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802.11 Application Framework 2.0.1 Getting Started Guide

This document provides basic information about how to get started with the 802.11 Application Framework.

Contents

System Requirements

Software

- Windows 7 SP1 (64-bit) or Windows 8.1 (64-bit)
- LabVIEW Communications System Design Suite 2.0
  - Installed with the 802.11 Application Framework enabled

Hardware

To use the 802.11 Application Framework for bidirectional data transmission, you need two NI RF devices, either USRP RIO devices with 40 MHz, 120 MHz, or 160 MHz bandwidth, or FlexRIO modules. The two devices can be connected to either one host computer or several host computers, which can be either a PC or PXI chassis. Special test modes using the loopback functionality provided by the framework can be executed with only one NI USRP device. The setup options are shown in Figure 1.

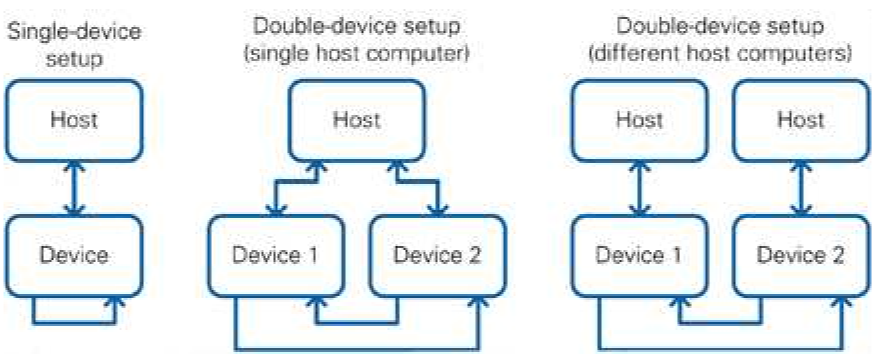

Figure 1 Hardware Configuration Options

Depending on the chosen configuration, the following hardware is required.

Configuration	All setups			USRP RIO setup			FlexRIO/FlexRIO adapter module setup	
	Host PC	SMA Cable	Antenna	USRP	Attenuator	MXI adapter	FlexRIO FPGA module	FlexRIO adapter module
Single device, cabled	1	1	0	1	1	1	1	1
Single device, over-the-air[1]	1	-	2	1	-	1	1	1
Double device, cabled	1	2	-	2	2	2	2	2
Double device, over-the-air[1]	1	-	4	2	-	2	2	2

- Controller: Recommended—PXIe-1085 with a PXIe-8135 controller installed. A second controller is needed for separate host operation.
- SMA cable: Female/female cable that is included with the NI USRP device.
- Antenna: Refer to the *RF Multi Station Mode: Over-the-Air Transmission* section for more information about this mode.
- NI USRP device: USRP-294xR/295xR with 40 MHz, 120 MHz, or 160 MHz bandwidth
- Attenuator with 30 dB attenuation and male/female SMA connectors that are included with the NI USRP device.
- FlexRIO FPGA module: PXIe-7975R/7976R FlexRIO FPGA Module
- FlexRIO adapter module: NI 5791 RF transceiver adapter module

The preceding recommendations assume you are using PXI-based host systems. You can also use a PC with a PCI-based or PCI Express-based MXI adapter, or a laptop with an Express card-based MXI adapter.

Ensure your host has at least 20 GB of free disk space and 8 GB of RAM. To compile bitfiles for the NI RF device FPGA, your system should be equipped with 16 GB RAM.

Caution: Before using your hardware, read all product documentation to ensure compliance with safety, EMC, and environmental regulations.

Caution: To ensure the specified EMC performance, operate the RF devices only with shielded cables and accessories.

Caution: To ensure the specified EMC performance, the length of all I/O cables except for those connected to the GPS antenna input of the USRP device must be no longer than 3 m (10 ft).

Caution: The USRP-29xx and NI 5791 RF devices are not approved or licensed for transmission over the air using an antenna. As a result, operating this product with an antenna may violate local laws. Ensure that you are in compliance with all local laws before operating this product with an antenna.

Understanding the Components of This Sample Project

The project is comprised of LabVIEW host code and LabVIEW FPGA code for the supported NI USRP or FlexRIO hardware targets. The related folder structure and the components of the project are described in the next subsections.

Folder Structure

To create a new instance of the 802.11 Application Framework, select **Launch a Project » Application Frameworks » 802.11 Design USRP RIO v2.0.1**. The following files and folders are created inside the specified folder:

- **802.11 Design USRP RIO v2.0.1.lvproject**—This project file contains information about the linked subGVIs, targets and build specifications.
- **802.11 Host.gvi**—This top-level host VI implements an 802.11 station. The host interfaces with the bitfile build from the top-level FPGA VI, **802.11 FPGA STA.gvi**, located in the target specific subfolder.
- **Builds**—This folder contains the precompiled bitfiles for the selected target device.
- **Common**—The common library contains generic subVIs for the host and FPGA that are used in the 802.11 Application Framework. This code includes mathematical functions and type conversions.
- **FlexRIO/USRP RIO**— These folders contain target-specific implementations of host and FPGA subVIs, which include code to set gain and frequency. This code is in most cases adapted from the given target-specific streaming sample projects. They also contain the target-specific top-level FPGA VIs.
- **802.11 v2.0.1**—This folder comprises the 802.11 functionality itself separated into several FPGA folders and a host directory.

