Supporting IPv6 DNS64/NAT64 Networks

With IPv4 address pool exhaustion imminent, enterprise and cellular providers are increasingly deploying IPv6 DNS64 and NAT64 networks. A DNS64/NAT64 network is an IPv6-only network that continues to provide access to IPv4 content through translation. Depending on the nature of your app, the transition has different implications:

- If you're writing a client-side app using high-level networking APIs such as `NSURLSession` and the CFNetwork frameworks and you connect by name, you should not need to change anything for your app to work with IPv6 addresses. If you aren't connecting by name, you probably should be. See Avoid Resolving DNS Names Before Connecting to a Host to learn how. For information on CFNetwork, see *CFNetwork Framework Reference*.
- If you're writing a server-side app or other low-level networking app, you need to make sure your socket code works correctly with both IPv4 and IPv6 addresses. Refer to RFC4038: Application Aspects of IPv6 Transition.

What's Driving IPv6 Adoption

Major network service providers, including major cellular carriers in the the United States, are actively promoting and deploying IPv6. This is due to a variety of factors.

> **Note:** World IPv6 Launch is an organization that tracks deployment activity at a global scale. To see recent trends, visit the World IPv6 Launch website.

IPv4 Address Depletion

For decades, the world has known that IPv4 addresses would eventually be depleted. Technologies such as Classless Inter-Domain Routing (CIDR) and network address translation (NAT) helped delay the inevitable. However, on January 31, 2011, the top-level pool of Internet Assigned Numbers Authority (IANA) IPv4 addresses was officially exhausted. The American Registry for Internet Numbers (ARIN) is projected to run out of IPv4 addresses in the summer of 2015—a countdown is available here.

IPv6 More Efficient than IPv4

Aside from solving for the IPv4 depletion problem, IPv6 is more efficient than IPv4. For example, IPv6:

- Avoids the need for network address translation (NAT)
- Provides faster routing through the network by using simplified headers
- Prevents network fragmentation
- Avoids broadcasting for neighbor address resolution

4G Deployment

The fourth generation of mobile telecommunication technology (4G) is based on packet switching only. Due to the limited supply of IPv4 addresses, IPv6 support is required in order for 4G deployment to be scalable.

Multimedia Service Compatibility

IP Multimedia Core Network Subsystem (IMS) allows services such as multimedia SMS messaging and Voice over LTE (VoLTE) to be delivered over IP. The IMS used by some service providers is compatible with IPv6 only.

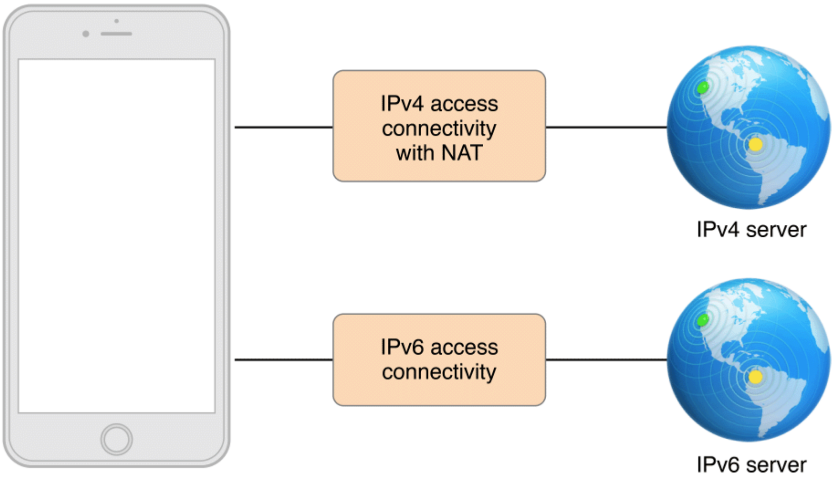
Cost

Service providers incur additional operational and administrative costs by continuing to support the legacy IPv4 network while the industry continues migrating to IPv6.

DNS64/NAT64 Transitional Workflow

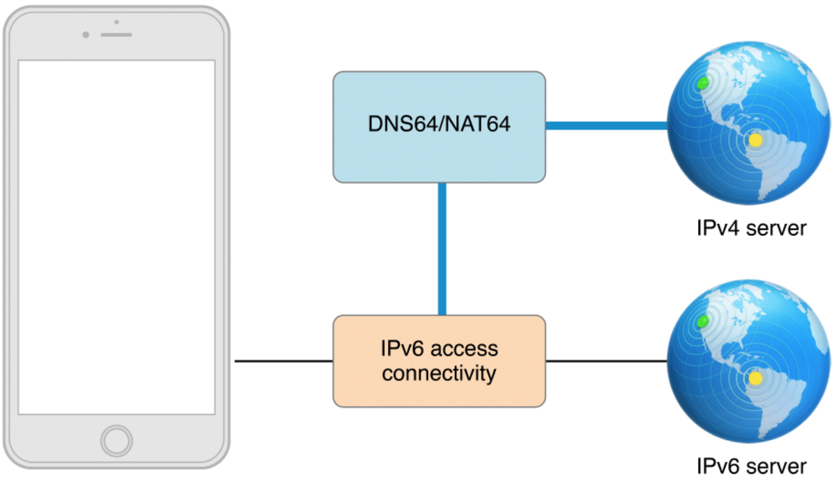
To help slow the depletion of IPv4 addresses, NAT was implemented in many IPv4 networks. Although this solution worked temporarily, it proved costly and fragile. Today, as more clients are using IPv6, providers must now support both IPv4 and IPv6. This is a costly endeavor.

