Wireless
Wi-Fi

Dual Channel Wi-Fi Windows Station Integration and Operations Guide

WR-GL-Windows-STA-V01-190513

RELEASED

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1 SCOPE

1.1 Introduction and Overview

This document describes how to build and use the Dual Channel Wi-Fi (DCW) feature on PCs running the Windows operating system.

1.2 Purpose of Document

The purpose of this document is to explain the software compilation process for the Dual Channel Wi-Fi feature on the Windows platform. In addition to the integration steps, a basic user manual and troubleshooting guide are included.

2 REFERENCES

2.1 Informative References

None

3 TERMS AND DEFINITIONS

This document uses the following terms.

data channel	A downstream-only Wi-Fi connection used in Dual Channel Wi-Fi for offloading traffic from the primary channel connection.
.NET Framework	A framework developed by Microsoft that uses the Common Language Runtime (CLR), which is used for development of C# Windows applications.
primary channel	The main Wi-Fi connection used in Dual Channel Wi-Fi for both DCW signaling and upstream and downstream traffic.
Visual Studio	A compiler and IDE provided by Microsoft for development on the Windows platform.
Wi-Fi	A technology enabling the wireless transmission and reception of LAN traffic.
Windows	A proprietary operating system developed and owned by Microsoft.
Windows Defender	A security solution available on the Windows OS that includes a firewall component.

4 ABBREVIATIONS AND ACRONYMS

This document uses the following abbreviations.

AP	access point
API	application programming interface
CLR	Common Language Runtime
CPU	central processing unit
DCW	Dual Channel Wi-Fi
DLL	dynamic-link library
IDE	integrated development environment

IP	Internet Protocol
GUI	graphical user interface
LAN	local area network
MMC	Microsoft Management Console
NDIS	Network Driver Interface Specification
OS	operating system
PC	personal computer
PCIe	Peripheral Component Interconnect Express
RRAS	Routing and Remote Access Service
SCM	Service Control Manager
SSID	service set identifier
UAC	User Account Control
USB	Universal Serial Bus

5 ARCHITECTURE OVERVIEW

The Windows operating system (OS) provides several useful application programming interfaces (APIs) and services that are used by Dual Channel Wi-Fi (DCW) (Figure 1). In addition to what is provided by Microsoft, a handful of third-party libraries are used as well.

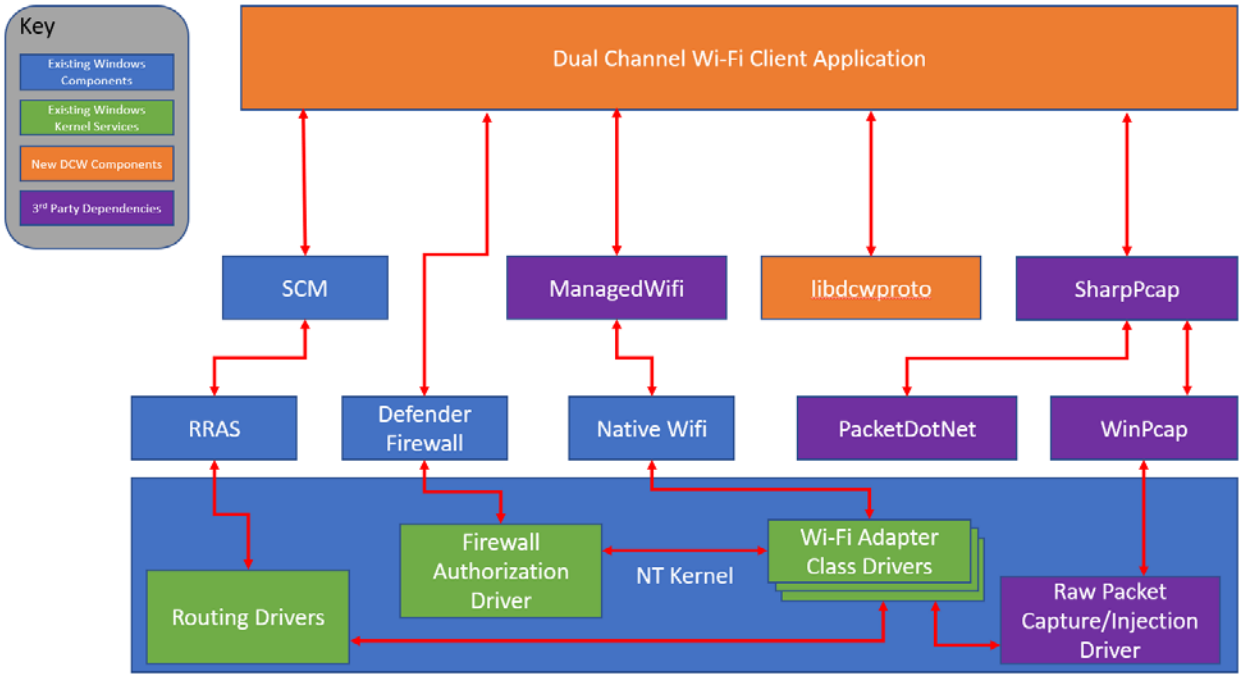


Figure 1 – Windows Dual Channel Wi-Fi Station S/W Architecture Overview

5.1 Client Application

The Dual Channel Wi-Fi Client Application is the heart of the Windows Dual Channel Wi-Fi station functionality. The application is a C# graphical user interface (GUI) application that "minimizes" to the Windows tray when running. The application automatically controls all Dual Channel Wi-Fi signaling and adapter control. Wi-Fi adapters are managed abstractly through the Windows "Native Wifi" services.

Because the architecture of the Windows OS abstracts Wi-Fi adapter control through the "Native Wifi" services, most Wi-Fi adapters certified for Windows should be compatible with Dual Channel Wi-Fi. The Dual Channel Wf-Fi client application manages data channel adapters by using functionality exposed through the "Native Wifi" APIs.

5.2 Control Packet Input/Output

WinPcap is used to expose raw Ethernet frame input/output on the primary channel interface for the Dual Channel Wi-Fi signaling message. To support this function, the primary channel interface is not running in promiscuous mode. Instead, a filter is applied to ensure the client application only receives Dual Channel Wi-Fi packets.

This function was primarily tested and developed using WinPcap; however, if desired, Npcap can be used instead. Use of Npcap has been tested, with no known issues.

WARNING: Using either WinPcap or Npcap for Dual Channel Wi-Fi introduces a potential security vulnerability. In the future, this functionality may need to be moved into a standalone NDIS driver specifically developed for Dual Channel Wi-Fi.

WinPcap website	https://www.winpcap.org/
Npcap website	https://nmap.org/npcap/

5.3 Asymmetrical Routing

Though Windows does support asymmetrical traffic reception, it is not turned on by default and must be enabled. The Dual Channel Wi-Fi Client enables it by invoking the Routing and Remote Access Service (RRAS) though the Service Control Manager (SCM) APIs. Startup of the RRAS triggers the loading of all the drivers required for Windows routing functionality. Thus, simply starting the RRAS is enough to enable asymmetrical traffic reception, which is required for Dual Channel Wi-Fi.

5.4 Preventing Data Channel Transmission

The Windows Defender Firewall in Windows 10 is used to block all packets attempting to transmit through a data channel interface. The ability to create per-interface rule filters is new to Windows 10, so the client application requires this version to automatically block data channel transmission. The client application will run on earlier versions of Windows, but it is recommended that some manual action be taken to block traffic being sent on the data channel interfaces.

6 HARDWARE COMPONENTS

The following hardware components are required for building and running this software.

- A PC capable of running Windows
- Two or more Windows-compatible Wi-Fi adapters installed

7 SOFTWARE COMPONENTS

7.1 Code Repositories

All Dual Channel Wi-Fi code is currently stored in the CableLabs GitHub team "DCW," located at https://github.com/orgs/cablelabs/teams/dcw/repositories.

Each individual software component can be found in their respective git repositories.

libdcwproto	https://github.com/cablelabs/libdcwproto
windcwclient	https://github.com/cablelabs/windcwclient

7.2 Building

These are the build instructions for compiling the Windows Dual Channel Wi-Fi client.

7.2.1 Build Machine Dependencies

Building the Windows Dual Channel Wi-Fi client requires both the C and C# toolchains. Visual Studio Community provides the tools needed to build the Windows client. For this example, Visual Studio Community 2017 was used to build; it can be obtained from https://visualstudio.microsoft.com/vs/community/.

A git client is also required to download the code repositories. For this example, TortoiseGit was used; it can be obtained from https://tortoisegit.org/.

Note: TortoiseGit is not required—another git client can be substituted.

7.2.1.1 Visual Studio Installation Customization

During the initial install of Visual Studio, the following components may be required for working with and building the Dual Channel Wi-Fi client.

