the faster 802.11n mode, so the Macs behaved as though they had a G card inside. Apple was apparently waiting for the standard's progress to be clear before switching on the new 802.11n capabilities. (Clever buyers who cracked their Macs open figured this out long before Apple made it official.)

All current Apple computers include Wi-Fi and have at least dual-band 802.11n built in; at the time of this writing, only the MacBook Air's 2013 version has 802.11ac. 802.11ac will certainly be added to each refresh of each Mac model. See **Table 3**, shortly ahead, for the full rundown by model over AirPort's history.

If you use a simultaneous dual-band base station to offer two Wi-Fi networks each with same name, then an Apple adapter in a Mac running 10.5 Leopard or later automatically chooses the fastest and best connection. This ensures that the connection will always be the best one for the circumstances.

Table 3: Wi-Fi Flavor by Model (as of August 2013)	
Model(s)	Fastest Supported Wi-Fi Type
MacBook Air (June 2013)	802.11ac
iPhone 4, iPhone 4S, 4th-generation iPod touch	802.11n (2.4 GHz only)
iPad, iPad 2, 3rd-generation iPad, 4th-generation iPad (2012), iPad mini (2012), iPhone 5, 5th-generation iPod touch (2012)	802.11n (dual band)
All Core 2 Duo, i5, and i7 Macs: MacBook and MacBook Pro (2006–), Mac Pro (2008–), and Mac mini (2009–), iMac (2006–, except 1.83 GHz 17-inch)	802.11n (dual band)
iPhone, iPod touch (2007–2009)	802.11g
MacBook and MacBook Pro (Core Duo, 2006), 1.83 GHz 17-inch iMac (Core 2 Duo, 2006), Mac Pro (2006)	802.11a/g
iBook G4, iMac (2003–2006), eMac (2003–2004), Mac mini (Core Solo/Duo, 2006–2007), PowerBook G4 (2003–2005), Power Mac G5 (all)	802.11g
iBook G3, iMac (2000–2003), G4 Cube, Power Mac G4 (1999–2002), PowerBook G3 (2000–2002), PowerBook G4 (2001–2002), eMac (2002)	802.11b

Plug In Your Base Station and Get Started

Let's get unpacking! This chapter focuses on plugging in your base station and on launching AirPort Utility, the program that modifies a base station's settings.

(The next chapter, [Set Up a Network](#), helps you determine which network type you want to use your base station with, and provides specific instructions for a streamlined setup. Also, [Connect Your Devices](#), later, explains how to connect via Wi-Fi from any computer in the vicinity to the newly set up base station.)

Unpack and Power Up

Unpack the base station to determine what you have and if you need any additional hardware:

- 1. Remove the base station from its box and check the parts:** The box includes just a few necessary parts: the base station, a setup booklet, a booklet full of software licensing information (extraneous for users, but required), and an AC power cord.
- 2. Is the power cord long enough?** Plan to buy an extension cord if the included 6.5 foot/2 meter cord is too short for your purposes. The Extreme and Time Capsule work best level on a table or floor, where the top of the unit has an unobstructed line of sight to the rest of the room it's in. If you can, don't put it inside a cabinet or behind a computer. (For now, your goal is to plug the base station in where you can set it up, though you may wish to skip ahead and read [Pick the Right Place](#) before you continue.)
- 3. Do you need an Ethernet cable?**

Configuring a base station may be simpler if you temporarily hook it to your computer or existing LAN with an Ethernet cable.

In the likely case that you plan to connect the base station to a broadband router or other network, you also need at least one Ethernet cable in order to make that connection. All Apple Wi-Fi devices have auto-sensing, auto-switching Ethernet, so regardless of the particulars of your cable, the base station will make it work.

Note: TidBITS publisher Adam Engst hit some problems when he used older Ethernet cables in his network. He described them in an article, [Switch Your Network to Gigabit Ethernet](#).

Now it's time to power up. Plug your base station into an electrical outlet, and plug an Ethernet cable from your Mac into any of the three LAN ports on the Time Capsule or Extreme, or the single LAN Ethernet port on the Express. If you'd rather have mobility while configuring, you can also set up via Wi-Fi, but you must reconnect after each time you change password or naming options.

Flashy: In a neat addition, each Ethernet port on a base station has a tiny green LED that lights up when an Ethernet cable is connected to the port and a live connection is on the other end of the cable; the LED flashes to indicate activity (**Figure 3**). Also, a green/amber LED on the front of the base station shows the status of the base station. [Light Reading](#), earlier, has more about the front LED.

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