Components

The 802.11 Application Framework provides a real-time orthogonal frequency-division multiplexing (OFDM) physical layer (PHY) and lower media access control (MAC) implementation for an IEEE 802.11-based system. The 802.11 Application Framework LabVIEW project implements the functionality of one station, including receiver (RX) and transmitter (TX) functionality.

Statement of Compliance and Deviations

The 802.11 Application Framework is designed to be compliant with the IEEE 802.11 specifications. To keep the design easily modifiable, the 802.11 Application Framework focuses on the core functionality of the IEEE 802.11 standard.

- 802.11a- (Legacy mode) and 802.11ac- (Very High Throughput mode) compliant PHY
- Training field based packet detection
- Signal and data field encoding and decoding
- Clear Channel Assessment (CCA) based on energy and signal detection
- 802.11a compliant lower-MAC components to support Data frame and ACK frame transmission
- MPDU generation and multi-node addressing
- ACK generation with 802.11 IEEE-compliant SIFS timing (16 μs)

The 802.11 Application Framework supports the following features:

- Long guard interval only
- Single input single output (SISO) architecture, ready for MIMO
- VHT20 and VHT40 for the 802.11ac standard
- A-MPDU with a single MPDU for the 802.11ac standard
- Initial transmissions only, architecture ready for retransmissions
- The backoff value is fixed on the FPGA but is configurable during run-time through the host interface. A backoff value of 4 is used to approximate channel sensing for DIFS time for initial channel access

- Packet-by-packet automatic gain control (AGC) allowing for over the air transmission and reception.

Refer to the 802.11 Application Framework white paper for more information about the 802.11 Application Framework design.

Running This Sample Project

This section describes the main steps needed to run the 802.11 Application Framework using the RF loopback operation mode. Other operation modes are described in the *Additional Operation Modes and Configurations Options* section.

Configuring the Hardware

Depending on the configuration, follow the steps in either the *Configuring USRP Setup* or *Configuring FlexRIO/FlexRIO Adapter Module Setup* section.

Configuring the USRP RIO Setup

1. Ensure the NI USRP device is properly connected to the host system running LabVIEW.
2. Create the RF loopback configuration using one RF cable and attenuator:
   a. Connect the cable to RF0/TX1.
   b. Connect the 30 dB attenuator to the other end of the cable.
   c. Connect the attenuator to RF1/RX2.
3. Power on the USRP device.
4. Power on the host system.

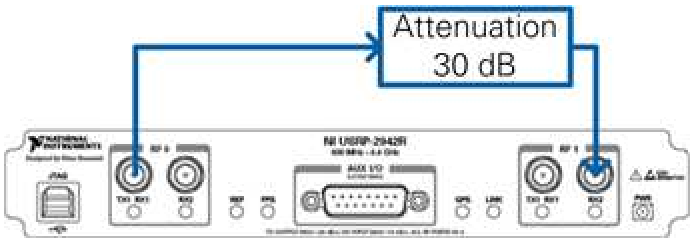

Figure 2 NI USRP Hardware Configuration

Configuring the FlexRIO Adapter Module Setup

1. Ensure the FlexRIO device is properly installed in the system running LabVIEW.
2. Create an RF loopback configuration connecting the TX of the NI 5791 with the RX of the NI 5791.

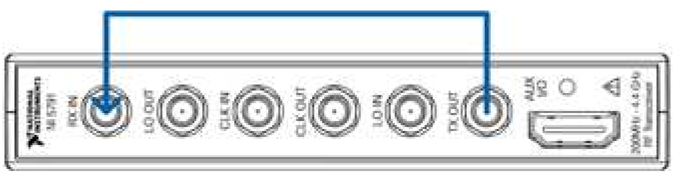

Figure 3 FlexRIO Adapter Module Hardware Configuration

Running the LabVIEW Host Code

Ensure the LabVIEW Communications System Design Suite and the 802.11 Application Framework are installed on your system. Installation is started by running `setup.exe`from the provided installation media. Follow the installer prompts to complete the installation process.

1. Launch LabVIEW Communications System Design Suite by selecting **LabVIEW Communications 2.0** from the Start menu.
2. From the Project Templates on the **Launch A Project** tab, select **Project Application Frameworks » 802.11 Design...** to launch the project.
   - Select **802.11 Design USRP RIO v2.0.1** if you are using a USRP RIO setup
   - Select **802.11 Design FlexRIO v2.0.1** if you are using a FlexRIO setup.
3. Within that project, the top-level host VI **802.11 Host.gvi** appears.
4. Configure the RIO identifier in the **RIO Device** control. You can use NI Measurement & Automation Explorer (MAX) to get the RIO identifier for your device.
5. (USRP RIO devices only) Specify the correct device bandwidth.
6. Run the LabVIEW host VI by clicking the run button ( ).
   - If successful, the **Device Ready** indicator lights.
   - If you receive an error, try one of the following:
     - Ensure your RIO device is connected properly.
     - Check the configuration of **RIO Device**.
     - (USRP RIO devices only) Check that you have specified the correct device bandwidth.

7. Enable the station by setting the **Station** control to **On**.
8. Select the **Basic** tab, and verify the shown RX Constellation matches the modulation and coding scheme configured using the **MCS** and **Subcarrier Format** parameters. For example, 16 QAM is used for MCS 4 and 20 MHz 802.11a.

The 802.11 Application Framework user interface is shown in Figure 4. All application settings as well as graphs and indicators are described in the following subsections.

