

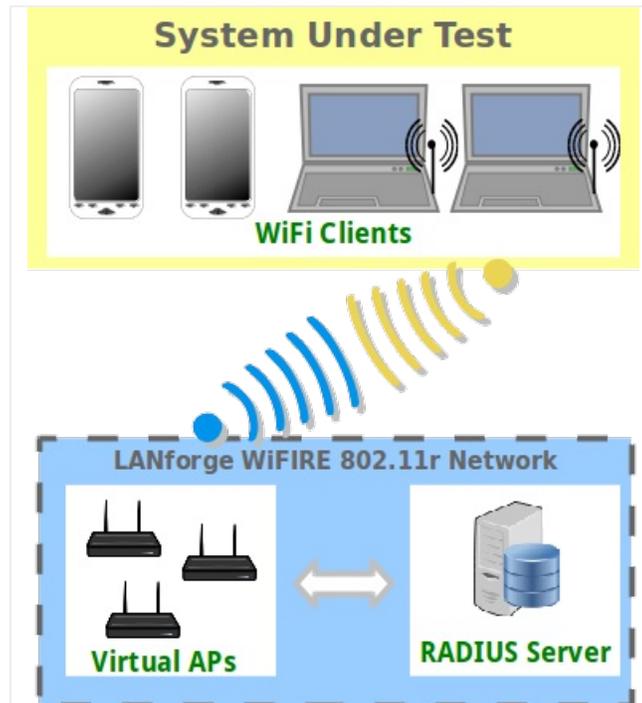
LANforge WiFi Access Point Network with 802.11r

Goal: Configure a virtual AP network with 802.11r to allow testing fast transition (FT) clients.

Configure virtual Access Points to use 802.11r with FT-EAP. This example uses a LANforge CT523 system but the procedure will work on all CT523, CT524 and CT525 multi-radio systems.

The wifi clients under test are also 802.11r enabled so that they can initiate FT Requests and roam. Here we are using another LANforge WiFi as the system under test to emulate 802.11r stations and force them to roam.

In LANforge, each virtual access point will be running its own hostapd process configured to enable 802.11r and bridged to other virtual access points. The bridged VAP network will emulate the Distributed System (DS) for FT over-the-DS roaming.



1. Setup a single virtual access point on each wifi NIC for at least two NICs and configure them for the same channel and SSID.
 - A. Go to the Port Manager tab, select the parent device such as wiphy0, click Modify, set a specific channel/frequency. Repeat for wiphy1.
 - B. Select wiphy0, click Create, fill out appropriate information and create a virtual access point. Repeat for wiphy1.

- C. The new vap should appear in the Port-Mgr table. Double-click to modify. Configure SSID and select WPA2 but do not fill in the Key/Phrase:

vap1 (ct523-3n-f20) Configure Settings

Port Status Information
Current: LINK-DOWN GRO NONE
Driver Info: Port Type: WIFI-AP Parent: wiphy0

Port Configurables

Standard Configuration | Advanced Configuration | Misc Configuration | Custom WiFi

Enable

- Set IF Down
- Set MAC
- Set TX Q Len
- Set MTU
- Set Offload
- Set PROMISC

Services

- HTTP
- FTP

Low Level

- PROMISC
- TSO Enabled
- UFO Enabled
- GSO Enabled
- LRO Enabled
- GRO Enabled

General Interface Settings

- Down Aux-Mgt
- DHCP-IPv6 DHCP Release DHCP Vendor ID: None
- DHCP-IPv4 **Secondary-IPs** DHCP Client ID: None
- DNS Servers: BLANK Peer IP: NA
- IP Address: 0.0.0.0 Global IPv6: AUTO
- IP Mask: 0.0.0.0 Link IPv6: AUTO
- Gateway IP: 0.0.0.0 IPv6 GW: AUTO
- Alias: MTU: 1500
- MAC Addr: 00:0e:8e:6c:38:71 TX Q Len: 1000
- Rpt Timer: medium (8 s) WiFi Bridge: NONE

WiFi Settings

- SSID: 80211r-ssid AP: DEFAULT
- Key/Phrase: Mode: (802.11abgn-AC)
- Freq/Channel: 5220/44 Rate: OS Default
- DTIM-Period: 2 Max-STA: 2007
- Beacon: 240
- WPA WPA2 OSEN WEP Disable HT40 Disable HT80 Disable SGI
- Verbose Debug