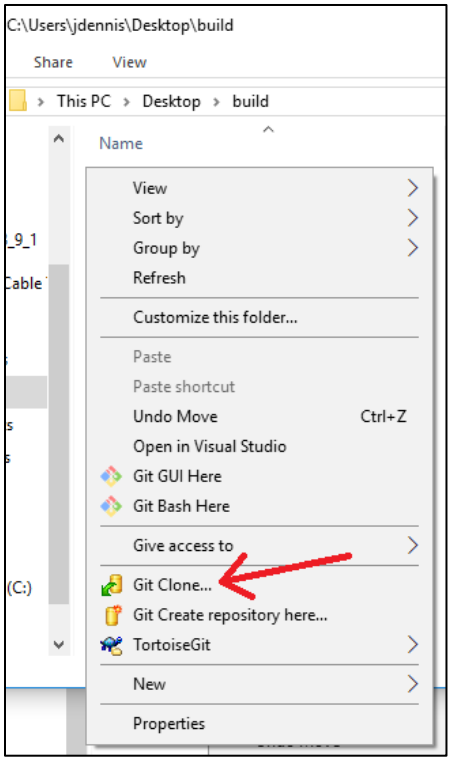
- .NET desktop development
- Universal Windows Platform development
- Desktop development with C++
- Game development with C++

7.2.2 Code Cloning

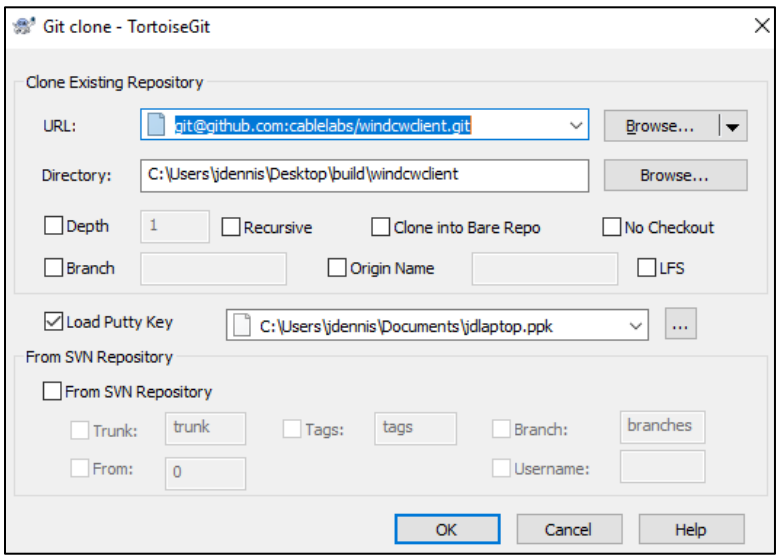
Before building, the code must be cloned from the GitHub repositories. First, create a directory where the source code is to be stored. For the purposes of this example, a folder named “build” was created on the pc desktop.

C:\Users\jdennis\Desktop\build\

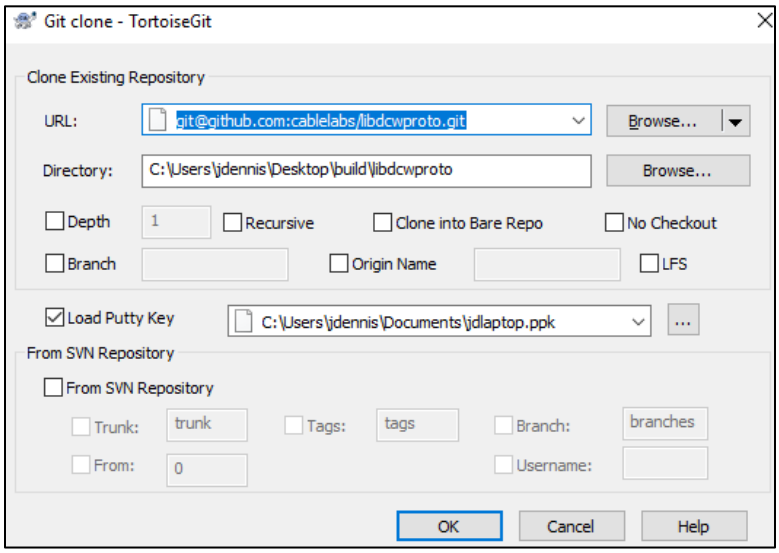
From the build directory, right-click in the empty space to access the Git Clone operation from the menu.



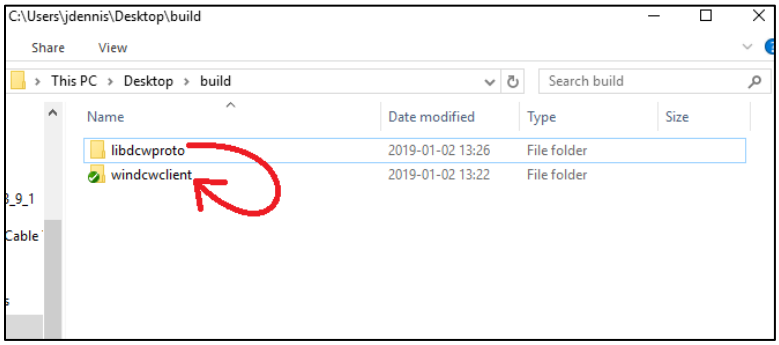
In the Git Clone dialog, the GitHub URL for the Windows Dual Channel Wi-Fi Client (Directory field) is provided.



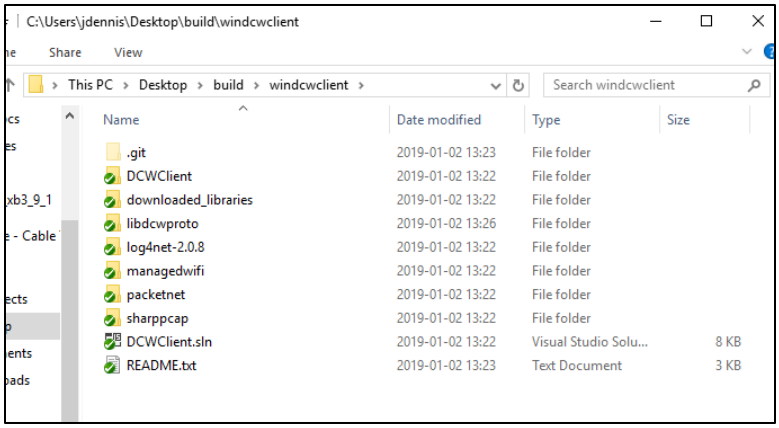
After the Windows Dual Channel Wi-Fi Client is cloned, it is also required to clone the Dual Channel Wi-Fi protocol library (libdcwproto) (Directory field) because it is a dependency.



After cloning the “libdcwproto” component, simply move the directory into the “windcwclient” directory.

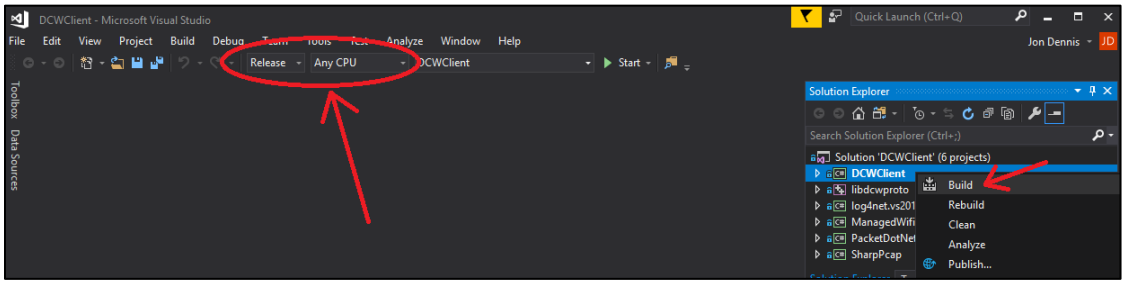


A complete clone should look similar to the following.

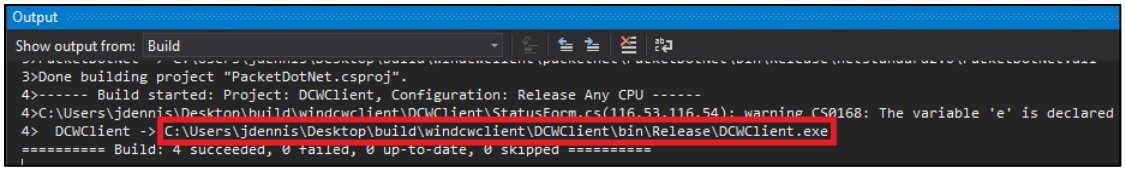


7.2.3 Building the Windows Dual Channel Wi-Fi Component

After each repository has been cloned into its respective directory, double-click the “DCWClient.sln” file to open the entire solution in Visual Studio. Configure the target to the “Release / Any CPU” profile, then right-click the “DCWClient” component in the solution explorer and click the “Build” option.



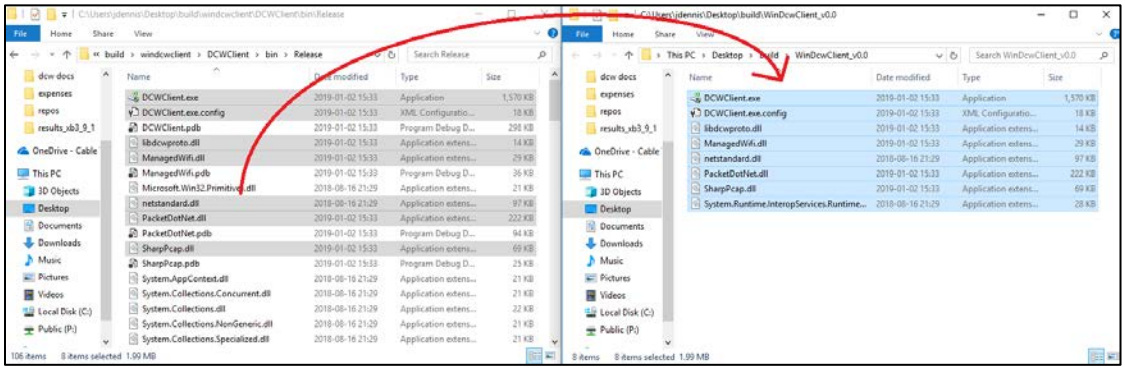
A successful build will show in the output pane and provide the full path to the output binary filename “DCWClient.exe”.