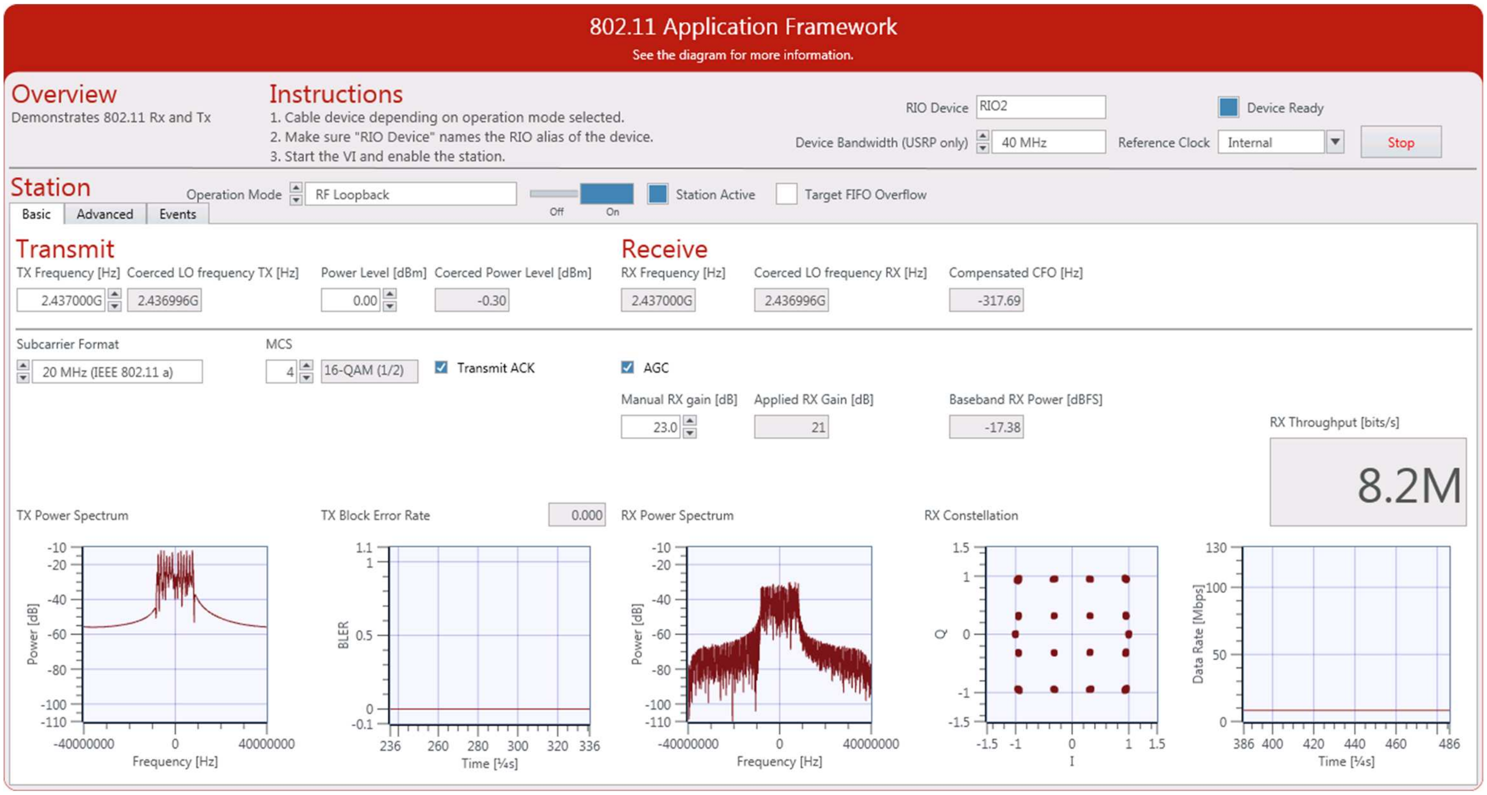

Figure 4 Application Framework Basic Tab

Application Settings

Application settings are applied when the VI starts, and cannot be changed once the VI is up and running. To change these settings, stop the VI, apply changes, and restart the VI.

Parameter	Description
RIO Device	The RIO address of the RF hardware device.
Reference Clock	Configures the reference for the device clocks. The reference frequency must be 10 MHz. You can choose from the following sources: **Internal** – Uses the internal reference clock. **REF IN / ClkIn** – The reference is taken from the REF IN port (USRP-294xR and USRP-295XR) or the ClkIn port (NI 5791). **GPS** – The reference is taken from the GPS module. Only applicable for the USRP-2950/2952/2953R devices. **PXI_CLK** – The reference is taken from the PXI chassis. Only applicable for PXIe-7975R/7976R FlexRIO FPGA targets with NI 5791 adapter modules.
USRP Bandwidth	(USRP RIO devices only) Configures the device bandwidth of the USRP RIO device.

Static Runtime Settings

Static runtime settings can only be changed while the station is switched off. The parameters are applied when the station is switched on.

Parameter	Description
Operation Mode	The 802.11 Application Framework provides three kinds of modes: **RF Loopback -** Connects the TX path of one device with the RX path of the same device using RF cabling. RF loopback is the default operation mode.

	RF Multi Station - Regular data transmission with two independent stations running on individual devices connected either with antennas or by cabled connections. **Baseband loopback** - Similar to RF loopback, but the external cable loopback is replaced by the internal digital baseband loopback path.
TX Frequency	Center frequency of the transmitter. Valid values depend on the device the station is running on.
Power Level	Output power level considering the transmission of a CW signal that has full DAC range. The high peak-to-average power ratio of OFDM means that the output power of transmitted 802.11 frames is usually 9 dB to 12 dB below the adjusted power level.