Figure 10-1 A cellular network that provides separate IPv4 and IPv6 connectivity



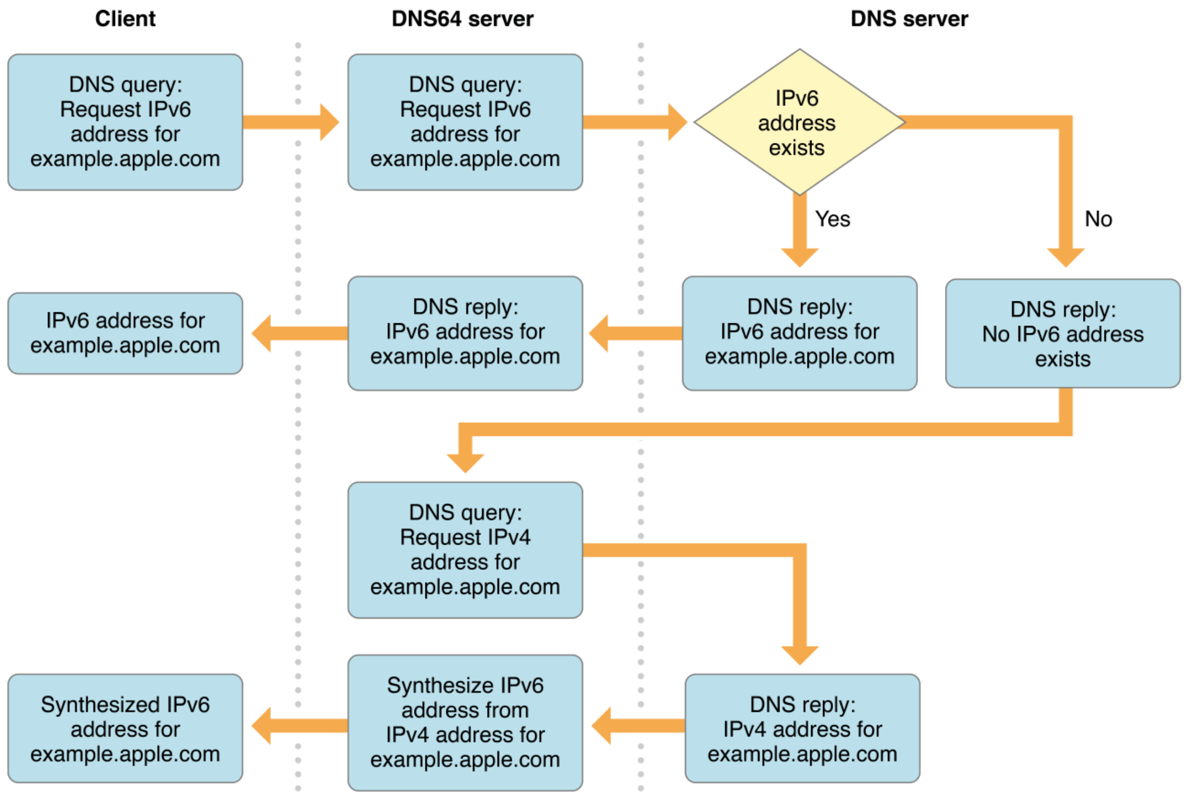
Ideally, providers want to drop support for the IPv4 network. However, doing so prevents clients from accessing IPv4 servers, which represent a significant portion of the Internet. To solve this problem, most major network providers are implementing a DNS64/NAT64 transitional workflow. This is an IPv6-only network that continues to provide access to IPv4 content through translation.

Figure 10-2 A cellular network that deploys an IPv6 network with DNS64 and NAT64



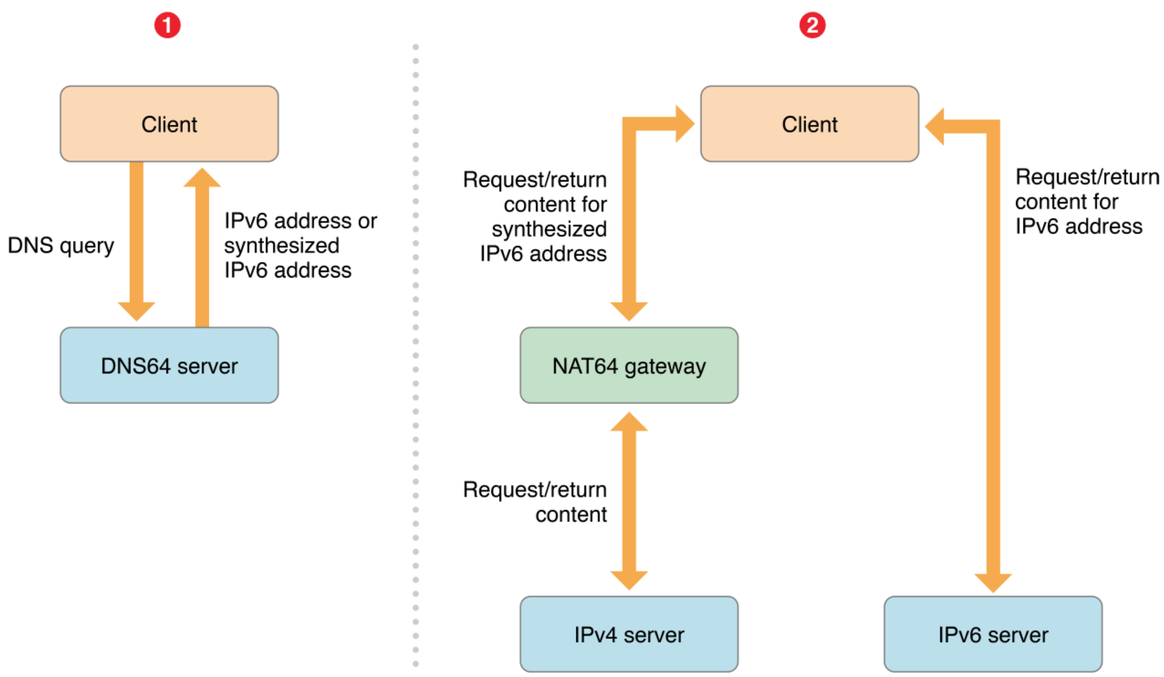
In this type of workflow, the client sends DNS queries to a DNS64 server, which requests IPv6 addresses from the DNS server. When an IPv6 address is found, it's passed back to the client immediately. However, when an IPv6 address isn't found, the DNS64 server requests an IPv4 address instead. The DNS64 server then synthesizes an IPv6 address by prefixing the IPv4 address, and passes that back to the client. In this regard, the client always receives an IPv6-ready address. See Figure 10-3.