7.2.4 Packaging

After a successful build, the output can be packaged in a zip file for delivery. First, create an empty directory for the copied release files. In this example, the path is “C:\Users\jdennis\Desktop\build\WinDcwClient_v0.0\”. Open the directory in Windows File Explorer. Then, open a new window in Windows File Explorer and navigate to the “DCWClient” component output directory, which is “DCWClient/bin/Release/” from the cloned “windcwsolution” solution directory. Copy over the following files.

- DCWClient.exe
- DCWClient.exe.config
- libdcwproto.dll
- ManagedWifi.dll
- netstandard.dll
- PacketDotNet.dll
- SharpPcap.dll
- System.Runtime.InteropServices.RuntimeInformation.dll



At this point, the WinPcap installed and additional Dual Channel Wi-Fi documentation may be included in the release directory as well. After all the files are in place, the “WinDcwClient_v0.0” release folder can be zipped and distributed.

8 USER GUIDE

8.1 Prerequisites

8.1.1 Windows 10

The Dual Channel Wi-Fi Client has been developed for and tested on the Windows 10 operating system exclusively. Although Dual Channel Wi-Fi does work with versions as early as Windows 7, Windows 10 is recommended for the optimal experience. All instructions in the document are written for the Windows 10 operating system.

8.1.2 Running Dual Channel Wi-Fi on Windows 7

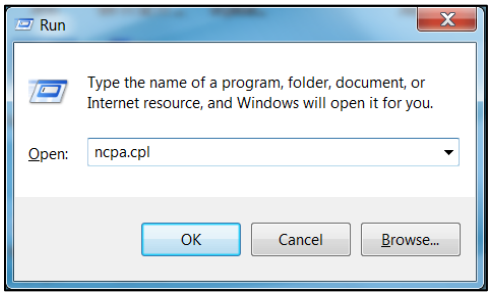
The Windows Defender Firewall adapter-based filtering functionality, which Dual Channel Wi-Fi uses to prevent data channel transmission, was not yet introduced in Windows 7. To work around this limitation, a non-routable, static IP address must be manually assigned to all data channels and a block rule must be manually added to the firewall.

WARNING: The instructions in Section 8.1.2 pertain only to Windows 7. Do not follow these steps if using Windows 10.

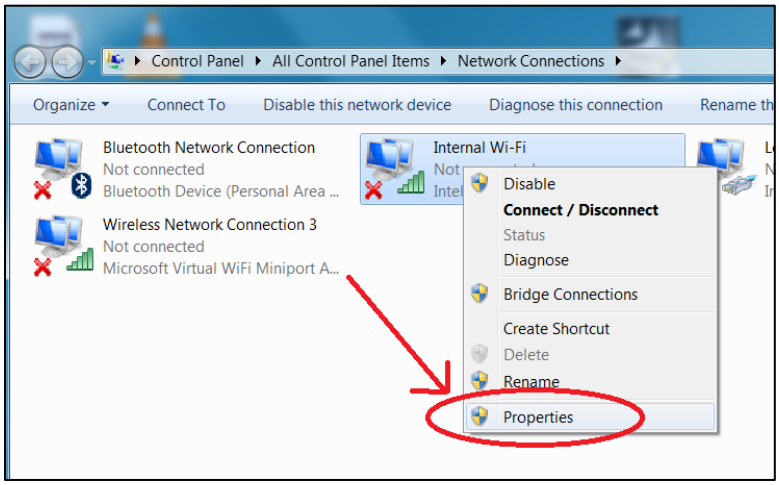
8.1.2.1 Manual Data Channel Adapter Setup

Each data channel adapter must be manually provisioned with a minimal set of protocols and services.

To open the “Network Connections” control panel, first enter the Windows+R key combination on the keyboard to open the “Run” dialog. Type in “ncpa.cpl” then click “OK”.

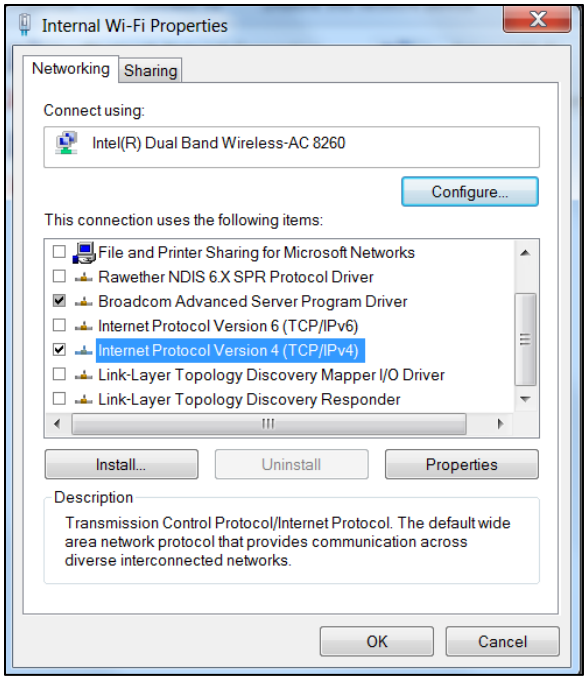


In the “Network Connections” control panel, right-click the adapter that will be used as the data channel, then select the “Properties” option.

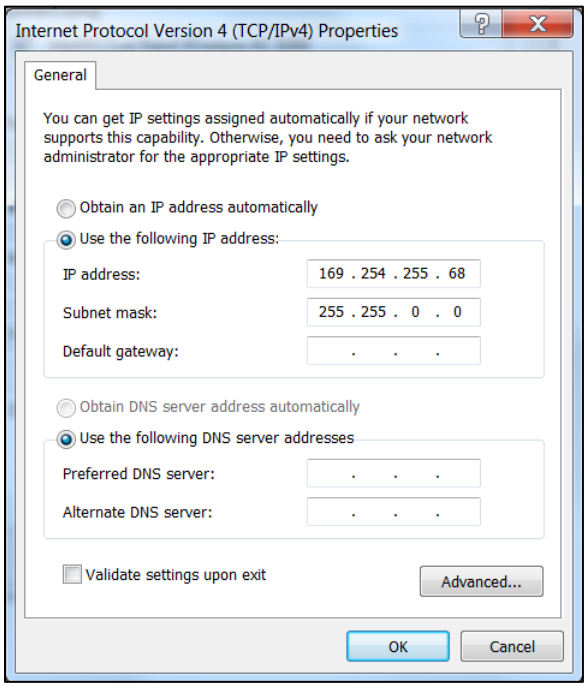


With the adapter's properties dialog open, uncheck all items in the list except for the "Internet Protocol Version 4 (TCP/IPv4)" protocol. This reduces the chance of "noise" packets/frames getting transmitted on this adapter.

Note: The dialog may not allow all items to be disabled/unchecked.



To proceed with manual IP address assignment, click the "Internet Protocol Version 4 (TCP/IPv4)" item, then click the "Properties" button. Assign a non-routable IP address to this interface. For this example, a random address within the 169.254.0.0/16 subnet was assigned.

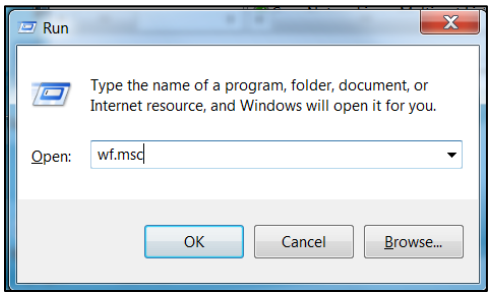


Click "OK" to save and close the IPv4 settings, then click "OK" to save the adapter settings.

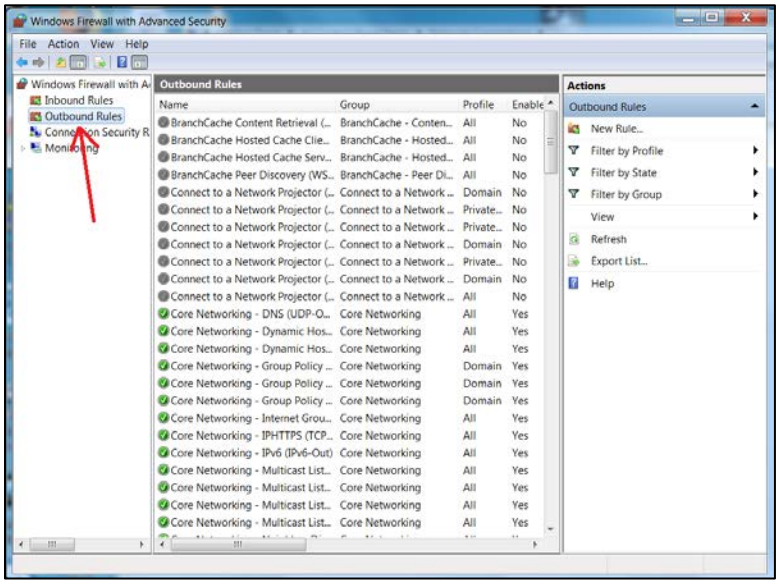
8.1.2.2 Manually Block Outgoing IP Traffic

After each data channel adapter has been manually provisioned with an IP address, each data channel IP address must be added to the Windows Firewall to block transmission on these addresses.