Dynamic Runtime Settings

Dynamic Runtime Settings can be changed any time and are applied immediately, even when the station is active.

Parameter	Description
Subcarrier Format	Allows you to switch between IEEE 802.11 standard formats, 802.11a or 802.11ac, and bandwidth settings (20 MHz or 40 MHz).
MCS	Modulation and coding scheme index used to encode data frames. ACK frames are always sent with MCS 0. Be aware that not all MCS values are applicable for all subcarrier formats and the meaning of the MCS changes with the subcarrier format. The text field next to the MCS field shows the modulation scheme and coding rate for the current MCS and Subcarrier Format.
Transmit ACK	If enabled, ACK frames are transmitted after SIFS = 16 μs in response to successfully received data frames.
AGC	If enabled, the optimum gain setting is chosen depending on the received signal power strength. The RX gain value is taken from Manual RX Gain if the AGC has been disabled.
Manual RX Gain	Manual RX gain value. Applied if AGC is disabled.

Graphs and Indicators

To monitor the status of the station, the 802.11 Application Framework provides a variety of indicators and graphs.

Parameter	Description
Coerced LO Frequency TX	Actually used TX frequency.
Coerced Power Level	Power level a continuous wave of 0 dBFS provides for the current device settings. The average output power of 802.11 signals is approximately 10 dB below this level. Indicates the actual power level considering RF frequency and device-specific calibration values from the EEPROM.
RX Frequency	The RX frequency is equal to the TX frequency because 802.11 protocols operate in half-duplex mode.
Coerced LO Frequency RX	Actually used RX frequency.
Compensated CFO	Carrier frequency offset detected by coarse frequency estimation unit.
Applied RX Gain	RX gain value currently applied. This value is the Manual RX Gain when the AGC is disabled, or the calculated RX gain when AGC is enabled. In both cases, the gain value is coerced by the capabilities of the device.
Baseband RX Power	Actual receiver's baseband power. When the AGC is enabled, the 802.11 Application Framework attempts to keep this value at -25 dBFS by changing the RX gain accordingly.
TX Power Spectrum	A snapshot of the current baseband spectrum from the TX.
TX Block Error Rate	Error rate is calculated as a ratio of sent frames versus received ACKs. In addition, the most recent value is displayed on the upper right of the graph.
RX Power Spectrum	A snapshot of the current baseband spectrum from the RX.
RX Constellation	The I/Q constellation of the received data field.
RX Throughput	The data rate of successful received and decoded frames matching the Device MAC address.

Advanced Settings

The advanced tab provides access to more elaborate settings and display options.