Figure 10-3 DNS64 IPv4 to IPv6 translation process



When the client sends a request to a server, any IPv6 packets destined for synthesized addresses are automatically routed by the network through a NAT64 gateway. The gateway performs the IPv6-to-IPv4 address and protocol translation for the request. It also performs the IPv4 to IPv6 translation for the response from the server. See Figure 10-4.

Figure 10-4 Workflow of a DNS64/NAT64 transitional solution



IPv6 and App Store Requirements

Compatibility with IPv6 DNS64/NAT64 networks will be an App Store submission requirement, so it is essential that apps ensure compatibility. The good news is that the majority of apps are already IPv6-compatible. For these apps, it's still important to regularly test your app to watch for regressions. Apps that aren't IPv6-

compatible may encounter problems when operating on DNS64/NAT64 networks. Fortunately, it's usually fairly simple to resolve these issues, as discussed throughout this chapter.

Common Barriers to Supporting IPv6

Several situations can prevent an app from supporting IPv6. The sections that follow describe how to resolve these problems.

- **IP address literals embedded in protocols.** Many communications protocols, such as Session Initiation Protocol (SIP), File Transfer Protocol (FTP), WebSockets, and Peer-to-Peer Protocol (P2PP), include IP address literals in protocol messages. For example, the `FTP` parameter commands `DATA PORT` and `PASSIVE` exchange information that includes IP address literals. Similarly, IP address literals may appear in the values of SIP header fields, such as `To`, `From`, `Contact`, `Record-Route`, and `Via`. See Use High-Level Networking Frameworks and Don't Use IP Address Literals.
- **IP address literals embedded in configuration files.** Configuration files often include IP address literals. See Don't Use IP Address Literals.
- **Network preflighting.** Many apps attempt to proactively check for an Internet connection or an active Wi-Fi connection by passing IP address literals to network reachability APIs. See Connect Without Preflight.
- **Using low-level networking APIs.** Some apps work directly with sockets and other raw network APIs such as `gethostbyname`, `gethostbyname2`, and `inet_aton`. These APIs are prone to misuse or they only support IPv4—for example, resolving hostnames for the `AF_INET` address family, rather than the `AF_UNSPEC` address family. See Use High-Level Networking Frameworks.
- **Using small address family storage containers.** Some apps and networking libraries use address storage containers—such as `uint32_t`, `in_addr`, and `sockaddr_in`—that are 32 bits or smaller. See Use Appropriately Sized Storage Containers.

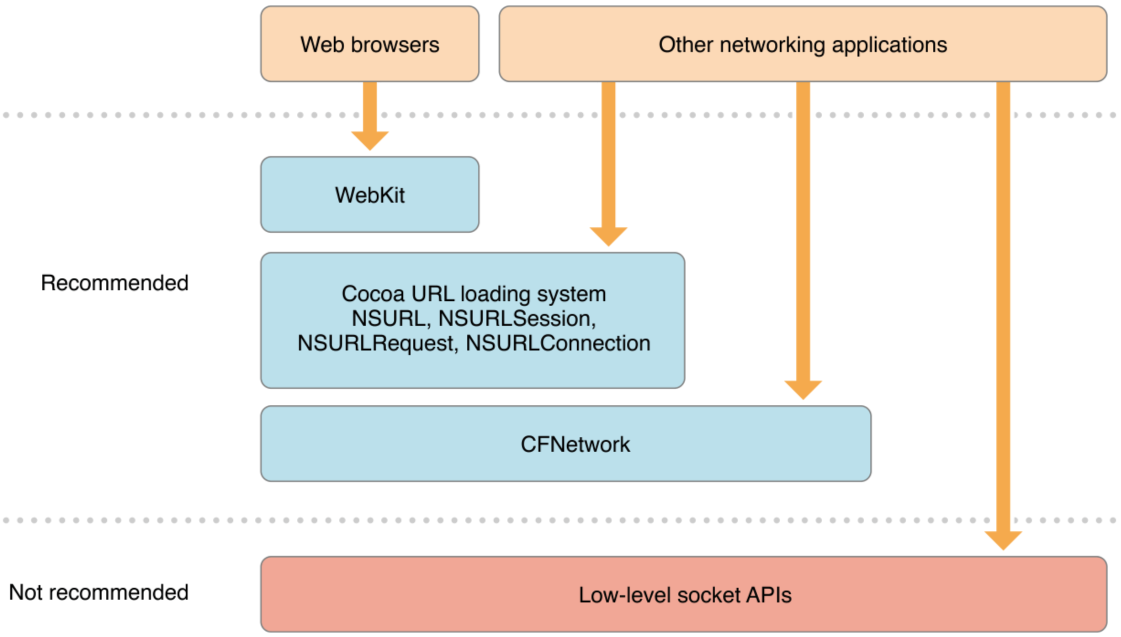
Ensuring IPv6 DNS64/NAT64 Compatibility

Adhere to the following guidelines to ensure IPv6 DNS64/NAT64 compatibility in your app.

Use High-Level Networking Frameworks

Apps requiring networking can be built upon high-level networking frameworks or low-level POSIX socket APIs. In most cases, the high-level frameworks are sufficient. They are capable, easy to use, and less prone to common pitfalls than the low-level APIs.