Print | View Details | Logs | Probe | Display Scan | Sync | Apply | OK | Cancel

- D. Select the **Advanced Configuration** tab in the Port-Modify window and check the box Advanced/802.1x and fill in the RADIUS IP/Port/Secret. Here the RADIUS server will be another instance of hostapd configured on a bridge interface and accessible via localhost.

vap1 (ct523-3n-f20) Configure Settings

Port Status Information
 Current: LINK-DOWN GRO NONE
 Driver Info: Port Type: WIFI-AP Parent: wiphy0

Port Configurables

Standard Configuration **Advanced Configuration** Misc Configuration Custom WiFi

Advanced WiFi Settings

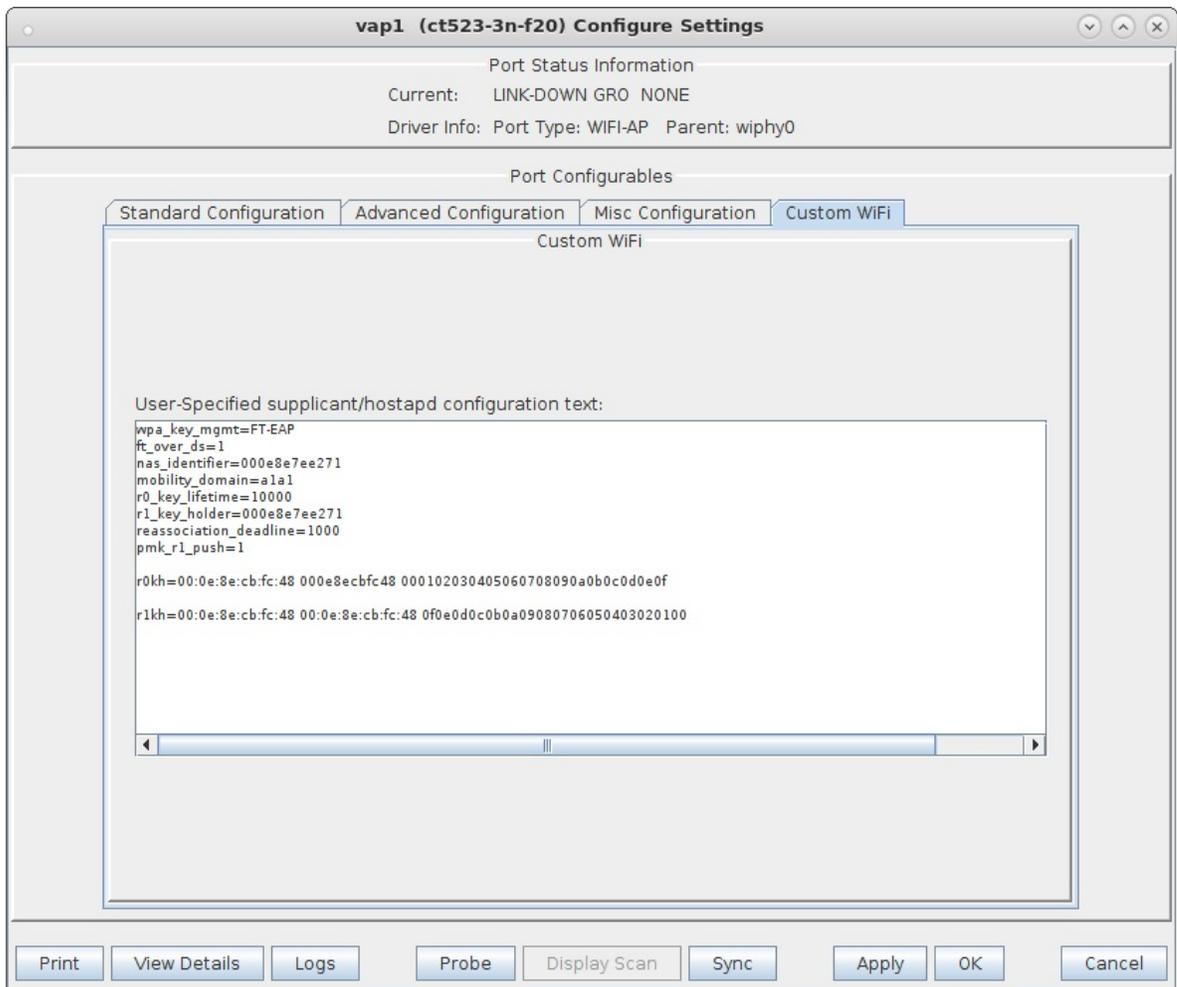
Select 'WPA2' on the Standard Configuration screen to enable Advanced/802.1x and enable Advanced/802.1x to enable most of these. Enabling 802.11u enables others.

