Smart Radio Configuration Guide

Advanced Mesh Router for Private Wireless Networks

Introduction

The purpose of this guide is to aid in the software configuration of the Smart Radio. The Smart Radio is available in three different form factors: Embedded, External, and Wearable. As each form factor is designed to cater to a particular use case, there are differences in the hardware interfaces between the three designs. Go to https://doodlelabs.com/products/smart-radio/ for more information. This guide is organized as follows.

Smart Radio Settings

Default Network Configuration

The Smart Radio runs Doodle Labs Mesh Rider® OS, a customized version of Openwrt with enhancements. These enhancements are useful for applications requiring low-latency command-and-control transmission, HD Video, high-throughput and long range. Fig 1 shows the default network configuratio of Smart Radio.

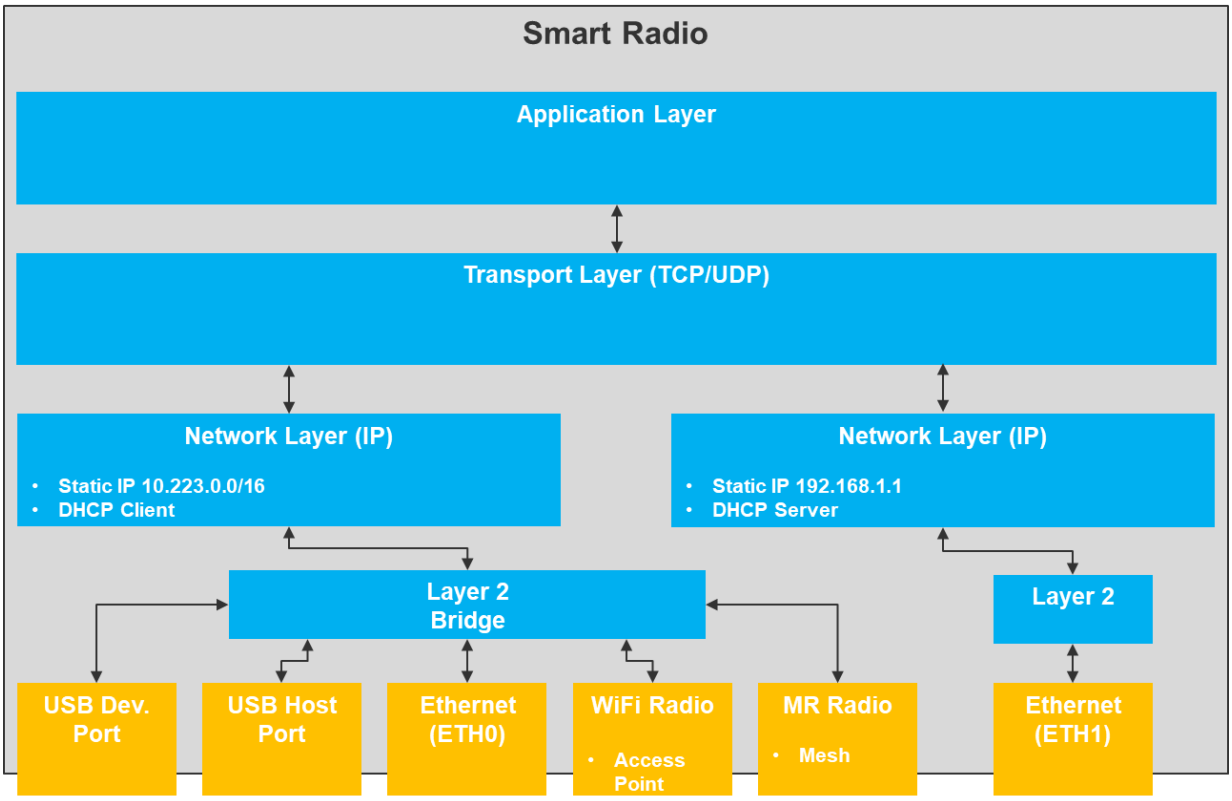

Fig. 1 Default Network Configuration

Not all interfaces are available in every model. Table 1 shows the available interfaces for the different radio form factors. ETH1 is configured by default as a configuration interface which is not remotely accessible, but it can be re-configured if necessary.

Table 1: Available Interfaces for Smart Radios

Interface	Embedded	External	Wearable
Mesh Rider Radio	Yes	Yes	Yes
Ethernet (ETH0)	Yes	Yes	No
Ethernet (ETH1)	Yes	Yes	Yes
USB Device Port	No	No	Yes
USB Host Port	Yes	Yes	Yes
WiFi Radio	No	No	Yes

Wireless Settings

The radio's Mesh Rider wireless settings can be found by navigating to `network → wireless` in the GUI. There should only be one radio interface present if you setup your network using the

`Simple Configuration` menu (discussed later). To modify the wireless settings, click `Edit`. You should see a page similar to the one below. We recommend the following updates.

- For point-to-point networks such as a Control Station controlling a single UAV, or Robot, Enable `Dynamically Adjust txpower based on neighbor sounding (Transmit Power Control).`
- At power up, the Smart Radio will scan the environment and choose the best channel for the environment. A different channel can be chosen manually.
- For 2.4-GHz ISM-band radios, use a channel bandwidth of 15-MHz to avoid normal WiFi interference. This is especially important in urban areas.
- Change the Mesh ID and under Wireless Security
- Change the password.