Figure 10-5 Networking frameworks and API layers



- **WebKit.** This framework provides a set of classes for displaying web content in windows, and implements browser features such as following links, managing a back-forward list, and managing a history of pages recently visited. WebKit simplifies the complicated process of loading webpages—that is, asynchronously requesting web content from an HTTP server where the response may arrive incrementally, in random order, or partially due to network errors. For more information, see *WebKit Framework Reference*.
- **Cocoa URL loading system.** This system is the easiest way to send and receive data over the network without providing an explicit IP address. Data is sent and received using one of several classes—such as `NSURLSession`, `NSURLRequest`, and `NSURLConnection`—that work with `NSURL` objects. `NSURL` objects let your app manipulate URLs and the resources they reference. Create an `NSURL` object by calling the `initWithString:` method and passing it a URL specifier. Call the `checkResourceIsReachableAndReturnError:` method of the `NSURL` class to check the reachability of a host. For more information, see *URL Session Programming Guide*.
- **CFNetwork.** This Core Services framework provides a library of abstractions for network protocols, which makes it easy to perform a variety of network tasks such as working with BSD sockets, resolving DNS hosts, and working with HTTP/HTTPS. To target a host without an explicit IP address, call the `CFHostCreateWithName` method. To open a pair of TCP sockets to the host, call the `CFStreamCreatePairWithSocketToCFHost` method. For more information, see CFNetwork Concepts in *CFNetwork Programming Guide*.

If you do require the low-level socket APIs, follow the guidelines in RFC4038: Application Aspects of IPv6 Transition.

> **Note:** *Getting Started with Networking, Internet, and Web* and *Networking Overview* provide detailed information on networking frameworks and APIs.

Don’t Use IP Address Literals

Make sure you aren’t passing IPv4 address literals in dot notation to APIs such as `getaddrinfo` and `SCNetworkReachabilityCreateWithName`. Instead, use high-level network frameworks and address-agnostic versions of APIs, such as `getaddrinfo` and `getnameinfo`, and pass them hostnames or fully qualified domain names (FQDNs). See `getaddrinfo(3) Mac OS X Developer Tools Manual Page` and `getnameinfo(3) Mac OS X Developer Tools Manual Page`.

> **Note:** In iOS 9 and OS X 10.11 and later, `NSURLSession` and `CFNetwork` automatically synthesize IPv6 addresses from IPv4 literals locally on devices operating on DNS64/NAT64 networks. However, you should still work to rid your code of IP address literals.

Connect Without Preflight

The Reachability APIs (see *SCNetworkReachability Reference*) are intended for diagnostic purposes *after* identifying a connectivity issue. Many apps incorrectly use these APIs to proactively check for an Internet connection by calling the `SCNetworkReachabilityCreateWithAddress` method and passing it an IPv4 address of `0.0.0.0`, which indicates that there is a router on the network. However, the presence of a router doesn’t guarantee that an Internet connection exists. In general, avoid preflighting network reachability. Just try to make a connection and gracefully handle failures. If you must check for network availability, avoid calling the `SCNetworkReachabilityCreateWithAddress` method. Call the `SCNetworkReachabilityCreateWithName` method and pass it a hostname instead.

Some apps also pass the `SCNetworkReachabilityCreateWithAddress` method an IPv4 address of `169.254.0.0`, a self-assigned link-local address, to check for an active Wi-Fi connection. To check for Wi-Fi or cellular connectivity, look for the network reachability flag `kSCNetworkReachabilityFlagsIsWWAN` instead.

Use Appropriately Sized Storage Containers

Use address storage containers, such as `sockaddr_storage`, that are large enough to store IPv6 addresses.

Check Source Code for IPv6 DNS64/NAT64 Incompatibilities

Check for and eliminate IPv4-specific APIs, such as:

- `inet_addr()`

- `inet_aton()`
- `inet_lnaof()`
- `inet_makeaddr()`
- `inet_netof()`
- `inet_network()`
- `inet_ntoa()`
- `inet_ntoa_r()`
- `bindresvport()`
- `getipv4sourcefilter()`
- `setipv4sourcefilter()`

If your code handles IPv4 types, make sure the IPv6 equivalents are handled too.

IPv4	IPv6
`AF_INET`	`AF_INET6`
`PF_INET`	`PF_INET6`
`struct in_addr`	`struct in_addr6`
`struct sockaddr_in`	`struct sockaddr_in6`
`kDNSServiceProtocol_IPv4`	`kDNSServiceProtocol_IPv6`

Use System APIs to Synthesize IPv6 Addresses

If your app needs to connect to an IPv4-only server without a DNS hostname, use `getaddrinfo` to resolve the IPv4 address literal. If the current network interface doesn't support IPv4, but supports IPv6, NAT64, and DNS64, performing this task will result in a synthesized IPv6 address.

Listing 10-1 shows how to resolve an IPv4 literal using `getaddrinfo`. Assuming you have an IPv4 address stored in memory as four bytes (such as `{192, 0, 2, 1}`), this example code converts it to a string (such as `"192.0.2.1"`), uses `getaddrinfo` to synthesize an IPv6 address (such as a `struct sockaddr_in6` containing the IPv6 address `"64:ff9b::192.0.2.1"`) and tries to connect to that IPv6 address.