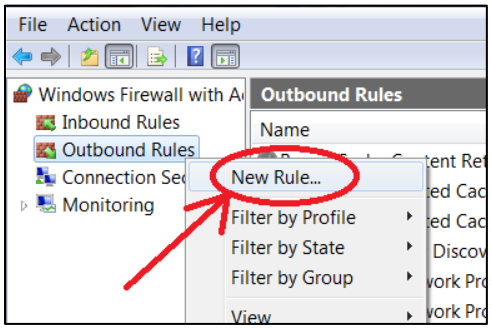
To open the "Windows Firewall with Advanced Security" MMC snap-in, first enter the Windows+R key combination on the keyboard to open the "Run" dialog. Type in "wf.msc" then click "OK".



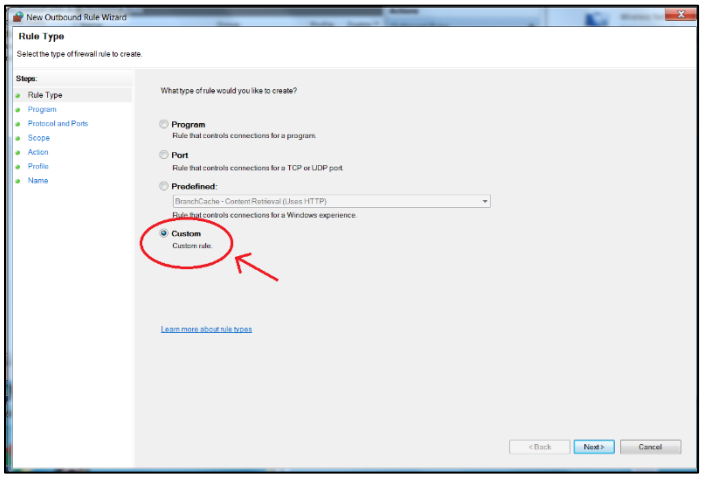
In the "Windows Firewall with Advanced Security" MMC snap-in window, click the "Outbound Rules" option on the left pane. All the configured firewall rules acting on outbound traffic will be displayed.



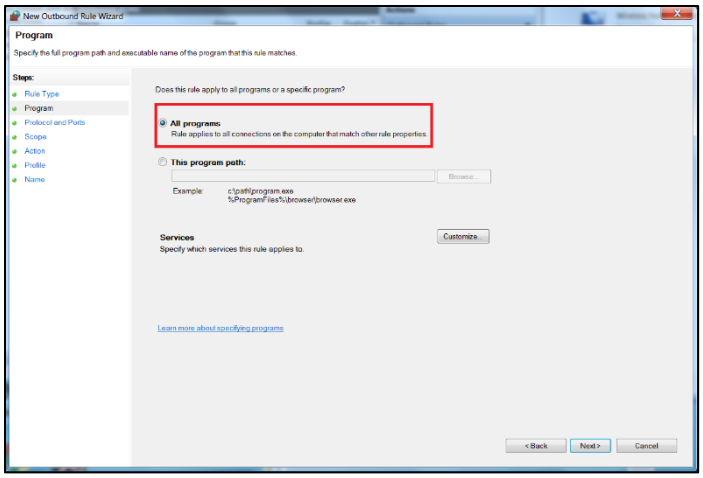
Right-click the "Outbound Rules" option on the left pane, then click the "New Rule…" option.



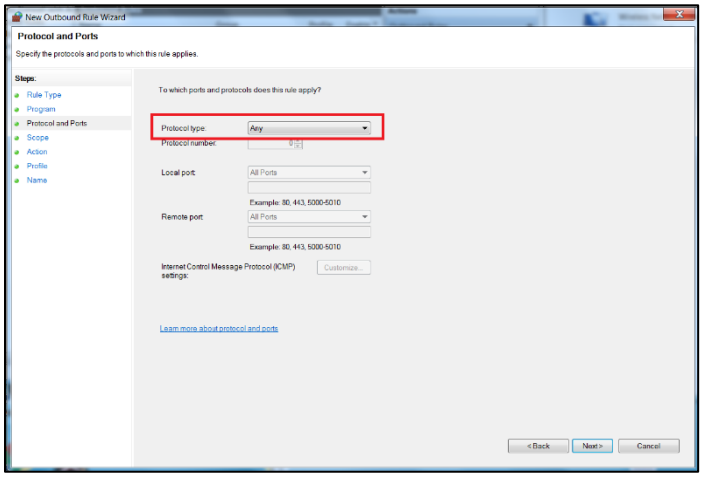
This will open the “New Outbound Rule Wizard” window. Choose the “Custom” option, then click “Next”.



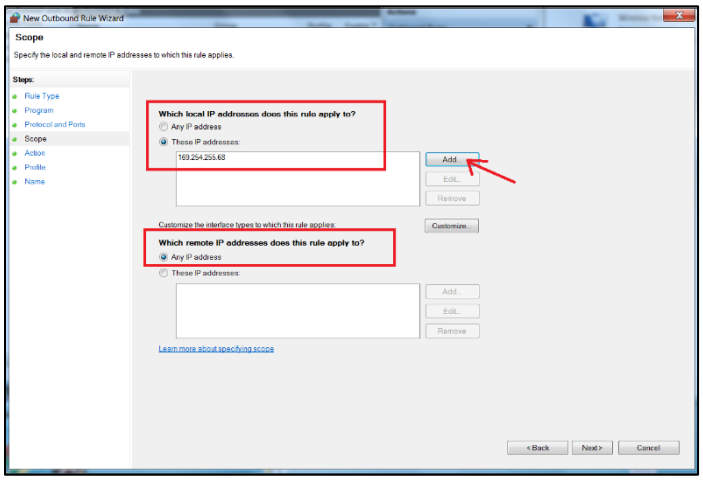
Ensure “All programs” is selected, then click “Next”.



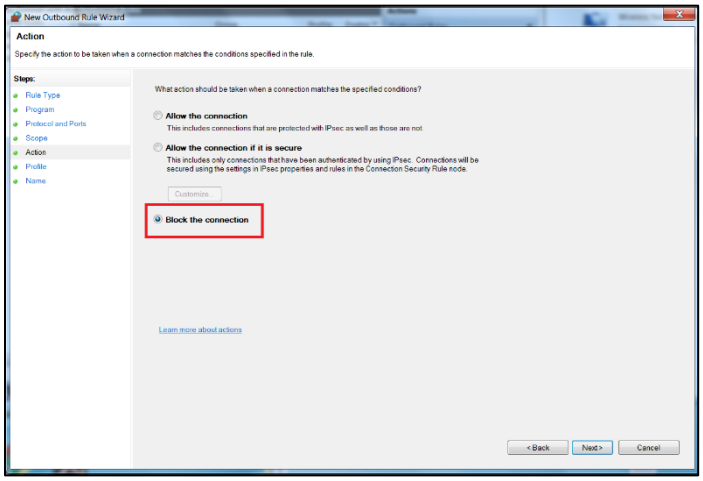
Ensure that the “Any” option is selected for the protocol type, then click “Next”.



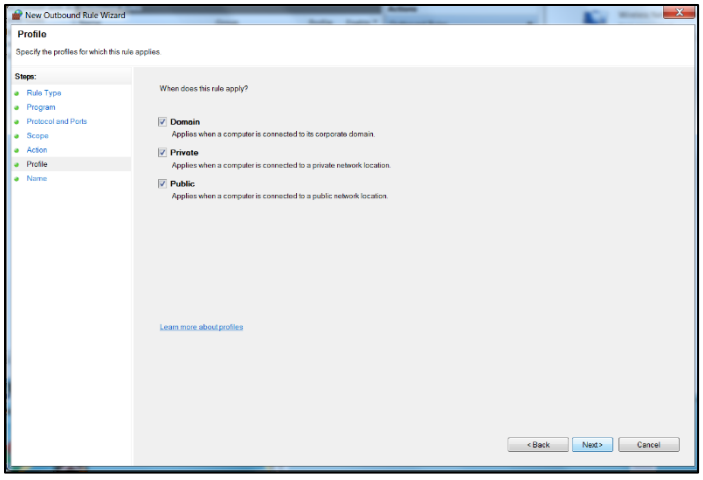
For the local IP address rule application, select “These IP addresses”. Click “Add…” to add the assigned IP address (Section 8.1.2.1). For the remote IP address rule application, ensure “Any IP address” is selected. Click “Next”.



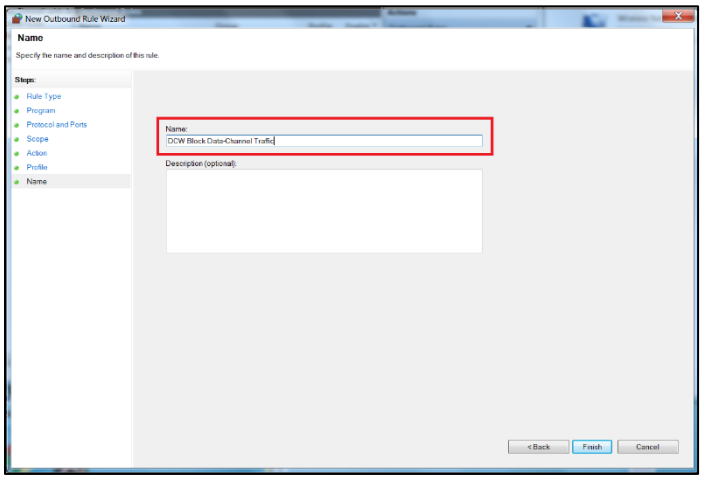
Ensure “Block the connection” is selected, then click “Next”.