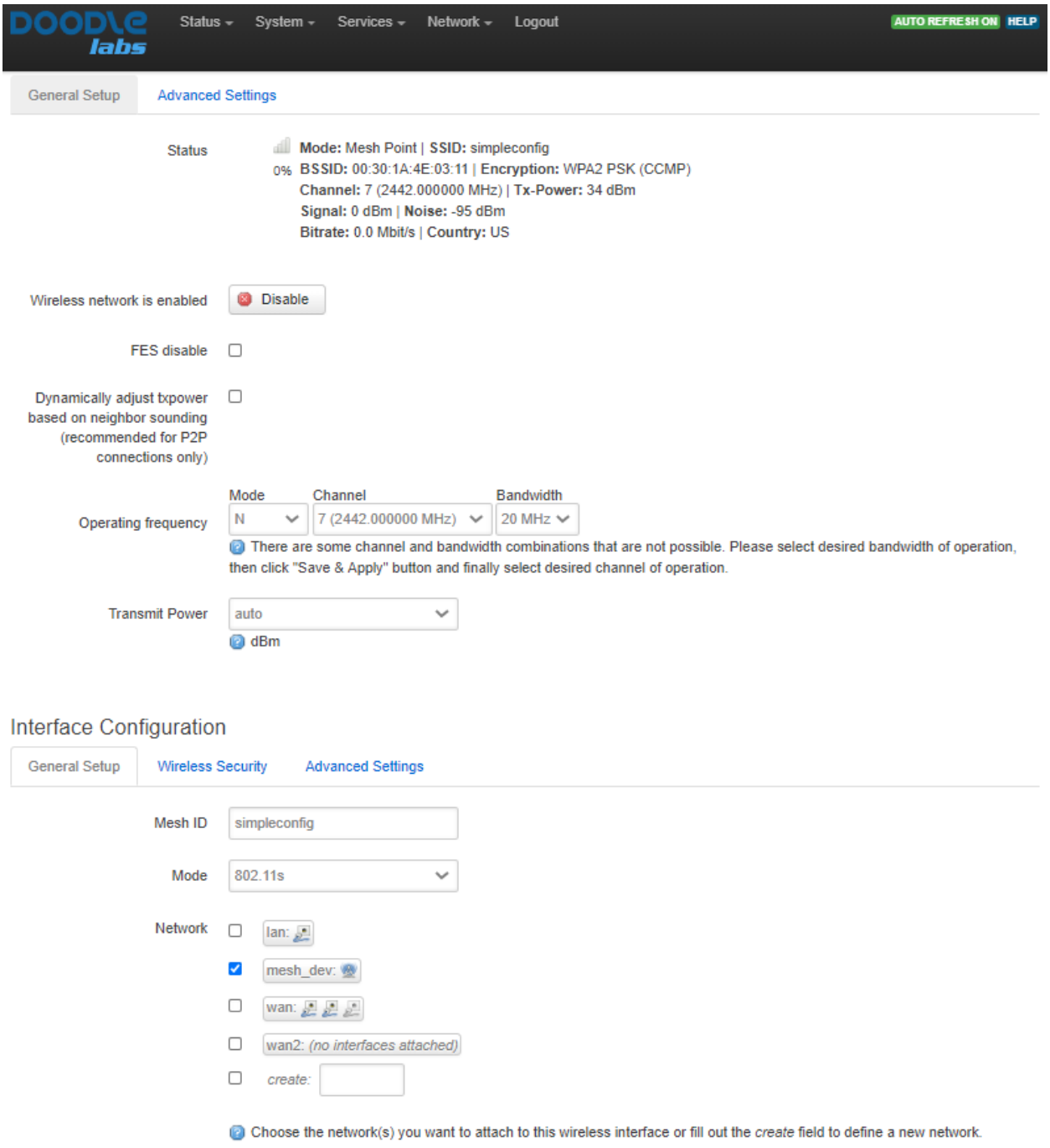

Fig. 2 Wireless Settings

Network Interface Settings

Network interface settings can be modified in the `Network → Interfaces` tab. Below are some common changes you *may* want to make.

- Enable a DHCP server on *one* of the radios.
    - Click `Edit` next to the `WAN` interface. You should see a page similar to the picture below. Change the `Protocol` from `DHCP` to `Static Address`. Add an IPv4 address and netmask of your choosing, then scroll to the bottom of the page, and un-check `Disable DHCP for this Interface`. Click `Save & Apply`.
- You may also wish to enable a DHCP server on the `LAN` interface (`ETH1`). The steps are similar to those above.
- Change the default static IP address of ETH0. To do this, edit the `WAN2` interface, and change the static IP address to your liking.

Fig. 3 Network Interface Settings

Firewall Settings

The Firewall configurationis located under `Network → Firewall` and can be modified over the GUI and CLI at `/etc/config/firewall`.

We shall use the iperf application as an example to demonstrate setting a firewall rule to allow access to port 5001 of the router. Navigate to the Firewall page, and click the Traffic Rules tab. In the “Open ports on router” section, enter the name, protocol, and port number as “Allow iperf”, “TCP”, and “5001” respectively so that clients is able to connect to port 5001.