Listing 10-1 Using `getaddrinfo` to resolve an IPv4 address literal

```
#include <sys/socket.h>
#include <netdb.h>
#include <arpa/inet.h>
#include <err.h>

    uint8_t ipv4[4] = {192, 0, 2, 1};
    struct addrinfo hints, *res, *res0;
    int error, s;
    const char *cause = NULL;

    char ipv4_str_buf[INET_ADDRSTRLEN] = { 0 };
    const char *ipv4_str = inet_ntop(AF_INET, &ipv4, ipv4_str_buf, sizeof(ipv4_str_buf));

    memset(&hints, 0, sizeof(hints));
    hints.ai_family = PF_UNSPEC;
    hints.ai_socktype = SOCK_STREAM;
    hints.ai_flags = AI_DEFAULT;
```

```
    error = getaddrinfo(ipv4_str, "http", &hints, &res0);
    if (error) {
        errx(1, "%s", gai_strerror(error));
        /*NOTREACHED*/
    }
    s = -1;
    for (res = res0; res; res = res->ai_next) {
        s = socket(res->ai_family, res->ai_socktype,
                   res->ai_protocol);
        if (s < 0) {
            cause = "socket";
            continue;
        }

        if (connect(s, res->ai_addr, res->ai_addrlen) < 0) {
            cause = "connect";
            close(s);
            s = -1;
            continue;
        }

        break;  /* okay we got one */
    }
    if (s < 0) {
        err(1, "%s", cause);
        /*NOTREACHED*/
    }
    freeaddrinfo(res0);
```

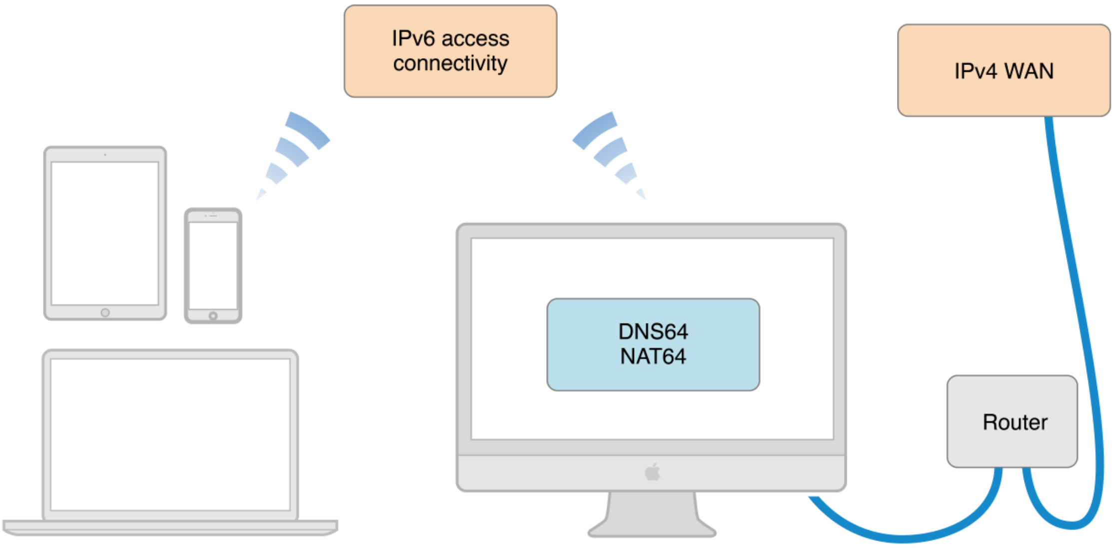
Note: The ability to synthesize IPv6 addresses was added to `getaddrinfo` in iOS 9.2 and OS X 10.11.2. However, leveraging it does not break compatibility with older system versions. See `getaddrinfo(3) Mac OS X Developer Tools Manual Page`.

Test for IPv6 DNS64/NAT64 Compatibility Regularly

The easiest way to test your app for IPv6 DNS64/NAT64 compatibility—which is the type of network most cellular carriers are deploying—is to set up a local IPv6 DNS64/NAT64 network with your Mac. You can then connect to this network from your other devices for testing purposes. See Figure 10-6.

Important: IPv6 DNS64/NAT64 network setup options are available in OS X 10.11 and higher. In addition, a Mac-Based IPv6 DNS64/NAT64 network is compatible with client devices that have implemented support for RFC6106: IPv6 Router Advertisement Options for DNS Configuration. If your test device is not an iOS or OS X device, make sure it supports this RFC. Note that, unlike DNS64/NAT64 workflows deployed by service providers, a Mac-Based IPv6 DNS64/NAT64 always generates synthesized IPv6 addresses. Therefore, it does not provide access to IPv6-only servers outside of your local network.

Figure 10-6 A local Mac-based IPv6 DNS64/NAT64 network



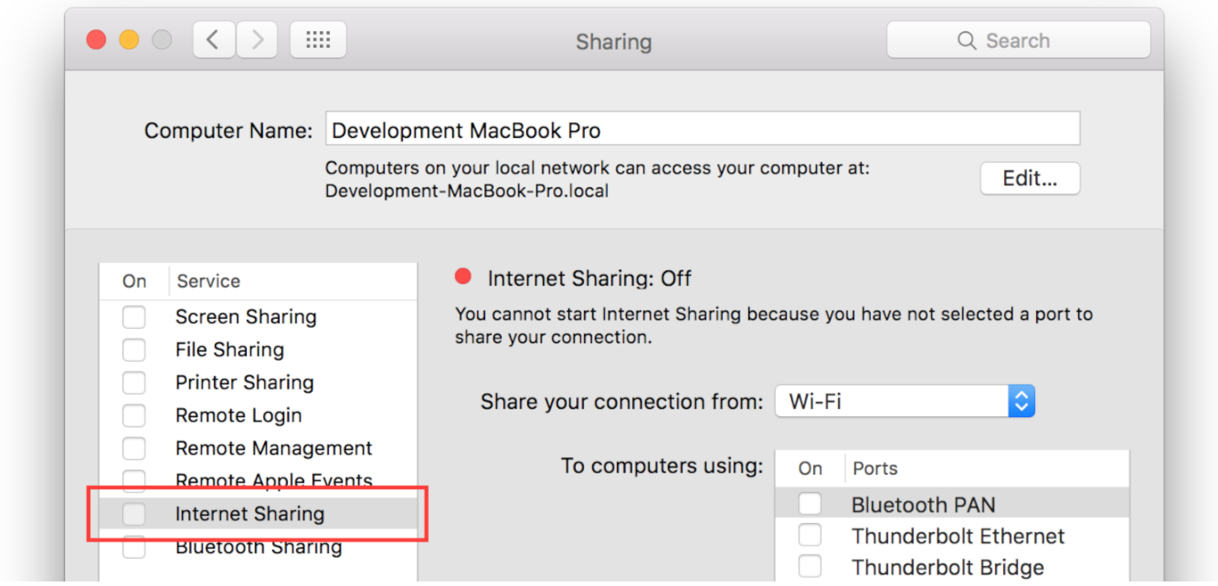
To set up a local IPv6 Wi-Fi network using your Mac

1. Make sure your Mac is connected to the Internet, *but not through Wi-Fi*.
2. Launch System Preferences from your Dock, LaunchPad, or the Apple menu.
3. Press the Option key and click Sharing. Don't release the Option key yet.