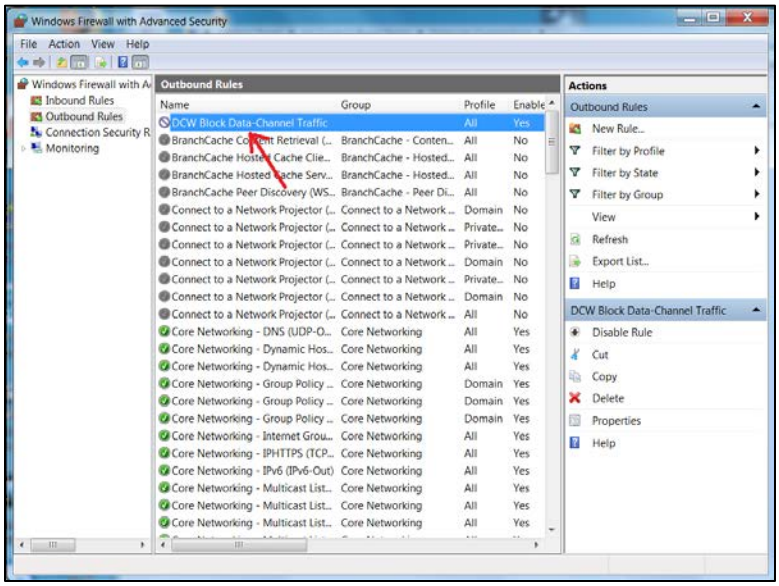
Ensure that all profiles are selected, then click “Next”.



Assign a human-friendly name for this rule that can be easily identified later if it is desired to revert to a non-Dual Channel Wi-Fi configuration. Click “Finish”.



The newly created rule should now appear in the “Outbound Rules” list.

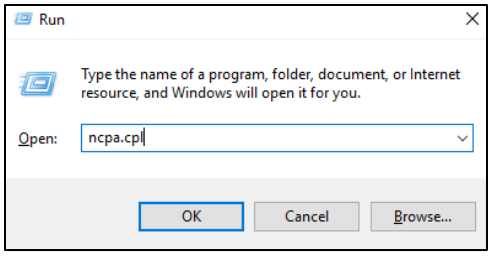


At this point, proceed with the documented setup instructions as normal.

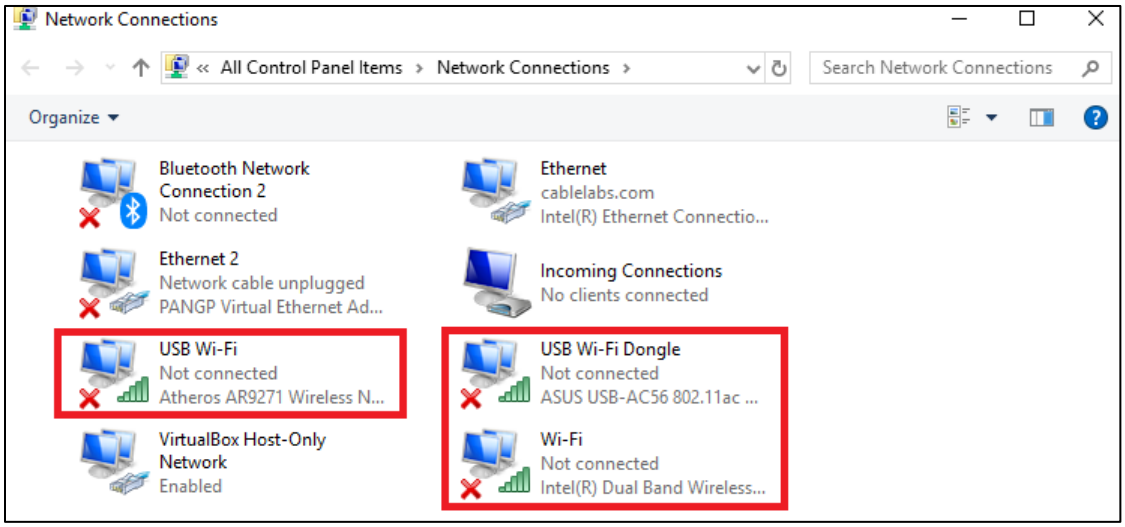
8.1.3 Two or More Wi-Fi Network Adapters

For the Dual Channel Wi-Fi client to work, two or more Wi-Fi network adapters need to be available for use. The installed and functional Wi-Fi network adapters on the computer can be verified in the Windows “Network Connections” control panel.

To open the “Network Connections” control panel, first enter the Windows+R key combination on the keyboard to open the “Run” dialog: Type in “ncpa.cpl” then click “OK”.



In the “Network Connections” control panel, available Wi-Fi adapters are denoted by the “green bars” in the network adapter icon. In the following example, three Wi-Fi network adapters are enabled and available for use.



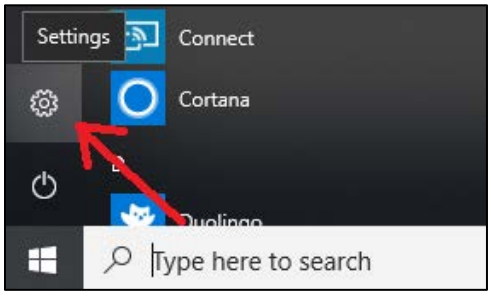
8.1.4 WinPcap Component Installation

To perform network signaling, the Dual Channel Wi-Fi Client requires a lower level protocol functionality. The WinPcap component provides that functionality and is therefore a requirement for using the Dual Channel Wi-Fi Client.

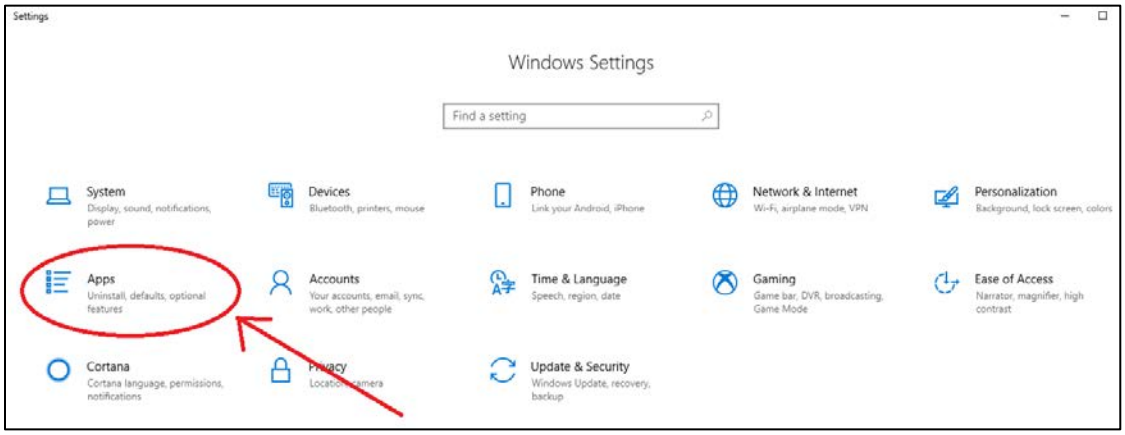
8.1.4.1 Checking for Existing WinPcap Installation

If a tool such as Wireshark is already installed, the WinPcap component may already be installed on the machine. It is advised to check for an existing WinPcap copy before downloading and installing a fresh copy of WinPcap.

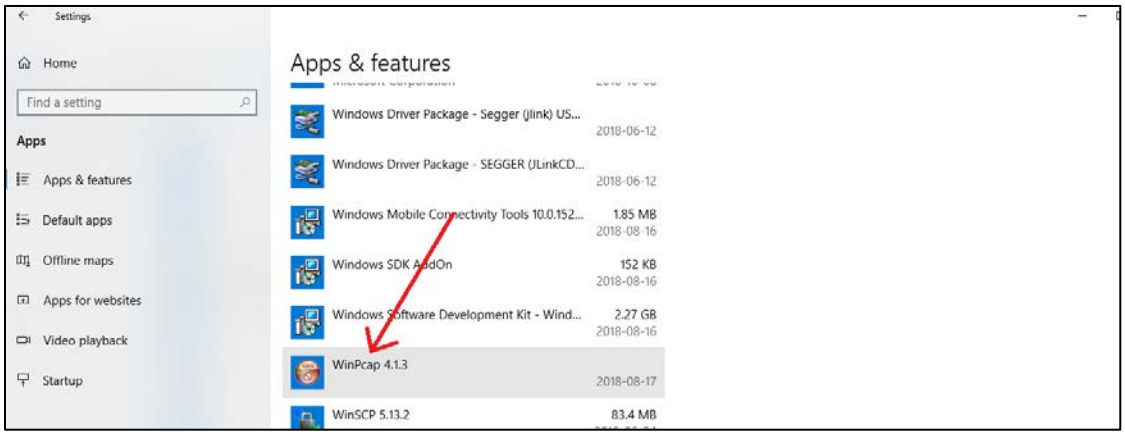
To open the "Windows Settings" window, first open the Start menu then click the Settings (gear) icon.