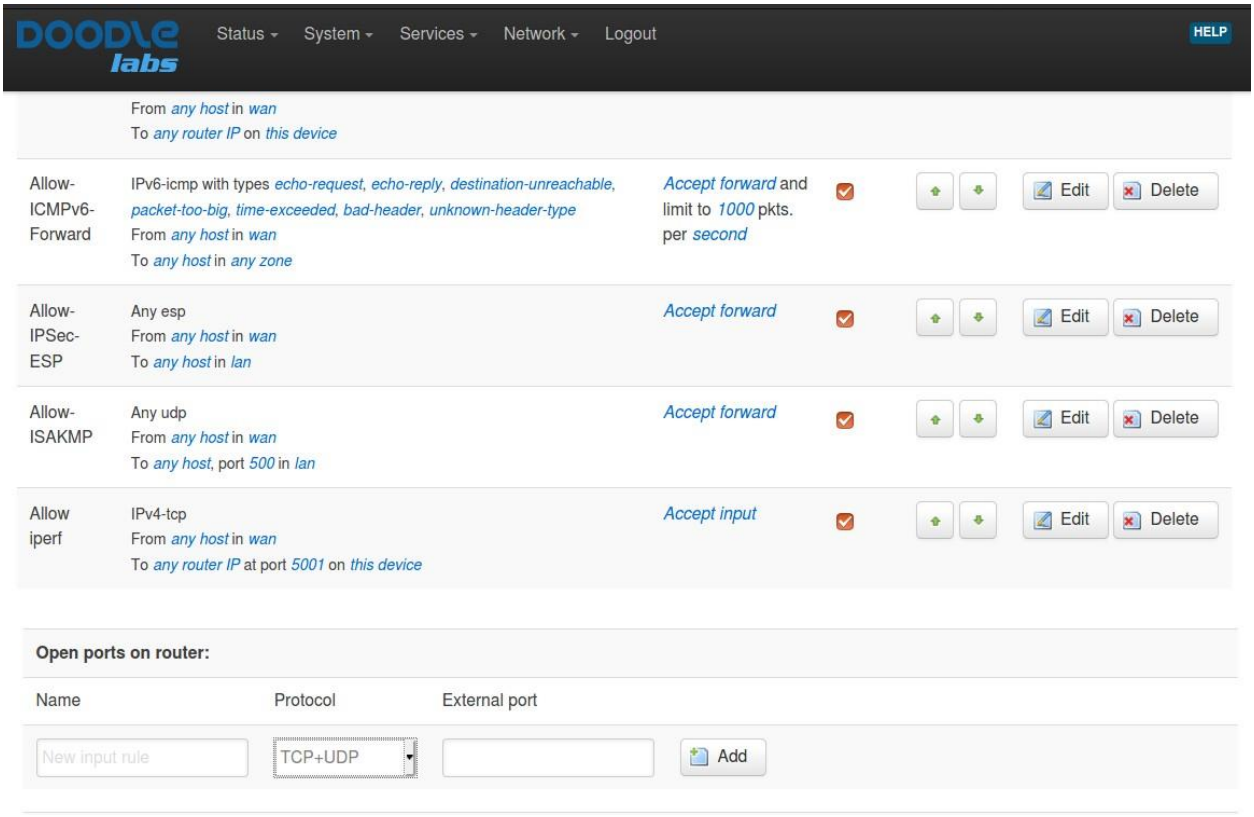

Fig. 4 Firewall Settings

Before port 5001 is opened, run iperf in server mode inside the Smart Radio.

```
root@smartradio-301a4e8646:~# iperf -s
```

If you try and connect to the iperf server from your local machine, you will get an error, `connect failed: Connection refused`. After opening the firewall at port 5001, you should be able to connect to the iperf server.

Extensive information regarding Firewall configuration is available at the openwrt.org website.

Differentiated Services

Different types of traffic can be prioritized in the Differentiated Services menu. This is useful when operating in a crowded wireless medium. There are four different queues – Voice, Video, Best Effort, and Background. The Voice queue optimizes latency and may also be used for command and control, the Video queue optimizes throughput, the Best Effort Queue is essentially unoptimized, and the Background queue is for low-priority data.

In order to use these QoS features, open up the web GUI and navigate to `network → differentiated services`. The Smart Radio includes software to map different network protocols or ports to the various QoS queues. To do so, click `Enable Differentiated Services`, and add a classification rule to suit the application's needs. For example, you can send all UDP traffic to the Video queue which is beneficial for video transmission.

URLLC (Ultra Reliable Low Latency Channel)

The Smart Radio includes protocol optimizations for URLLC applications as well as video optimizations. URLLC applications typically include command and control (C&C) data, but can be extended to any application requiring a reliable low latency. Assuming that we have a C&C application which uses network port 7000 over UDP. In the screenshot below, first click `Optimize Command & Control for URLLC`. Next click `Add`, and then change the new classification rule to use `Port 7000`, and set the `DSCP` value to `CS6`. The comment section can be filled if desired. Finally click `Save & Apply` and wait for the page to refresh.