Figure 10-7 Opening Sharing preferences

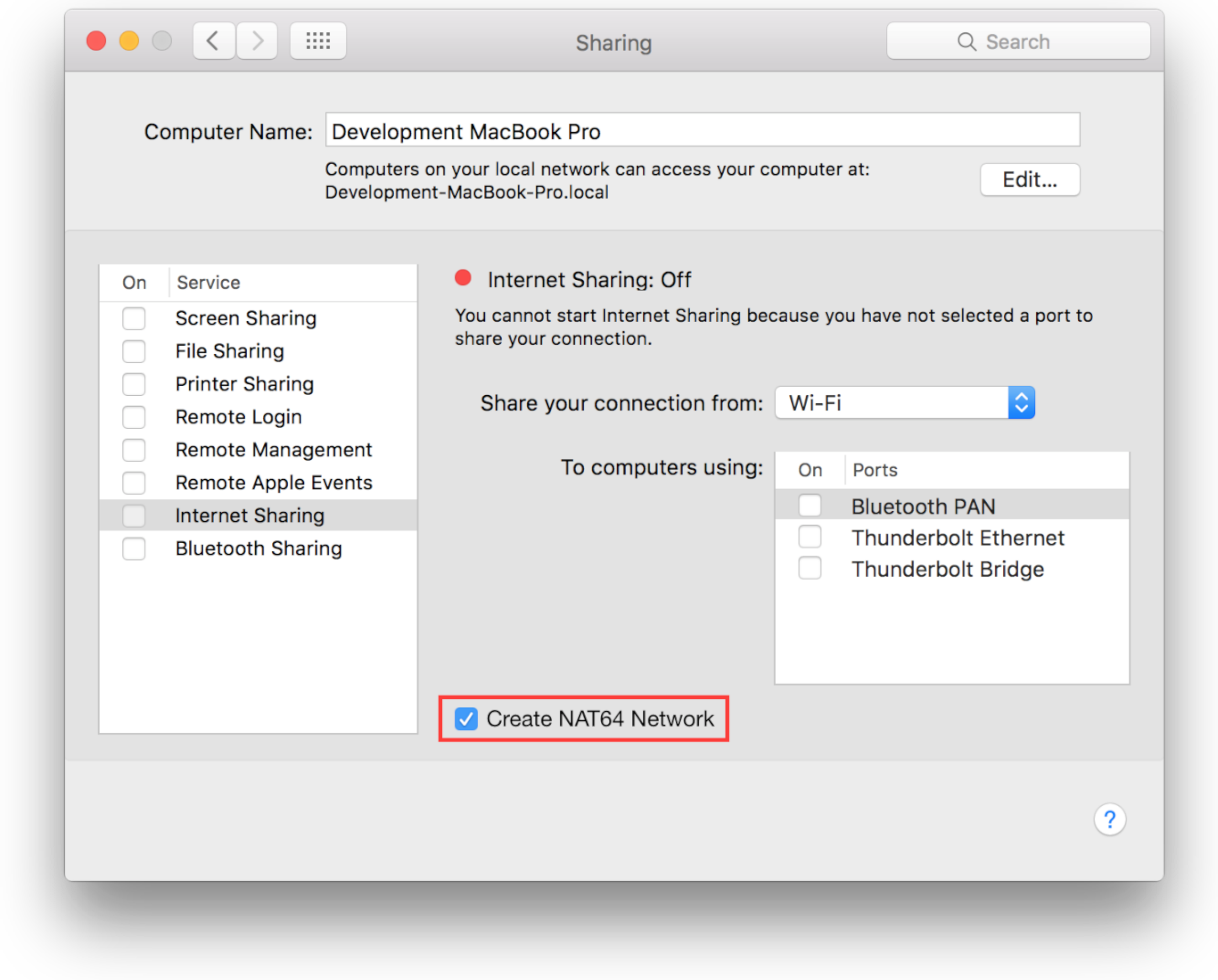
4. Select Internet Sharing in the list of sharing services.

Figure 10-8 Configuring Internet sharing



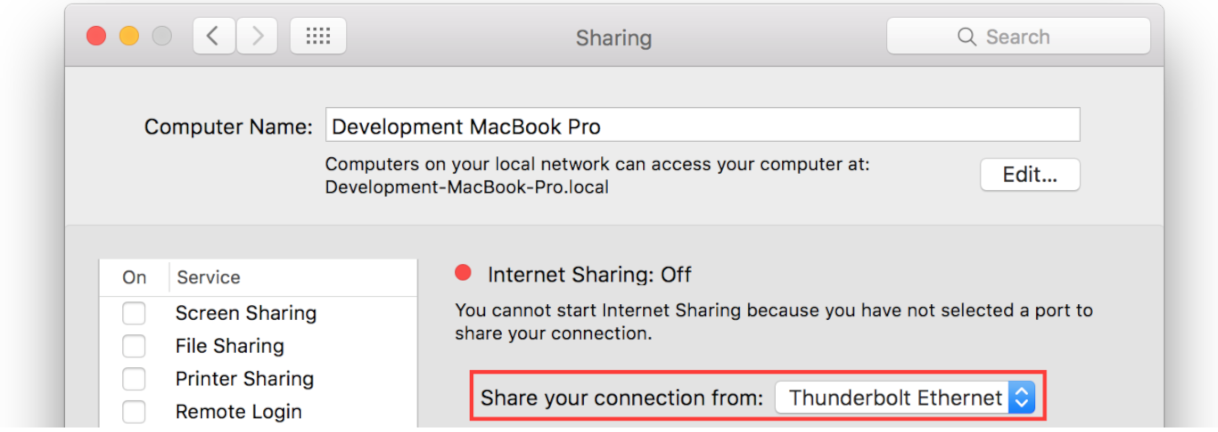
5. Release the Option key.
6. Select the Create NAT64 Network checkbox.