In the "Windows Settings" window, click the "Apps" option.



Scroll through the list. If "WinPcap" if present, then there is no need to download and install WinPcap.

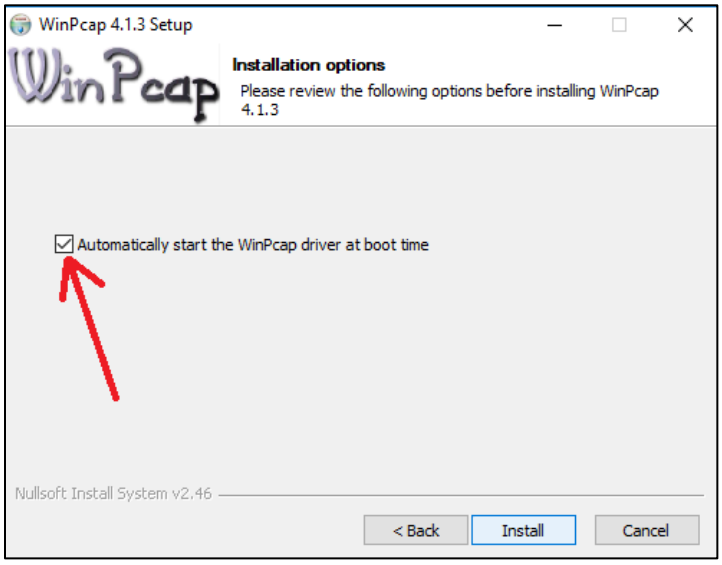


8.1.4.2 WinPcap Download and Installation

WinPcap can be obtained from https://www.winpcap.org/.

Note: A recent copy of the WinPcap installer is included with this file: “WinPcap_4_1_3.exe”.

Run the WinPcap installer. During the installation process, if the wizard gives a prompt to automatically start the WinPcap driver at boot time, enable this option, as shown below.



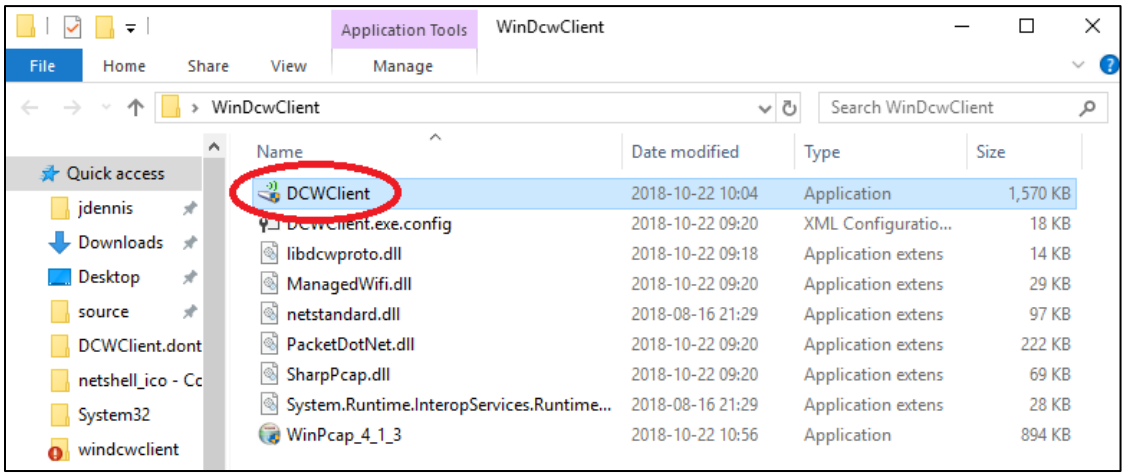
8.2 Using the Dual Channel Wi-Fi Client

The Dual Channel Wi-Fi Client must be manually started to enable Dual Channel Wi-Fi functionality. The client will continue to run in the Windows tray until it is manually shut down or until the computer is shut down or restarted.

8.2.1 Starting the Dual Channel Wi-Fi Client

Before starting the Dual Channel Wi-Fi Client, ensure all Wi-Fi network adapters are physically attached and functional (see Section 8.1.3).

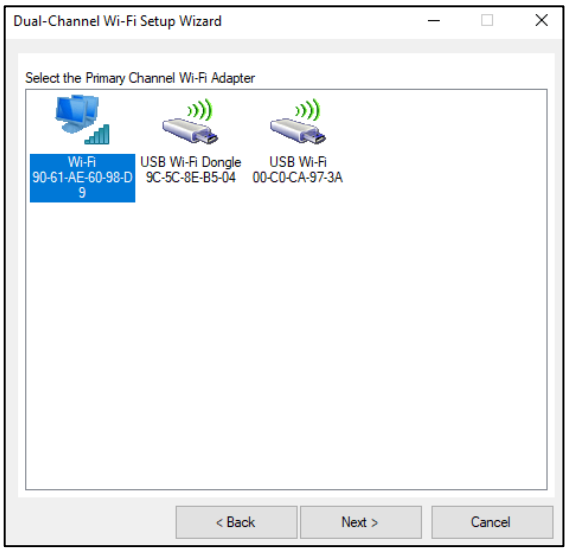
If the Dual Channel Wi-Fi Client files have been delivered in a zip file, extract the “WinDcwClient” directory first; running the files directly from the zip file will not work. After the “WinDcwClient” directory has been extracted, double-click the “DCWClient.exe” file to open the setup wizard.



Note: If prompted with the “User Account Control” (UAC) dialog asking to allow it to make changes to the computer, select “yes”.

8.2.1.1 Choosing the Primary Channel Adapter

Proceed with the Dual Channel Wi-Fi setup wizard. During setup, the wizard will give a prompt to select the Wi-Fi adapter to be used as the primary channel.

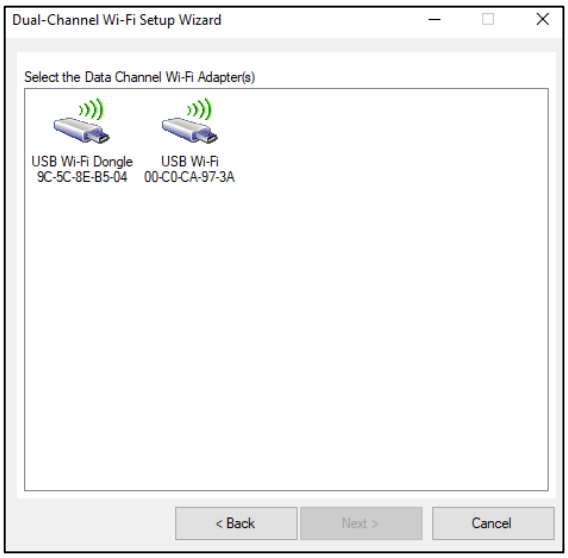


The primary channel adapter is the “normal” Wi-Fi network adapter used to communicate and to connect to and disconnect from the Wi-Fi access point(s).

Note: Built-in and PCI(e) adapters will be displayed with the standard Windows Wi-Fi network adapter icon, and USB adapters will be displayed with the USB Wi-Fi dongle icon.

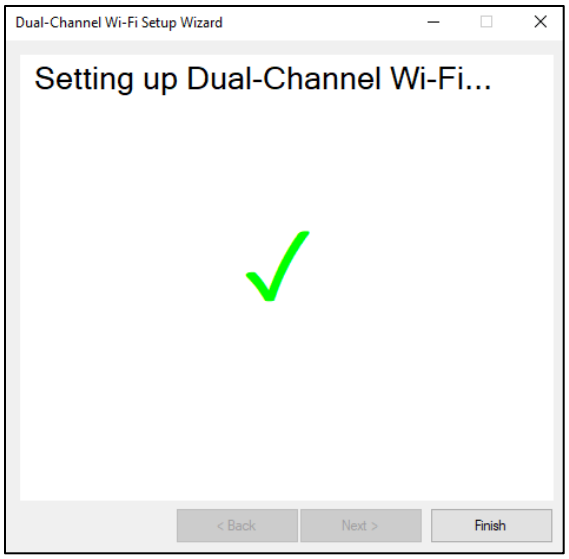
8.2.1.2 Choosing the Data Channel Adapter(s)

After the primary channel adapter is chosen, the wizard will then give a prompt to select one or more data channel Wi-Fi network adapters.

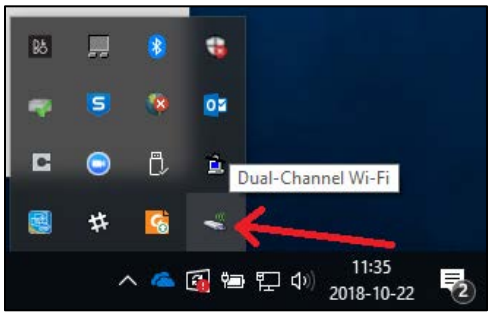


At least one data channel adapter must be selected, but additional adapters may be selected. While the Dual Channel Wi-Fi Client is running, these adapters will be dynamically managed by the Dual Channel Wi-Fi Client and will cease to function. The Dual Channel Wi-Fi Client will automatically connect and disconnect the selected adapter(s) depending on available Dual Channel Wi-Fi services. To use these adapters independently, the Dual Channel Wi-Fi Client must be shut down.