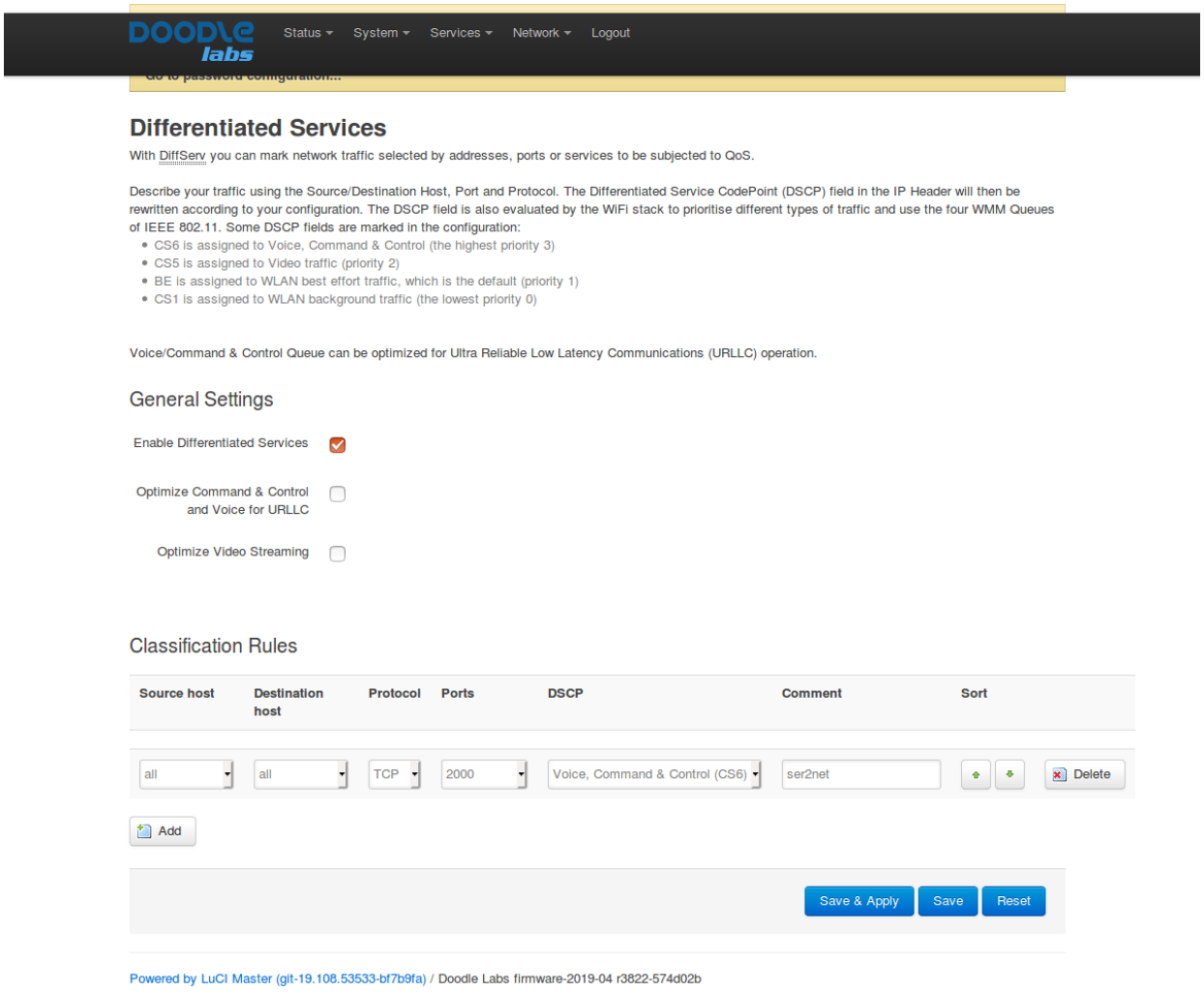

Fig. 5 Differentiated Services Settings

System Configuration using UCI

UCI Overview

Openwrt uses the UCI system for device configuration. Most of the configuration files can be found here,

```
root@LEDE:~# ls /etc/config/

batman-adv       diffserv         firewall         network
openvpn_recipes  system           ucitrack         wireless

dhcp             dropbear         luci             openvpn

rpcd             ubootenv         uhttpd
```

To show the current wireless configuration, type

```
root@LEDE:~# uci show wireless

wireless.radio0=wifi-device

wireless.radio0.type='mac80211'

wireless.radio0.path='platform/qca953x_wmac'

wireless.radio0.htmode='HT20'
```

Only the first four results are shown above. To change a setting, e.g. the wireless channel, use `uci set`:

```
root@LEDE:~# uci set wireless.radio0.channel=’10’
```

This change will be held in memory but will have an effect when the network settings are reloaded using

```
root@LEDE:~# /etc/init.d/network reload
```

Changes to the configuration can be stored using

```
root@LEDE:~# uci commit
```

Configuration Parameters

Table 2 shows information on commonly used and the Doodle Labs Smart Radio specific configuration parameters. For full technical discussion of all of the different configuration parameters of the Openwrt system, the user is encouraged to explore the OpenWrt documentation.

Table 2: Commonly used and Doodle Labs specific Configuration Parameters

Wireless	
wifi-device section	
txpower	Specifies the transmit power in dBm. Note that transmit power is also limited by local regulations, and a rate-dependent target power.
channel	This is the wireless operating channel.
fes_disabled	This will put the front-end-system in sleep mode (low power)
chanbw	Sets the channel bandwidth in MHz. Only model specific valid bandwidths can be used. Supported bandwidths are 3/5/10/20/26 with 0 being 20 MHz.
distance	This should be set to a value higher than the maximum expected transmission distance in meters.
rxantenna	Used to selectively enable the two antennas in a comma separated format. For example, '2' will enable only the second antenna and '1 2' will enable both antennas for reception.
txantenna	Used to selectively enable the two antennas in a comma separated format. For example, '2' will enable only the second antenna and '1 2' will enable both antennas for transmission.
nf_override	Sets a noise floor override in dBm, which can be useful to ignore interferences. Default value is approx. -95.
wifi-iface section	
mesh_fwding	Set to '0' to disable 802.11s forwarding. Mesh forwarding is typically handled by batman-adv.
mesh_ttl	Set to 1 to disable further forwarding in 802.11s. Forwarding typically handled by batman-adv
mcast_rate	Specify the multicast modulation rate in mesh networks, in bps (e.g. 12000 = 12 Mbit/s). If set higher, the range is decreased but the faster links are preferred.
Diffserv	
general section	
enabled	Set to 1 to enable diffserv
optimized_cc	Set to 1 to enable URLLC operation for the Command & Control and Voice Queue
optimized_vi	Set to 1 to enable URLLC operation for the Video queue
mark section	
dscp	Select the DSCP queue, e.g. BE = best effort
proto	Define the protocol, e.g. icmp, tcp or udp

srchost	The source and the destination host are IPv4 address (e.g. 192.168.1.2) can be used to apply rules only to a specific host. A network mask can be used to match entire networks. 192.168.1.0/24 will match traffic with an IP address in the range of 192.168.1.1 to 192.168.1.254. Blank fields will match any address.
dsthost	
ports	Affected ports for this rule. Valid ports in rules can be in the range 1-65535. Port ranges can be given in the form of a single port, an inclusive range <start-port>-<end-port> or as a comma separated list <port>,<port>. Both notations can not be mixed.
Mesh (batman-adv)	
bridge_loop_avoidance	Set to 1 if there is a chance that devices can be connected via Ethernet and Mesh at the same time
orig_interval	Interval of batman-adv originator messages (management frames). Default is 1000. Decrease to more frequently update the network topology, e.g for high mobility nodes. This may limit the maximum # of nodes on the network.

Smart Radio Ports

UART

The UART port is a standard TTL level 3-pin serial port (RX, TX, GND). The UART port can be used directly with directly with flight controllers such as the PixHawk 4. It is also possible to setup a network to serial relay, or a direct serial to serial link over the network. Please refer to Doodle Labs' Application Note on using the serial port for further details.

USB Device Port

The USB Device Port only supports Ethernet over USB protocols. It works with Laptops and Tablets as long as they support Ethernet over USB. The USB Device Port uses the ETH0 interface logically.