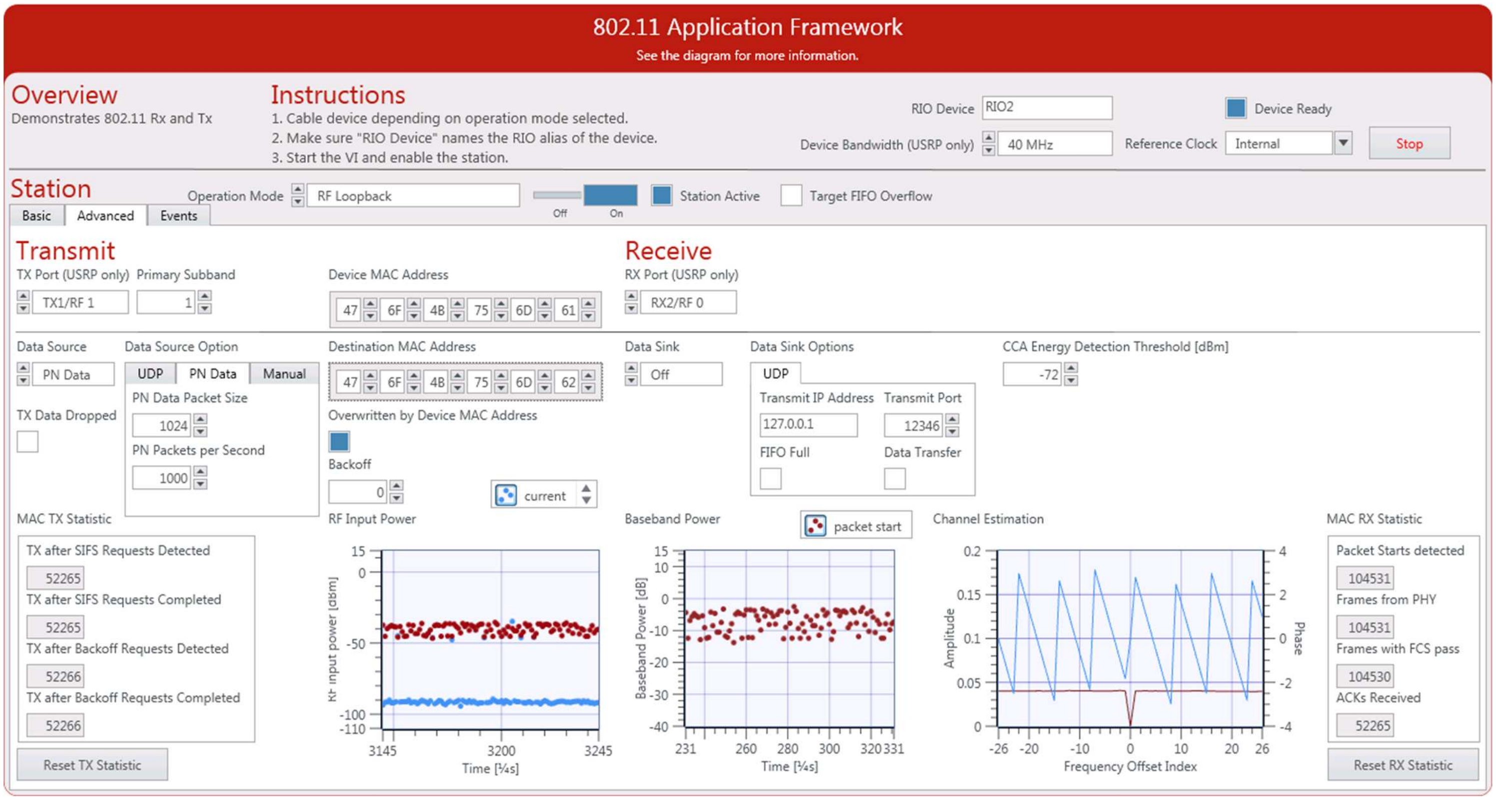

Figure 5 Application Framework Advanced Tab

Static Runtime Settings

Parameter	Description
TX Port	The RF port used for TX (applicable only for NI USRP devices).
RX Port	The RF port used for RX (applicable only for NI USRP devices).
Channel Selector	Selects the 20 MHz sub-band used for legacy transmissions in IEEE 802.11ac mode.
Device MAC Address	MAC address associated with the station.

Dynamic Runtime Settings

Parameter	Description
Data Source	Determines the source of MAC frames send from the host to the target. **UDP** - This method is useful for showing demos, such as when using an external video streaming application, or for using external network testing tool, such as Iperf. In this method, input data arrives at or is generated from the 802.11 station using UDP. **PN Data** - This method sends random bits and is useful for functional tests. Packet size and rate can be easily adapted. **Manual** - This method is useful to trigger single packets for debugging purposes.
Data Source Options	Each tab shows the options for the corresponding data sources. **Receive Port (UDP) -** A free UDP port to retrieve data for the transmitter. Usually between 1025 and 65535. **PN Data Packet Size (PN Data) -** Packet size in bytes (range is limited to 4061, which is a single A-MPDU reduced by MAC overhead) **PN Packets per second (PN Data) -** Average number of packets to transmit per second (limited to 10,000. The achievable throughput might be less depending on the configuration of the station).
Backoff	Fixed backoff that is applied before a frame is transmitted. The backoff is counted in number of slots of 9 µs duration.

UDP Data Sink	If enabled, received frames are forwarded to the configured UDP address and port (see below).
Transmit IP Address	Destination IP address for the UDP output stream.
Transmit Port	Target UDP port for UDP output stream, usually between 1,025 and 65,535.
Destination MAC Address	MAC address of the destination to which packets should be sent. If running in loopback mode, this address is ignored, and the Device MAC address is used instead.
CCA Energy Detection Threshold	If the energy of the received signal is above the threshold, the station qualifies the medium as busy and interrupts its backoff procedure, if any.

Graphs and Indicators

Parameter	**Comment**
RF Input Power	Displays the current RF input power in dBm regardless of the type of incoming signal if an 802.11 packet has been detected. This indicator displays the value at the packet start.
Baseband Power	Displays the baseband signal power at packet start.
Channel Estimation	Amplitude and phase of the estimated channel (based on L-LTF and VHT-LTF).
MAC TX Statistics	Number of TX after SIFS/backoff is detected/completed. The number of packets handled by the MAC TX.
MAC RX Statistics	Number of frames detected (by the synchronization), received subframes (frames with valid PLCP header), valid subframes (frames without format violations) and received ACKs.

Additional Operation Modes and Configurations Options

This chapter describes further configuration options and operation modes to complete once the initial setup as described in the *Running This Sample Project* section is complete.

In addition to the RF loopback configuration, the 802.11 Application Framework supports interaction with an arbitrary number of stations, hereafter referred to as RF Multi Station Mode. In the Multi Station Mode, each station acts as a single 802.11 device.

RF Multi Station Mode: Cabled

The following descriptions assume that a network with two stations is set up. Therefore, two RF devices (either NI USRP or FlexRIO adapter modules) are needed. As described in the *Hardware* section, you can control the two RF devices in two ways:

- **Option 1** — Both devices are controlled by a single host system, such as a single PXI chassis with an embedded controller. With this option, you need two copies of the 802.11 Application Framework because you cannot open the same LabVIEW project twice on a single host.
- **Option 2** — Each device is controlled by a separate host.

The two independent stations, each running on its own RF device, are referred to as station A and station B. Depending on the setup, follow the steps in either the Configuring USRP Setup or Configuring FlexRIO/FlexRIO adapter module Setup section.

Configuring the NI USRP RIO System

1. Ensure both NI USRP devices are properly connected to the host system running LabVIEW.
2. Create RF connections as shown in the following figure:
    - On station A, connect the cable to RF0/TX1.
    - Connect the other end of that cable to the 30 dB attenuator.
    - Connect the attenuator to RF1/RX2 on station B.
    - On station B, connect the cable to RF0/TX1.
    - Connect the other end of that cable to the 30 dB attenuator.
    - Connect the attenuator to RF1/RX2 on station A.