If setup is successful, a green checkmark will appear at the end of the setup wizard. Click “Finish”.

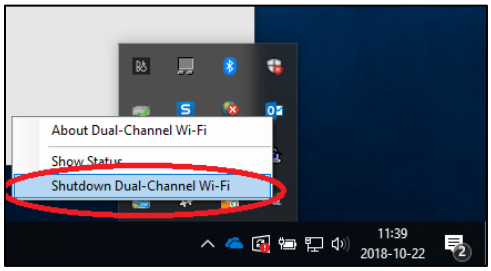


The Dual Channel Wi-Fi Client will be minimized to the Windows tray while operational.



8.2.2 Shutting Down the Dual Channel Wi-Fi Client

If Dual Channel Wi-Fi Client functionality is no longer desired, the Dual Channel Wi-Fi Client may be shut down by right-clicking on the Dual Channel Wi-Fi Client tray icon and clicking the “Shutdown Dual Channel Wi-Fi” option.

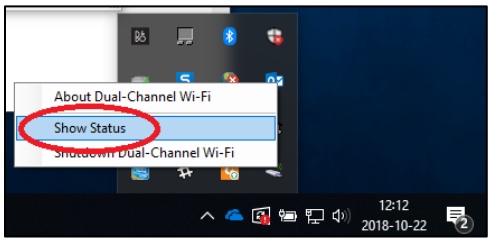


9 TROUBLESHOOTING

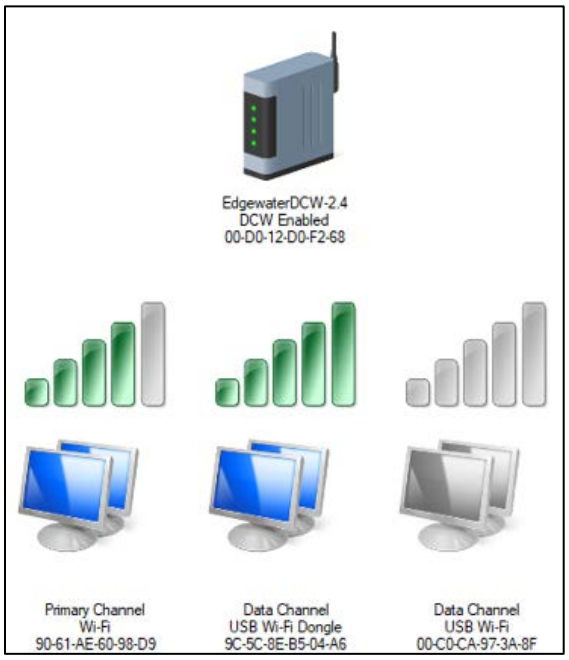
9.1 Accessing the Dual Channel Wi-Fi Client Status Page

Many Dual Channel Wi-Fi connection issues can be solved by first checking the status page. The status page is updated in real time, so it may be left open to monitor any changes.

To access the status page, right-click the Dual Channel Wi-Fi Client tray icon and click the "Show Status" option.

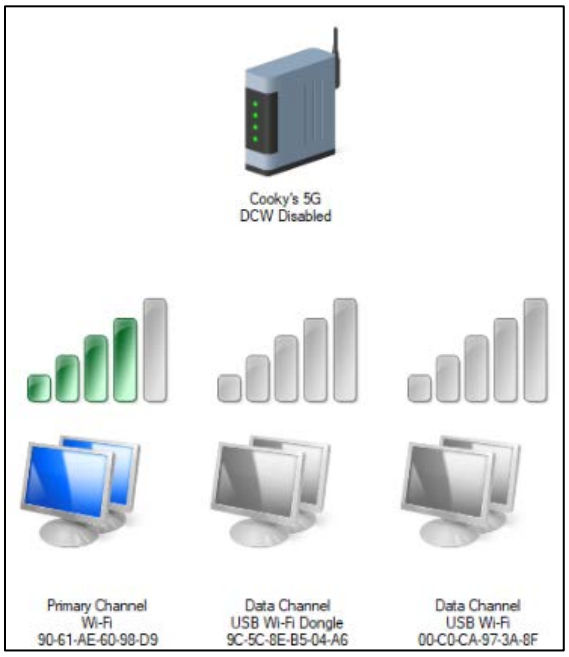


The image below shows what the status page looks like when an access point (AP) is fully connected to a Dual Channel Wi-Fi capable network.



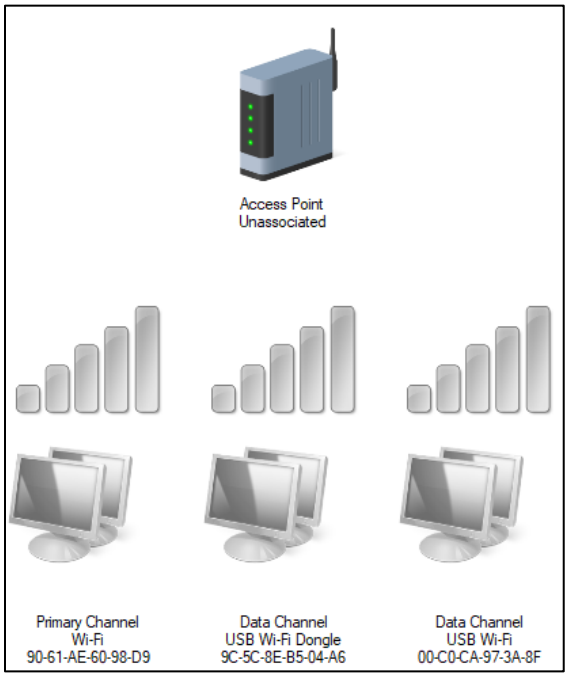
The Wi-Fi AP icon displays the associated service set identifier (SSID); the "DCW Enabled" message shows that the currently connected AP is operating in Dual Channel Wi-Fi mode. In the above example, the client (station) has two data channel Wi-Fi network interfaces, but one of them is grayed out, indicating that only one data channel is connected to the AP. In this case, the connected AP currently supports only one data channel.

The image below shows what the status page looks like when an AP is connected to a network that is not Dual Channel Wi-Fi capable.



The Wi-Fi AP icon displays the associated SSID; the "DCW Disabled" message shows that the currently connected AP is not operating in Dual Channel Wi-Fi mode. Both data channel Wi-Fi network interfaces are grayed out; indicating that they are disconnected and not currently in use.

The image below shows what the status page looks like when the primary channel is unassociated.



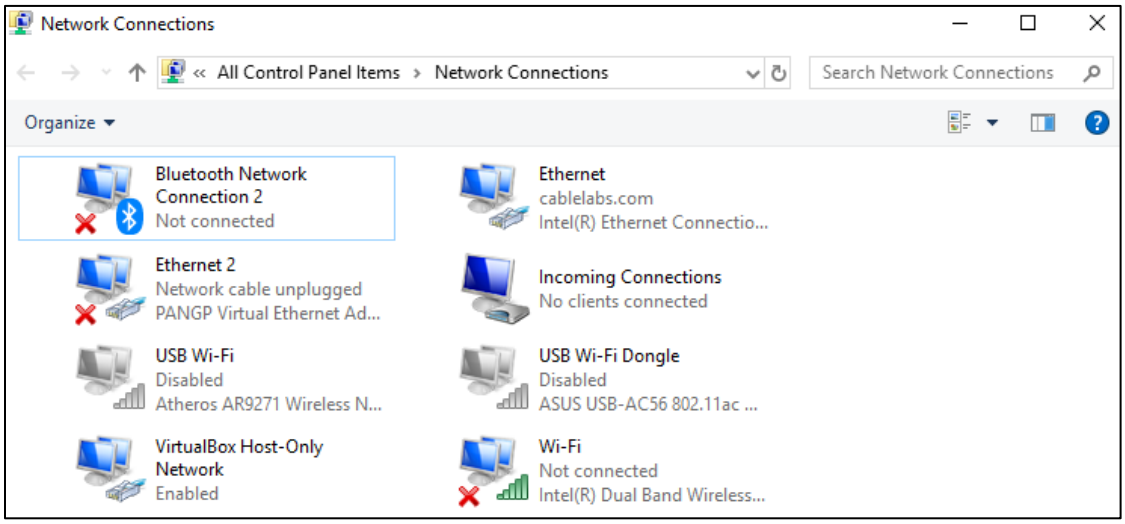
All Wi-Fi network interfaces are grayed out.

9.2 The Setup Wizard Crashes or Exits

Ensure the entire "WinDcwClient" directory has been correctly unzipped. If unsure, delete the entire "WinDcwClient" directory and unzip again.

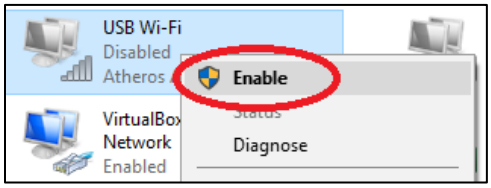
9.3 The Setup Wizard Does Not Display the Desired Wi-Fi Network Adapter

If a Wi-Fi network adapter is displayed in the Windows "Network Connections" control panel but is not an option in the Dual Channel Wi-Fi Client setup wizard, the adapter may need to be enabled. Open the Windows "Network Connection" control panel (see Section 8.1.3) to determine if an adapter is disabled or enabled.