USB Host Port

The USB port is a host port and is pre-configured as an Ethernet over USB interface. When plugged into a USB device or OTG port with a compatible Ethernet over USB configuration, a new interface, USB0, will be instantiated and bridged to the WAN interface. It is then possible to access the Smart Radio over the web browser or SSH at the default static IP address defined

earlier. It is possible to install other USB packages to include other USB functions for your application.

The Smart Radio has a USB hub inside and USB ports are accessible on the main and secondary connectors. USB0 on the main connector does not have a 5-V supply associated with it.

GPIO

In hardware version J and later, GPIOs are available for programming. The GPIOs are provided by an on-board MCU and interfaced to the Operating System over USB HID. A program "sr-ctrl-usb" is pre-installed in the system and is used to access the GPIOs. The general syntax for accessing the MCU is

```
root@LEDE:~# sr-ctrl-usb <r/w> <param #> <value>
```

r/w is either "0" for read or "1" for write. The parameter numbers for the three GPIOs are tabulated below. The possible values which can be read or written are "0 and "1" and correspond to 0-V and 3.3-V. Table 3 summarizes GPIO parameters.

Table 3: GPIO Parameters

Param #	Function
6	Logic level of GPIO1, 0 is GND and 1 is 3.3-V
7	Logic level of GPIO2, 0 is GND and 1 is 3.3-V
8	Logic level of GPIO3, 0 is GND and 1 is 3.3-V
11	Direction of GPIO1, 0 is Output and 1 is Input
12	Direction of GPIO2, 0 is Output and 1 is Input
13	Direction of GPIO3, 0 is Output and 1 is Input

As an example, if we want to write a level 1 to GPIO2, we first set the direction of GPIO2 to 0 and then we set the logic level to 1.

```
root@LEDE:~# sr-ctrl-usb 1 12 0
root@LEDE:~# sr-ctrl-usb 1 7 1
```

We can read the logic level of GPIO3 with,

```
root@LEDE:~# sr-ctrl-usb 1 13 1
```

```
root@LEDE:~# sr-ctrl-usb 0 8
```

Note that the GPIO directions are reset to input when the MCU is reset. When the MCU is reset, a reset flag is raised at param # 13 and it should be reset to zero by the user.

Wake-Up Timer

For very low power monitoring applications, the Smart Radio can be configured to completely shut down and wake up on a timer. In order to conserve power, the CPU itself shuts down and it requires around 30 seconds to boot up again. The command to shutdown the system is,

```
root@LEDE:~# sr-ctrl-usb 1 2 <time in seconds>
```

where `<time in seconds>` is the amount of time that the CPU should shut down for. This feature is only available in -J hardware variants.

Firmware Upgrade

The Mesh Rider OS can be upgraded using either the Web GUI, or the Linux console. Connect the host PC to the ETH1 port of the Smart Radio.

Console Method

1. Copy firmware from PC to the module:

```
scp firmware-sysupgrade.bin root@192.168.1.1:/tmp/
```

2. Login to Smart Radio by ssh root@192.168.1.1
3. Use the sysupgrade command to update the firmware.

```
sysupgrade -v /tmp/firmware-sysupgrade.bin
```

4. Wait until the update is complete. DO NOT CYCLE THE POWER SUPPLY UNTIL THE FIRMWARE HAS BEEN UPDATED!

Web GUI Method

1. Enter the following into the address bar of your browser

```
https://192.168.1.1/cgi-bin/luci/admin/system/flashops
```

2. At the bottom of the page, de-select the “keep settings” button
3. In the “image” field, click browse and select your firmware image
4. Click Flash Image
5. After the system has verified the image, click Proceed

Smart Radio Network Configurations

The Smart Radio supports many different network configurations. The Simple Config menu makes it easy to configure the radio. The Simple Config menu is accessed in the web GUI at network → simple config.

- Mesh (Factory Configuration)
- Mesh Gateway
- WDS Access Point
- WDS Client
- WDS Access Point Gateway
- Multi-Radio Mesh

Mesh Configuration

Figure 6 shows the mesh configuration. This is the factory setting of the Smart Radio.

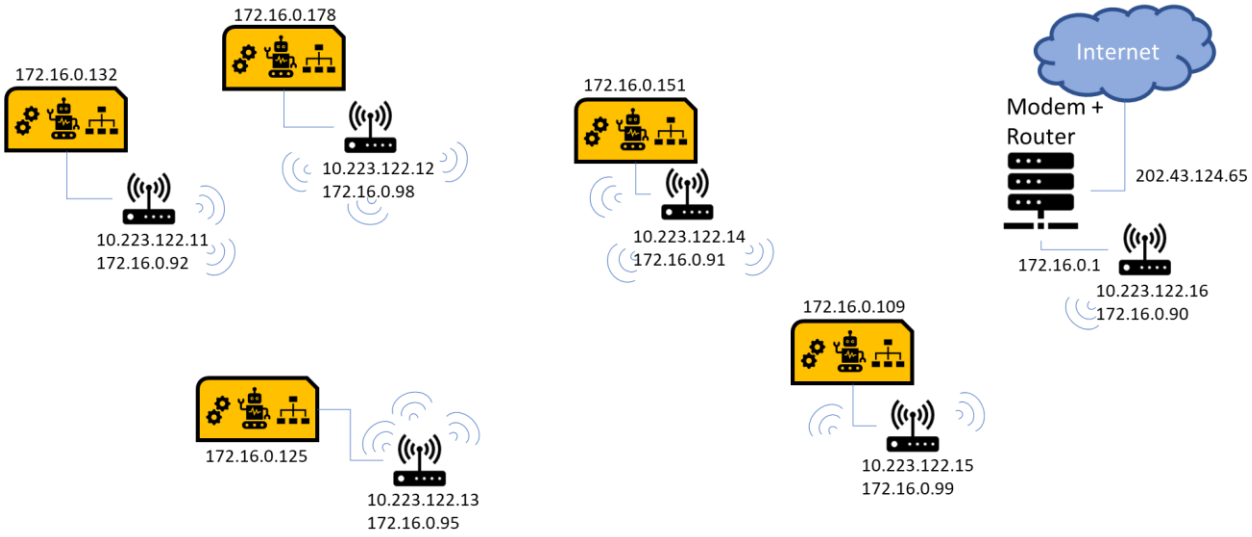

Figure 6 – Smart Radio Mesh Network

In this configuration, a Router is connected to one of the Smart Radios at ETH0, which acts as an Internet Gateway for the mesh. The Router runs a DHCP server which provides IP addresses to all of the host devices in the mesh. In the absence of the Gateway Router, you may use the Mesh Gateway configuration described next. If mesh network is not required, we suggest using the WDS AP/Client mode to get a slighly higher throughput.