Ignore Probes:	zero (0%)	HESSID:	00:00:00:00:00:00
Ignore Auth-Assoc:	zero (0%)	Realm:	
Ignore Assoc:	zero (0%)	IMSI:	
Ignore Re-Assoc:	zero (0%)	Milenage:	
Corrupt GTK:	zero (0%)	Domain:	
HS20 Capabilities		Consortium:	
HS20 Oper Class		RADIUS IP	127.0.0.1
HS20 WAN Metrics		RADIUS Port	1812
ieee80211w:	Disabled (0)	RADIUS Secret	lanforge
Venue Group:	Unspecified (0)	Venue Type:	Unspecified (0)
Network Type:	Private (0)	Address Types:	Not Available (0)
Network Auth:		3GPP Cell Net:	

Use 80211d
 Use 80211h
 Short-Preamble
 Advanced/802.1x
 HotSpot 2.0
 Disable DGAF
 Enable 802.11u
 802.11u Internet
 802.11u ASRA
 802.11u ESR
 802.11u UESA

Print View Details Logs Probe Display Scan Sync Apply OK Cancel

- E. Select the **Custom WiFi** tab in the Port-Modify window to fill in the additional hostapd options to enable and configure 802.11r. These lines will be appended to the end of the LANforge generated hostapd configuration file located in /home/lanforge/wifi of the resource in use.



vap1 00:0e:8e:7e:e2:71 - Your MAC will be different.

```
wpa_key_mgmt=FT-EAP
ft_over_ds=1
nas_identifier=000e8e7ee271 #vap1 MAC without colon delimiters, yours will differ.
mobility_domain=ala1
r0_key_lifetime=10000
r1_key_holder=000e8e7ee271 #vap1 MAC without colon delimiters, yours will differ.
reassociation_deadline=1000
pmk_r1_push=1

#r0kh is vap2 MAC address, vap2 nas identifier, AES key
r0kh=00:0e:8e:cb:fc:48 000e8ecbfc48 000102030405060708090a0b0c0d0e0f

#r1kh is vap2 MAC address, vap2 r1 key holder MAC, AES key
r1kh=00:0e:8e:cb:fc:48 00:0e:8e:cb:fc:48 0f0e0d0c0b0a09080706050403020100
```

full configuration file: [hostapd_vap1.conf](#)

vap2 00:0e:8e:cb:fc:48 - Your MAC will be different.

```
wpa_key_mgmt=FT-EAP
ft_over_ds=1
nas_identifier=000e8ecbfc48 #vap2 MAC without colon delimiters, yours will differ.
mobility_domain=ala1
r0_key_lifetime=10000
r1_key_holder=000e8ecbfc48 #vap2 MAC without colon delimiters, yours will differ.
reassociation_deadline=1000
pmk_r1_push=1

#r0kh is vap1 MAC address, vap1 nas identifier, AES key
r0kh=00:0e:8e:7e:e2:71 000e8e7ee271 0f0e0d0c0b0a09080706050403020100
```

```
#r1kh is vap1 MAC address, vap1 r1 key holder MAC, AES key
r1kh=00:0e:8e:7e:e2:71 00:0e:8e:7e:e2:71 000102030405060708090a0b0c0d0e0f
```

full configuration file: [hostapd_vap2.conf](#)

In this example, we are configuring push mode key distribution where the master key holder, R0KH, derives the R1 key for all secondary key holders, R1KH, listed in the configuration file and sends it to them over the DS via bridge interfaces. The R0KH and R1KH entries must be configured for all virtual access points in the 802.11r network.