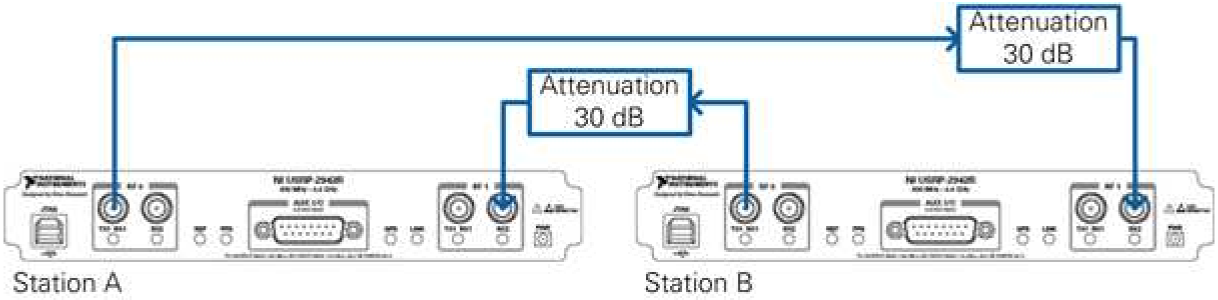

Figure 6 Cabled Connection of NI USRP Devices

Configuring the FlexRIO System

1. Ensure both FlexRIO devices are properly connected to the host system running LabVIEW.
2. Create RF connections as shown in the following figure:
    - On station A, connect the cable to TX.
    - Connect the cable RX on station B.
    - On station B, connect another cable to TX.
    - Connect the cable to RX on station A.

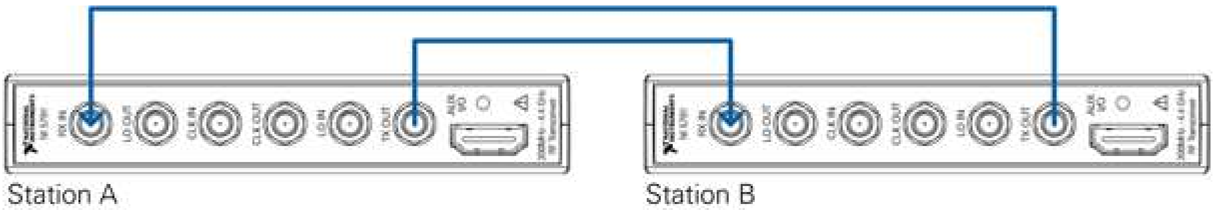

Figure 7 FlexRIO Adapter Module Cabled Connection

Running the LabVIEW Host Code

Instructions about running the LabVIEW host code have already been provided in the *Running This Sample Project* section for the RF Loopback operation mode. In addition to the instructions in that section, also complete the following steps:

- Set **operation mode** to **RF Multi Station**.
- Properly adjust the settings for **Device MAC Address** and **Destination MAC Address**.

If you use a setup in which a single host controls two RF devices, make sure each device is controlled from a separate project to avoid port conflicts.

RF Multi Station Mode: Over-the-Air Transmission

Over-the-air transmission is similar to the cabled setup. Cables are replaced by antennas suitable for the selected channel center frequency and system bandwidth.

Caution Read the product documentation for all hardware components, especially the NI RF devices, before using the system.

NI USRP and FlexRIO devices are not approved or licensed for transmission over the air using an antenna. As a result, operating those products with an antenna may violate local laws. Ensure that you are in compliance with all local laws before operating this product with an antenna.

Configuring the NI USRP RIO System

1. Ensure both NI USRP devices are properly connected to the host system running LabVIEW.
2. Create RF connections as shown in the following figure:
    - RF0/TX1 on station A to Antenna 1
    - RF1/RX2 on station A to Antenna 2
    - RF0/TX1 on station B to Antenna 3
    - RF1/RX2 on station B to Antenna 4

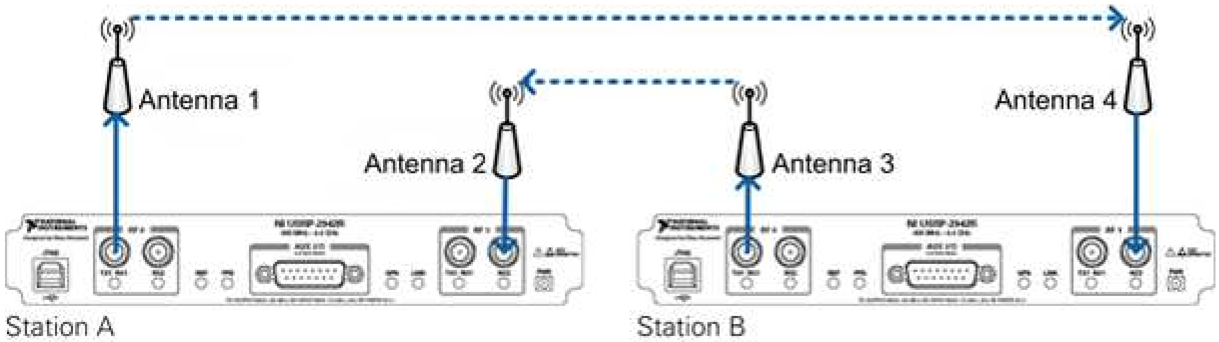

Figure 8 Antenna Connection for NI USRP Devices

Configuring the FlexRIO Setup

1. Ensure both FlexRIO adapter module devices are properly connected to the host system running LabVIEW.
2. Create RF connections as shown in the following figure:
    - TX on station A to Antenna 1
    - RX on station A to Antenna 2
    - TX on station B to Antenna 3
    - RX on station B to Antenna 4