There are two networks configured within each Smart Radio. The first is the mesh network, and the second is the configuration network.

- The mesh network consists of all Smart Radios and host platforms which join the mesh. ETH0 is bridged to the mesh network. The firewall is set up to allow input access using SSH or the web GUI. The mesh network has two IP addresses.
    - The first is a DHCP client.
    - The second is a static IP address equal to 10.223.x.y where x.y is the last four hexadecimal digits of the wireless MAC address. For example, a unit shipped with MAC address 00301A4E7AB0 has the last four HEX digits 7AB0 and x.y is equal to 122.176.
- The configuration network is meant to include only the Smart Radio and the host platform it is connected to via ETH1. The firewall is setup to allow all input access and it is designed to be a configuration port.
    - It has a static IP address equal to 192.168.1.1 and is not bridged to the mesh.

The Smart Radio can be accessed over the command line with

```
user@host-pc:~$ ssh root@<IP ADDRESS>
```

or using a web browser at the same IP address. <IP ADDRESS> depends on whether you are connected to ETH0 or ETH1. In Windows, use the PuTTY client. No password is set by default, and after setting one up, it is possible to setup public-key authentication following this guide.

Mesh Gateway Configuration

The Smart Radio also includes a gateway mode which obviates the need for an external router. The network diagram is shown in Figure 7.

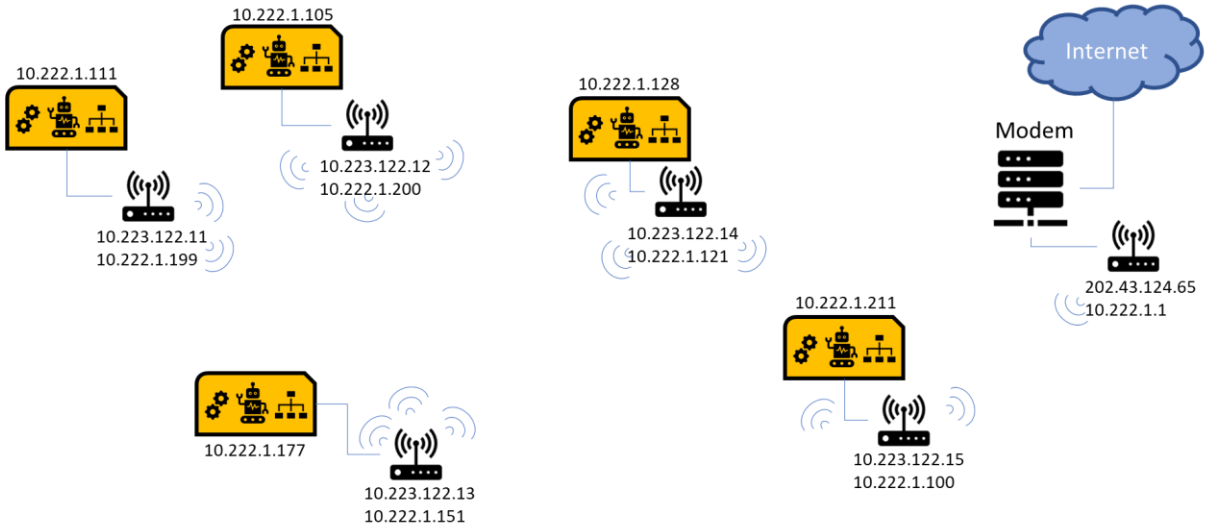

Figure 7 – Mesh Network with Gateway

The Smart Radio in gateway mode (on the right) configures the network with a 10.223.0.0/16 IP address range and acts as a DHCP server. All other Smart Radios are in normal mesh mode. In order to access the gateway device, either access it wirelessly, or connect to ETH1 and use the 192.168.1.0/24 subnet.

WDS AP/Client mode

The WDS AP/Client network diagram is shown in Figure 8. In WDS mode, traffic is bridged transparently between the router and the end device. As in the standard mesh mode, IP addresses are provided by the DHCP server running in the external router. The pre-defined static IP addresses of the Smart Radios are still active. WDS AP/Client mode establishes a star network topology. If mesh is not required, we recommend this mode since it is typically a little faster.

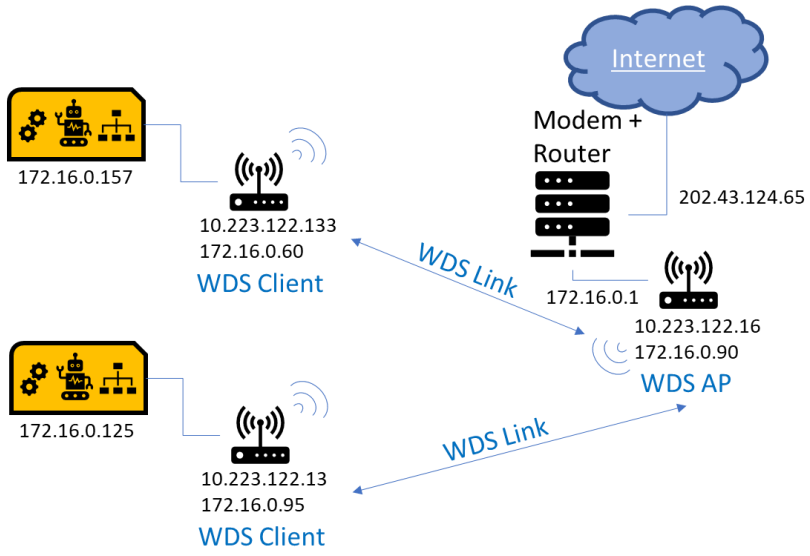

Figure 8 – WDS AP/Client Network

WDS Gateway Mode

WDS Gateway mode is an extension of the WDS AP/Client mode where the WDS AP is also an internet gateway. The WDS AP Gateway runs a DHCP server and performs NAT between the local 10.222.0.0/16 subnet and the wider network.