Figure 10-9 Enabling a local IPv6 NAT64 network



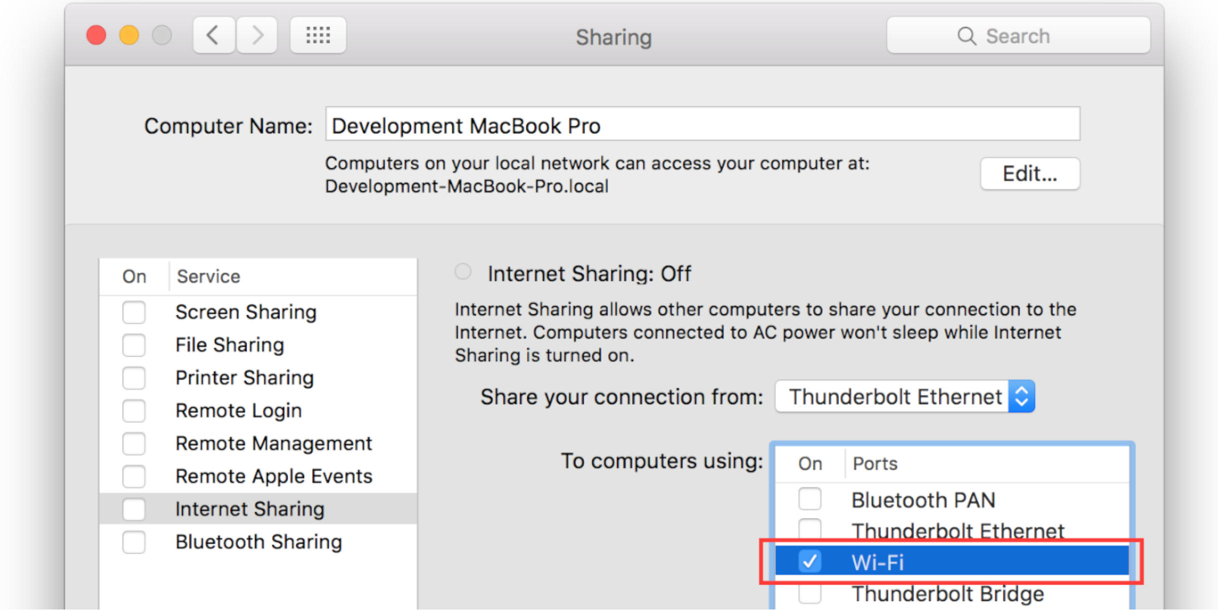
7. Choose the network interface that provides your Internet connection, such as Thunderbolt Ethernet.