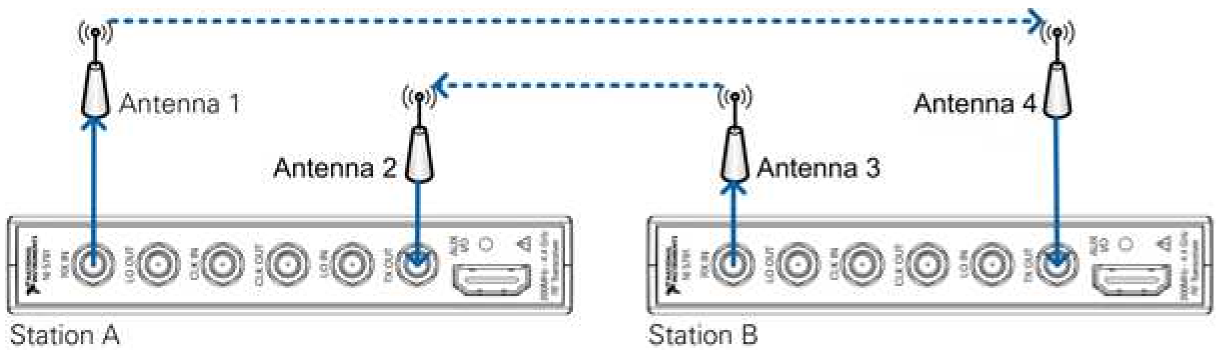

Figure 9 Antenna Connection for FlexRIO/FlexRIO adapter module Devices

Running the LabVIEW Host Code

Refer to the *RF Multi Station Mode: Cabled* sections for information about running the host code.

Baseband Loopback

The baseband loopback is similar to RF loopback. In this mode, the RF is bypassed. TX samples are transferred directly to the RX processing chain on the FPGA. No wiring on the device connectors is needed.

Additional Configuration Options

PN Data Generator

You can use the built-in pseudonoise (PN) data generator to create TX data traffic, which is useful for measuring the system throughput performance. The PN data generator is configured by the **PN Data Packet Size** and **PN Packets per Second** parameters. The data rate at the output of the PN Data Generator is equal to the product of both parameters. Notice that the actual system throughput seen on RX side depends on the transmission parameters, including the MCS value, and can be lower than the rate generated by the PN data generator.

The following steps provide an example of how the PN data generator can show the impact of the transmission protocol configuration on the achievable throughput. Notice that the given throughput values can be slightly different depending on the actual used hardware platform.

1. Set up, configure, and run the operation mode RF loopback as described previously.
2. Enable the station.
3. With the default settings you should see a throughput of about 8.2 Mbits/s.
4. Switch to the **Advanced** tab and set the PN Data Packet Size to 4000.
5. Set the number of packets per second to 10,000. This setting saturates the TX buffer for all possible configurations.
6. Switch back to the **Basic** tab and try different combinations of Subcarrier Format and MCS. Observe the changes in RX constellation and RX throughput.
7. Set Subcarrier Format to 20 MHz (IEEE 802.11a) and MCS to 7. Observe that the throughput is about 42.6 Mbits/s.
8. Disable ACK transmission.

9. Observe that the throughput increases to 46.4 Mbits/s, the BLER changes to one, and the BPSK dots disappear in the RX constellation graph.
10. Switch to the **Advanced** tab and change the backoff to 0.
11. Switch back to the **Basic** tab and observe that the RX throughput increases to 48.9 MBits/s.

Video Transmission

Transmitting videos highlights the capabilities of the 802.11 Application Framework. To perform a video transmission with two devices, set up a configuration as described in the *RF Multi Station Mode: Cabled* section. The 802.11 Application Framework provides a UDP interface, which is well suited for video streaming. The transmitter and receiver need a video stream application (e.g. VLC which can be downloaded from http://videolan.org). Any program capable of transmitting UDP data can be used as data source. Similarly, any program capable of receiving UDP data can be used as data sink.

Configure the Receiver

The host acting as receiver utilizes the 802.11 Application Framework to pass received 802.11 data frames and pass them via UDP to the video stream player.

1. Create a new project as described in Running the LabVIEW Host Code and set the correct RIO identifier in the **RIO device** parameter.

2. Set **Operation Mode** to **RF Multi Station.**

3. Switch to **Advanced** tab and set **Data Source** to **UDP.**

4. Enable the Station

5. Start cmd.exe and change to the VLC installation directory

6. Start the VLC application as a streaming client with the following command:
`vlc udp://@:12346`

Configure the Transmitter

The host acting as Transmitter receives UDP packets from the video streaming server and utilizes the 802.11 Application Framework to transmit them as 802.11 data frames.

1. Create a new project as described in Running the LabVIEW Host Code and set the correct RIO identifier in the **RIO device** parameter.

2. Set **Operation Mode** to **RF Multi Station.**

3. Switch to **Advanced** tab and set **Data Source** and **Data Sink** both to **UDP.**

4. Enable the **Station.**

5. Start cmd.exe and change to the VLC installation directory

6. Identify the path to a video file that shall be used for streaming.

7. Start the VLC application as a streaming server with the following command
`vlc "PATH_TO_VIDEO_FILE" :sout=#std{access=udp{ttl=1},mux=ts,dst=127.0.0.1:12345}`, where *PATH_TO_VIDEO_FILE* should be replaced with the location of the video that should be used.

The host acting as receiver will display the video streamed by the transmitter.

Troubleshooting

This section provides information about identifying the root cause of a problem if the system is not working as expected. It is described for a multi station setup (in which station A transmits data packets to station B) but it also applies to the RF loopback mode (in which station A and B are represented by the same device).

For normal operation, the following steps are performed:

1. Station A is transmitting data packets.
2. Station B is receiving data packets.
3. Station B is transmitting ACK packets.
4. Station A is receiving ACK packets.