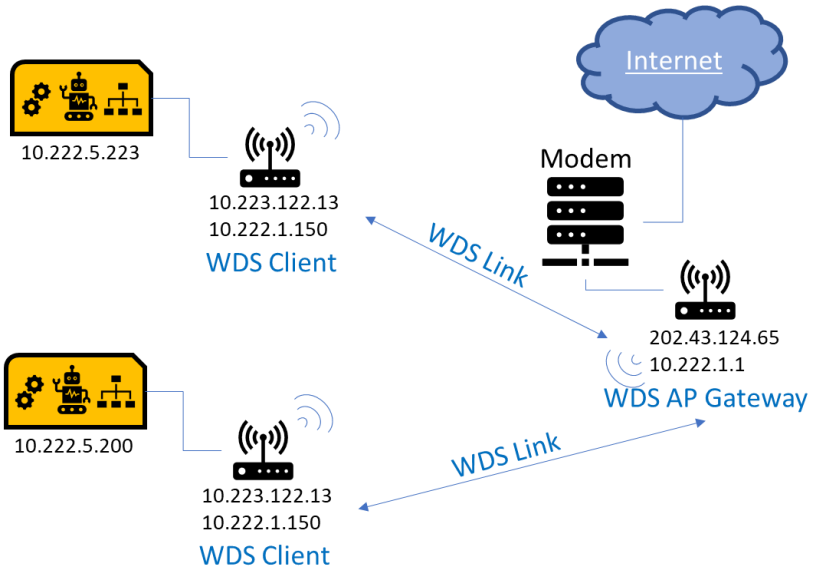

Figure 9 – WDS AP/Client Network with Gateway

Multi-Radio Mesh Mode

The Smart Radio supports direct connection between multiple radios using the ETH1 interface. In order to do this, change the configuration to multi-radio mesh mode in the Simple Config menu. Note that in this mode, ETH1 is no longer the configuration port and cannot be accessed at 192.168.1.1. Two example network configurations are shown in Figure 10.

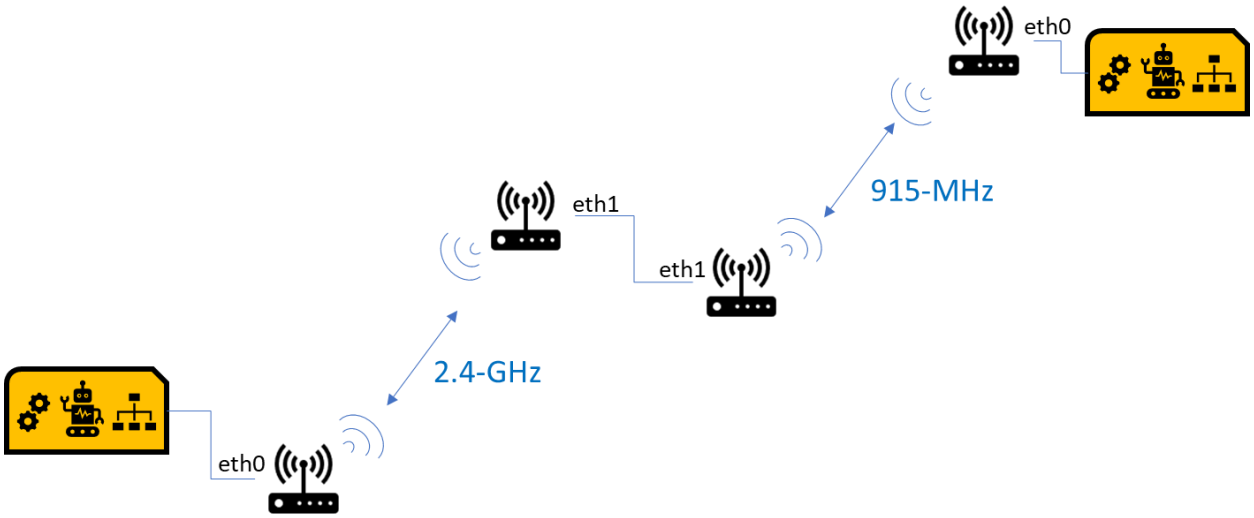

Figure 10 – Multi-Radio Mesh Network

In the above configuration, two radios are used to extend a link using two different frequencies to avoid having to share the medium. The two channels could be in the same band if desired; for example 2412 MHz and 2462 MHz.

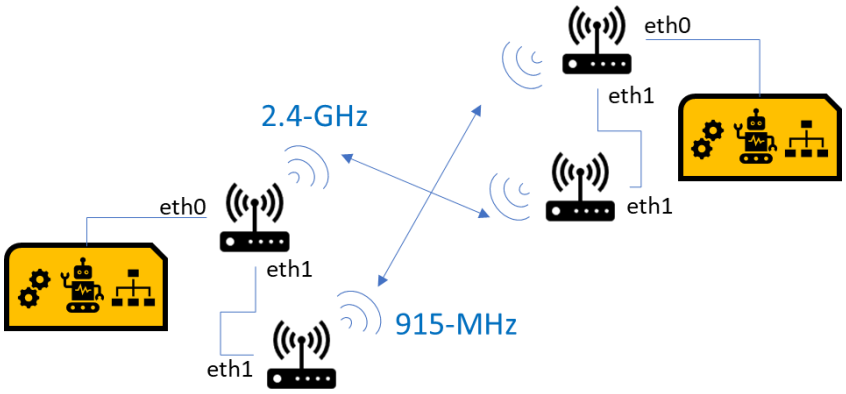

Figure 11 Multi-Radio Mesh Network with Failsafe

In the next configuration, the 915-MHz radios are used as a failsafe for the 2.4-GHz band. This is shown in Figure 11. If the 2.4-GHz link cuts off due to it being out of range, or due to excessive interference, network traffic will switch to the 915-MHz link automatically. An important point in the diagram above is that traffic entering the mesh from one side always takes 2 hops before leaving the mesh on the other side. This balance allows the mesh to react significantly faster than if one route required more hops than the other.