Figure 10-10 Choosing a network interface to share



8. Select the Wi-Fi checkbox.

Figure 10-11 Enabling sharing over Wi-Fi



9. Click Wi-Fi Options, and configure the network name and security options for your network.

Figure 10-12 Accessing Wi-Fi network options

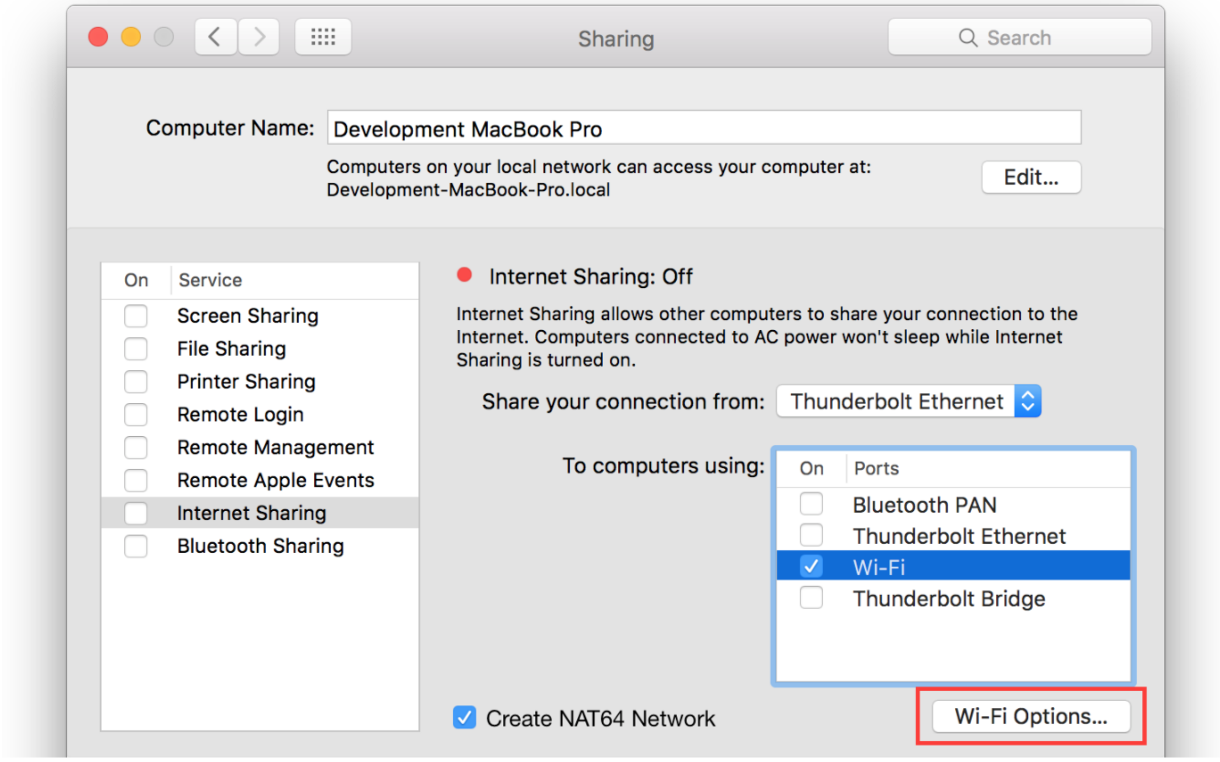
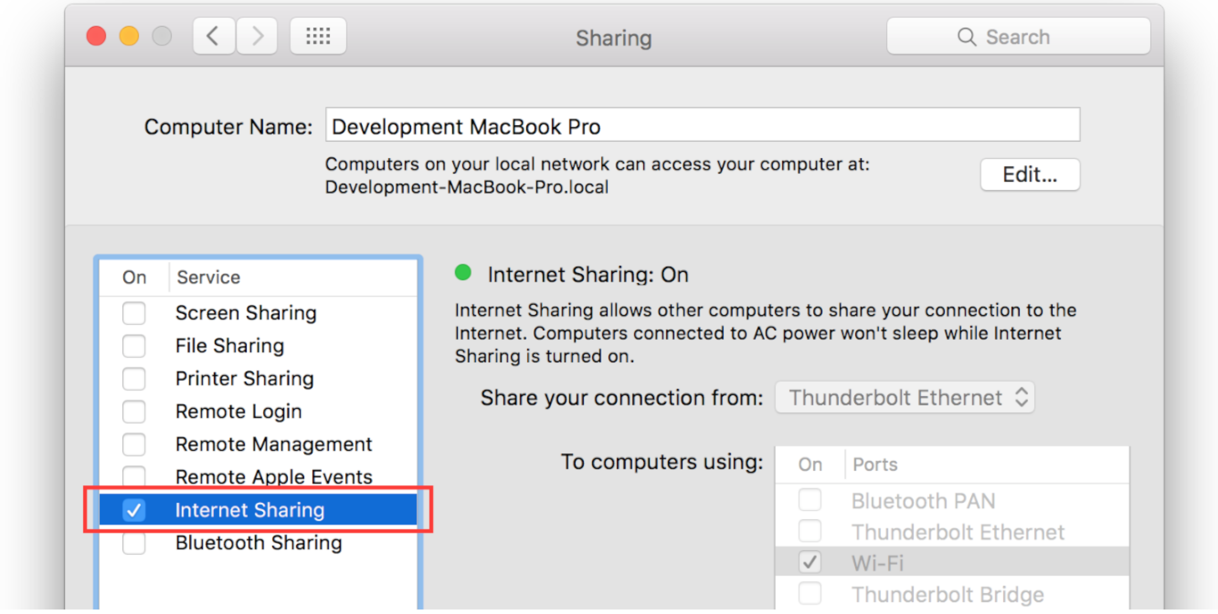


Figure 10-13 Setting up local Wi-Fi network options

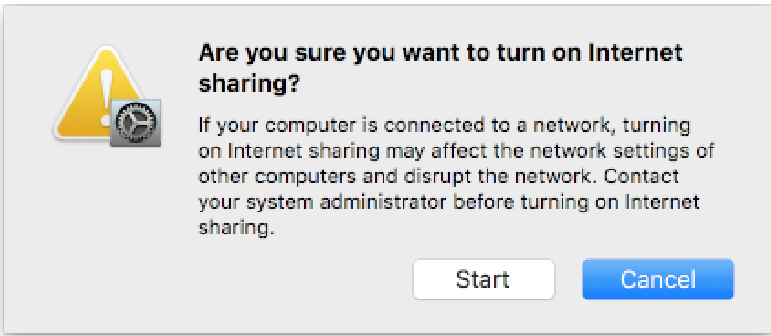
10. Select the Internet Sharing checkbox to enable your local network.

Figure 10-14 Enabling Internet sharing



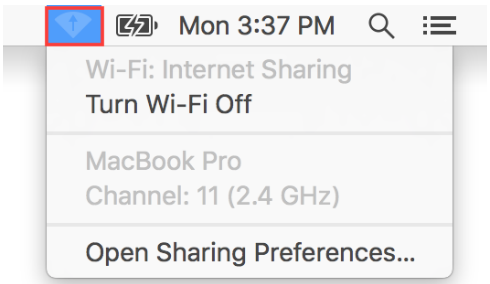
11. When prompted to confirm you want to begin sharing, click Start.

Figure 10-15 Starting Internet sharing



Once sharing is active, you should see a green status light and a label that says Internet Sharing: On. In the Wi-Fi menu, you will also see a small, faint arrow pointing up, indicating that Internet Sharing is enabled. You now have an IPv6 NAT64 network and can connect to it from other devices in order to test your app.

Figure 10-16 Internet sharing indicator



Important: To ensure that testing takes place strictly on the local IPv6 network, make sure your test devices don't have other active network interfaces. For example, if you are testing with an iOS device, make sure cellular service is disabled so you are only testing over Wi-Fi.

Resources

For more information on implementing networking, see:

- *Networking Programming Topics*
- *CFNetwork Programming Guide*
- *NSURLSession Class Reference*
- *WebKit Framework Reference*

For more information on the IPv6 transition, see:

- WWDC15 Video: Your App and Next Generation Networks
- RFC4038: Application Aspects of IPv6 Transition
- World IPv6 Launch website
- American Registry for Internet Numbers (ARIN) IPv4 Depletion Countdown

For technical issues encountered while transitioning to IPv6, see:

- Apple Developer Forums
- Developer Technical Support