The following tables provide information about how to verify normal operation and how to detect typical errors.

Step 1: Station A is transmitting data packets	
Normal Operation	Indication: • The counter values "TX after Backoff Requests Detected" and "… Completed" (part of "MAC TX Statistic") are increasing fast • The "TX data dropped" indicator is off

Error: **No data provided for transmission**	Indication: • The counter values "TX after Backoff Requests Detected" and "… Completed" are equal and do not increase • The "TX data dropped" indicator is off Solution: • Set "Data Source" to "PN Data" • Or alternatively: set "Data Source" to "UDP" and make sure that you use an external application to provide data to the UDP port configured as "Receive Port" in the "Data Source Options"
Error: **TX data was dropped because MAC TX considers the medium as busy**	Indication: • The counter value "TX after Backoff Requests Detected" is "1" and the value "TX after Backoff Requests Completed" is "0" • The "TX data dropped" indicator is on Solution: • Check the values of the curve "current" in the "RF Input Power" graph. Set the "CCA Energy Detection Threshold [dBm]" control to a value which is higher than the minimal value of this curve.
Error: **TX data was dropped because you try to send more data packets than the MAC ca Provide to the PHY**	Indication: • The counter value "TX after Backoff Requests Detected" and "Completed" (part of "MAC TX Statistic") are increasing slow • The "TX data dropped" indicator is flickering Solution: • Choose a higher "MCS" value, chose a lower packet size ("PN Data Packet Size") or reduce the frequency of the packets ("PN Packets per Second")

Step 2: Station B is receiving data packets	
Normal Operation	Indication: • The counter values "Packet Starts detected", "Frames from PHY" and "Frames with FCS pass" (part of "MAC RX Statistic") are increasing fast • The constellation in the "RX Constellation" graph matches the modulation order of the "MCS" selected at the transmitter • The "RX Throughput [bits/s]" is greater than zero.
Error: **wrong RF ports**	Indication: • The "RX Power Spectrum" does not show the same curve as the "TX Power Spectrum" Solution: • Verify that you have the cables or antennas connected to the RF ports which you have configured as "TX port (USRP only)" and "RX Port (USRP only)"

Step 3: Station B is transmitting ACK packets	
Normal Operation	Indication: • The counter values "TX after SIFS Requests Detected" / " Completed)" (part of "MAC TX Statistic") are increasing in the same speed as "Frames with FCS pass" in the "MAC RX Statistic"
Error: **ACK transmission is disabled**	Indication: • No ACK packet transmission is triggered (see description for "Normal operation"). Solution: • Make sure the checkbox "Transmit ACK" is checked

Error: MAC address mismatch	Indication: • No ACK packet transmission is triggered (see description for "Normal operation"). Solution: • Check that "Device MAC Address" of Station B matches the "Destination MAC Address" of Station A.

Step 4: Station A is receiving ACK packets	
Normal Operation	Indication: • The counter values "ACKs Received" (part of "MAC RX Statistic") are increasing in the same speed as "TX after Backoff Requests Completed" (part of "MAC TX Statistic") • The "TX Block Error Rate" is zero.

Known Issues

Make sure the USRP device is already running and connected to the host before the host is started. Otherwise the NI USRP device may not properly recognized by the host.

A complete list of issues and workarounds is located on the National Instruments website .

Related Information

NI USRP and LabVIEW Communications System Design Suite Getting Started Guide

IEEE Standards Association: 802.11 Wireless LANs

Refer to the LabVIEW Communications System Design Suite Manual, available online, for information about LabVIEW concepts or objects used in this sample project.

You also can use the **Context Help** window to learn basic information about LabVIEW objects as you move the cursor over each object. To display the **Context Help** window in LabVIEW, select **View»Context Help**.

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Notices are located in the %ProgramFiles(x86)%\National Instruments_Legal Information and %ProgramFiles(x86)%\National Instruments directories.

EULAs are located in the %ProgramFiles(x86)%\National Instruments\Shared\MDF\Legal\license directory.

Review %ProgramFiles(x86)%\National Instruments_Legal Information.txt for information on including legal information in installers built with NI products.

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Abbreviations

Abbreviation	**Meaning**
ACK	Acknowledgement
ADC	Analog Digital Converter
AGC	Automatic Gain Control
A-MPDU	Aggregated MPDU
BLER	Block Error Rate
BW	Bandwidth
CCA	Clear Channel Assessment
CW	Continuous Wave
DAC	Digital Analog Converter
FlexRIO adapter module	Frontend Adapter Module (RF module)
H2T	Host to Target
NACK	Negative Acknowledgement
MAC	Medium Access Control Layer
MCS	Modulation and Coding Scheme
MPDU	MAC PDU
OFDM	Orthogonal Frequency-Division Multiplexing
PDU	Protocol Data Unit
PHY	Physical Layer
PLCP	PHY Layer Convergence Protocol
PN	Pseudo Noise
QAM	Quadrature Amplitude Modulation
RF	Radio Frequency
RX	Receive
SIFS	Short Interframe Spacing
SISO	Single Input Single Output
T2H	Target to Host
TX	Transmit
UDP	User Datagram Protocol
VHT	Very High Throughput

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[1] If you are transmitting over the air, make sure to consider the instructions given in the *RF Multi Station Mode: Over-the-Air Transmission* section. The USRP-29xx and NI 5791 are not approved or licensed for transmission over the air using an antenna. As a result, operating those products with an antenna may violate local laws.

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