Application Notes

Doodle Labs has developed many application notes for Smart Radio. They are available in the Technical Library section of the website. Below list shows some of the commonly used application notes.

1. Optimizing the wireless link Throughput
2. Optimizing the wireless link Distance
3. Optimizing Latency for Command and Control Data
4. Video Streaming Tutorial
5. Expanding Smart Radio capabilities
6. Interference Mitigation Techniques
7. Remote Management of Smart Radio

Troubleshooting

This section provides basic trouble-shooting tips.

List of Known Issues

This is a list of known issues with the Smart Radio. Some of these issues are inherent to the underlying OpenWrt system and we are working to get them fixed.

1. In AP/Client mode, when attempting to switch to a new wireless network using the Web GUI “scan” option, it may be necessary to first remove the SSID and BSSID fields in the radio interface.
2. In AP/Client mode, when the AP changes its channel bandwidth, the Client will not automatically adjust its channel bandwidth setting.
3. When switching to reduced channel bandwidths, such as 5 MHz, it is necessary to first save and apply the reduced channel bandwidth before switching to a new channel. New operating channels will become available depending on the regulatory domain.
4. When switching to reduced channel bandwidths, the web GUI continues to display transmission rates based on 20-MHz bandwidth.
5. If the radio is configured with settings which do not conform to regulatory requirements, the radio interface can become locked-out. Manually re-configuring the radio interface over the command line may be necessary.

How to do Factory Reset

In case the radio becomes unresponsive due to misconfiguration, it is possible to restore the factory default configuration.

For Hardware Version H:

1. There is a dedicated reset pin on the main connector. The factory reset pin is internally pulled up to 3.3-V with a 10-kohm resistor.
2. Pull the Factory Reset pin to GND and hold it for between 5 and 30 seconds to reset the configuration to factory settings.
3. The Smart Radio will then reboot.

For Hardware Version J:

1. Look for a pin hole between the main and secondary connector of the Smart Radio
2. Insert a pin into the pinhole and push the reset button for between 5 and 30 seconds.
3. The Smart Radio will then reboot.

For the Wearable version (K):

1. Hold the Power Button down for between 30 and 40 seconds.
2. This will cause the LED lights to rapidly blink.
3. Stop pressing the Power Button and wait for the unit to reboot.

Unexpected Radio Resets

The unexpected radio resetting may point to an inadequate power supply or the unit may be overheating. Please ensure that the power supply can provide at least 20 W @ 5.5 V. It is necessary to provide adequate thermal management of the unit to ensure maximum performance at highest RF power.

In general, we suggest upgrading to the latest version of the Mesh Rider OS (available on the website).

Cannot Login to the Radio

First Time Login

The Smart Radio can be accessed via either of the Ethernet ports. ETH0 is bridged to the mesh network and has a unique IP address based on the MAC address (see the configuration guide for details). If you are having trouble logging in,

1. Try and login through ETH1.
2. Make sure to set a static IP address on your PC in the 192.168.1.0/24 subnet.
3. Make sure you can “ping” the radio at 192.168.1.1.
4. Temporarily disable the firewall on your PC.
5. Check the routing table to make sure that the route to 192.168.1.1 goes through the correct interface.
    a. Normally this is not necessary and if you have to go to this step, you should probably try a different PC first. This is an advanced topic with plenty of literature online which you can refer to.

Subsequent Login Fails

If you managed to login in the past, but cannot login due to a bad configuration change, you may need to factory reset your device. During the development stage, we recommend making regular backups of your configuration.

40-MHz mode not working

The 40-MHz setting is a bonding of two 20-MHz channels. The additional channel is on the high-side of the selected channel, and therefore only certain channels support 40-MHz mode (2442-MHz does not support a 40-MHz channel bandwidth). For example, if the selected channel is

2422 MHz, then the radio will use the 2422 and 2442 MHz channels. The radio automatically uses both channels only when both channels are clear, so you will often see it switching to 20-MHz mode.

Crash Dump Logging

If the Mesh Rider OS is suspected to be crashing, modify the /etc/config/system file to log crash dump persistently so that the message will be available after reboot or power cycle.

```
config   system
      option log_file '/opt/messages'
```

Please check the crash dump messages for possible causes of the crash or send it to tech-support if needed.

Connect with Tech Support

If none of the above tips help, please feel free to contact us (https://www.doodlelabs.com/about-us/tech-support/tech-support-request-form/). Please describe your problem in as much detail as possible, and include photos of the setup if possible.

Configuration Backup

Additionally, please create a backup of your configuration and send it with your email. You can create a backup in the web GUI by navigating to `system → backup/flash firmware` and clicking `Generate Archive`.

If you are having connectivity issues between nodes, please fill out this table and include it in your email.

Table 4: Tech Support Form

Question	Example
Model Name	RM-2450-2H-XS
Firmware version	firmware-2020-03, r4030-72047dd133
Test setup	Point-to-point, mesh, AP/Client
Type of Data	Video, Control signals, iperf, ping, multicast
Number of Antennas used	1 or 2
If one antenna, which one?	Antenna 0
Distance between nodes	100m
Height of the Antennas	3m
Number of nodes (mesh)	4