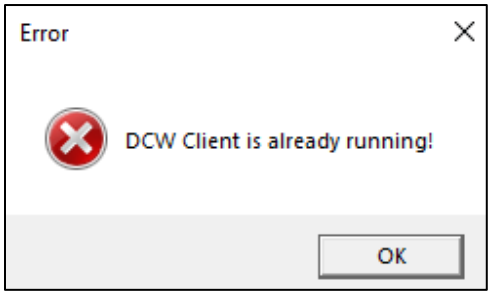
In the above example, the adapters "USB Wi-Fi" and "USB Wi-Fi Dongle" are disabled, indicated by the gray icons and the presence of the "Disabled" status label. Disabled adapters cannot be used for Dual Channel Wi-Fi.

To enable an adapter, right-click the desired adapter and click "Enable".



9.4 At Startup, an Error Message Says the Client Is Already Running

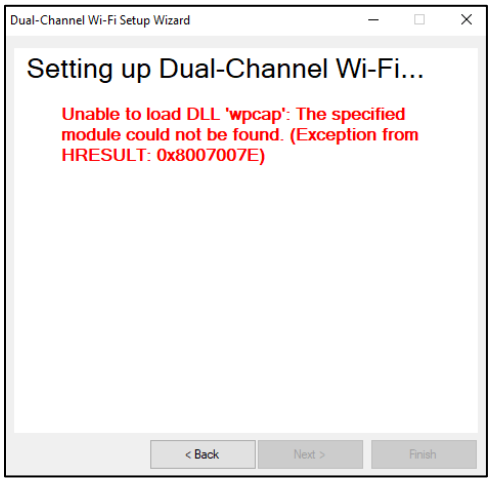
Only one Dual Channel Wi-Fi Client instance can be running at a time on a single system. An attempt to start a second instance will prompt the following message.



If it is desired to restart or reconfigure the Dual Channel Wi-Fi Client, the existing client must first be shut down (see Section 8.2.2).

9.5 The Dual Channel Wi-Fi Client Setup Wizard Cannot Be Completed

The Dual Channel Wi-Fi Client setup wizard may fail for several reasons. The most common error is related to the "wpcap" DLL. An error message similar to the one shown below indicates that the WinPcap component is either not installed or corrupt. In this event, it is advised to (re)install the WinPcap component (see Section 8.1.4.2).



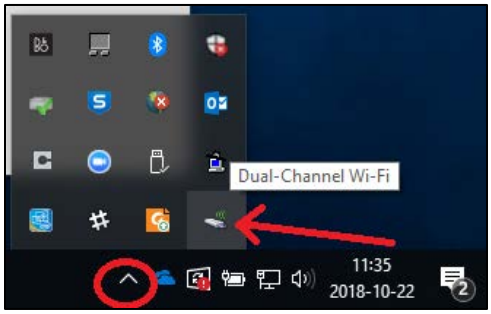
10 KNOWN ISSUES AND LIMITATIONS

10.1 The Dual Channel Wi-Fi Client Is Shut Down but the Former Data Channel Wi-Fi Network Adapters No Longer Function

There is a known issue that may occur if the Dual Channel Wi-Fi Client is not cleanly shut down: data channel Wi-Fi network interfaces that were previously used by the Dual Channel Wi-Fi Client may be permanently in a non-function state. There are a few ways to work around this issue.

First, ensure that the Dual Channel Wi-Fi Client is not currently running. The Dual Channel Wi-Fi Client icon will appear in the Windows tray when it is running.

The icon might be hidden to reduce clutter in the tray; click the arrow on the right of the tray to "Show hidden icons".



If the Dual Channel Wi-Fi Client icon is visible, follow the procedure outlined in Section 8.2.2 to cleanly shut down the client. At this point, the data channel interfaces should be restored to a functional state, ready for any use.

If the Dual Channel Wi-Fi Client is confirmed to be not running but the former data channel interfaces are still not functional, then it is likely that the Dual Channel Wi-Fi Client did not exit cleanly. To resolve this, the Dual Channel Wi-Fi Client should be restarted and cleanly shut down. During the setup process, any traces of a previous setup will be cleaned. Then the client will then be able to clean properly when it is shut down.

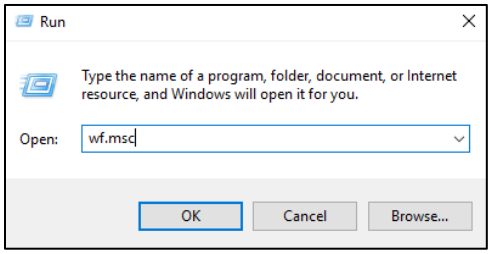
If you are unable to perform a complete startup and shutdown of the Dual Channel Wi-Fi Client, see Section 10.1.1. (below) for instructions on performing the cleanup procedure manually.

10.1.1 Manually Removing the Dual Channel Wi-Fi Client Windows Firewall Rules

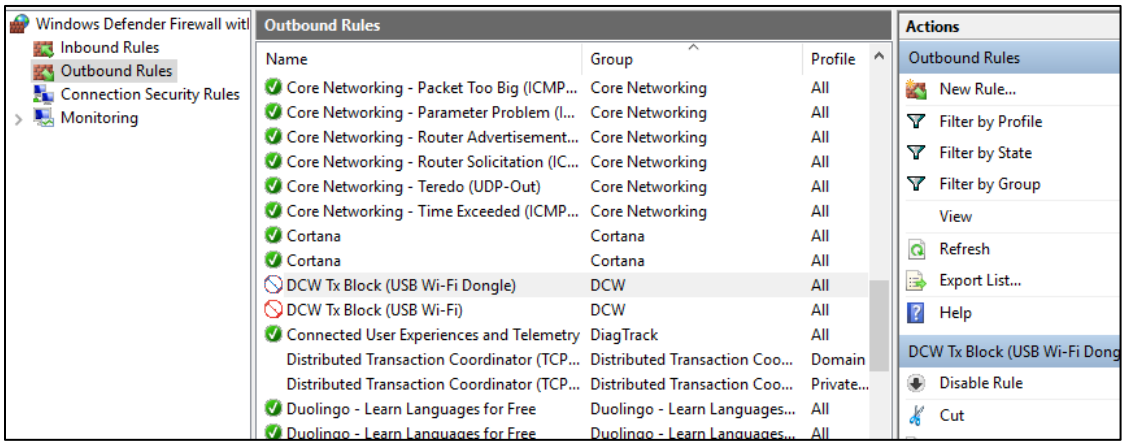
WARNING: Tampering with the Windows firewall without fully understanding the implications can leave a computer exposed to security vulnerabilities. These instructions are intended to be a last-resort measure. One should proceed at his or her own risk.

The Dual Channel Wi-Fi Client blocks all outbound traffic on the data channel Wi-Fi network interfaces by adding custom rules to the Windows firewall. These rules are removed when the Dual Channel Wi-Fi Client is shut down properly, but if it crashes or is force-killed, then these rules may not be removed, thus leaving the data channel Wi-Fi network interfaces in a permanent state of being unable to send network traffic. Restarting and shutting down the Dual Channel Wi-Fi Client will clean these rules, requiring no manual user intervention.

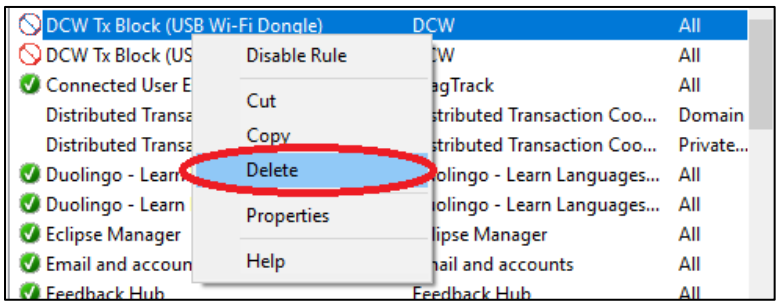
However, if the Dual Channel Wi-Fi Client cannot be run for any reason, the firewall rules can be cleaned manually by using the Windows Firewall MMC configuration snap-in tool. To access this tool, first enter the Windows+R key combination on the keyboard to open the "Run" dialog. Type in "wf.msc" then click "OK".



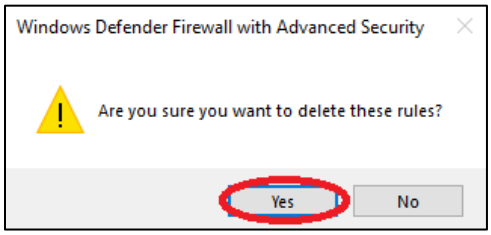
Click the "Outbound Rules" option on the left pane, then click the "Group" heading above the list to sort the rules by group. Scroll through the list until rules in the "DCW" group are found.



Each rule belonging to the "DCW" group must be deleted manually. For each rule in this group, right-click the desired rule then click "Delete".



When prompted to confirm the rule deletion, click “Yes” to proceed.



10.2 Dual Channel Wi-Fi Client Fails to Start on Windows 8.1

The Dual Channel Wi-Fi Client does not function on the Windows 8.1 operating system because it is unable to start the RRAS service.

10.3 Dual Channel Wi-Fi Client Does Not Consistently Acknowledge the AP_QUIT Message from the AP

It has been observed that the Windows Dual Channel Wi-Fi Client does not consistently send an acknowledgement message after receiving an AP_QUIT message from the AP. Although this bug is a deviation from the expected process, it has no impact because the acknowledgement message is ignored by all of the current DCW AP implementations.

* * *