For more information on hostapd 802.11r configuration, see:

general hostapd configuration

<https://www.w1.fi/cgiit/hostap/plain/hostapd/hostapd.conf>

how to enable wifi roaming

<https://blog.fem.tu-ilmenau.de/archives/1002-HowTo-enable-WiFi-roaming-with-hostapd-and-VLANs.html>

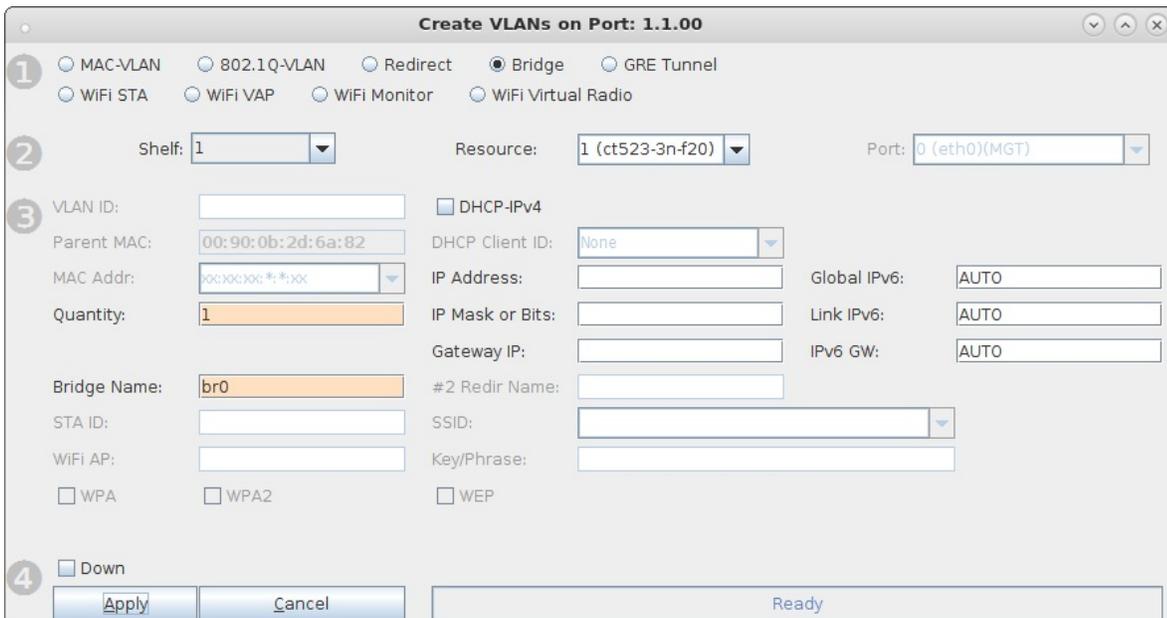
802.11r hostapd example

<ftp://ftp.raspberrypi-geek.com/pub/listings/rasp-pi-geek.com/04/AccessPoint/Listing04.txt>

F. Repeat above steps A-E for vap2 on wiphy1.

2. Create a bridge device for the first virtual access point, vap1. This bridge will be placed inside a virtual router so that it can serve DHCP requests and act as a RADIUS authentication server.

A. Go to the port manager tab, select Create, then select Bridge and enter Quantity 1 and a Bridge Name, then Apply to create the bridge.



- B. Modify the new bridge device to add vap1. Type vap1 in the text entry box, then select Add Ports, then select Apply.

br0 (ct523-3n-f20) Configure Settings

Port Status Information
Current: LINK-DOWN TSO UFO GSO GRO
Driver Info: Port Type: Bridge Cannot Detect

Port Configurables

Enable

- Set IF Down
- Set MAC
- Set TX Q Len
- Set MTU
- Set Offload
- Set Bridge Info

General Interface Settings

- Down
- Aux-Mgt
- DHCP-IPv6
- DHCP-IPv4
- DHCP Release
- DHCP Vendor ID: None
- DHCP Client ID: None
- DNS Servers: BLANK
- IP Address: 192.168.0.1
- IP Mask: 255.255.255.0
- Gateway IP: 0.0.0.0
- Alias:
- MAC Addr: 00:00:00:00:00:00
- Rpt Timer: medium (8 s)
- Peer IP: NA
- Global IPv6: AUTO
- Link IPv6: AUTO
- IPv6 GW: AUTO
- MTU: 1500
- TX Q Len: 0
- WiFi Bridge: NONE

Spanning-Tree

Aging Time: 300
Bridge Priority: 32768
Max Age: 20
Hello Time: 2
Forwarding Delay: 15

Bridge Information

Configured Ports | Current Ports

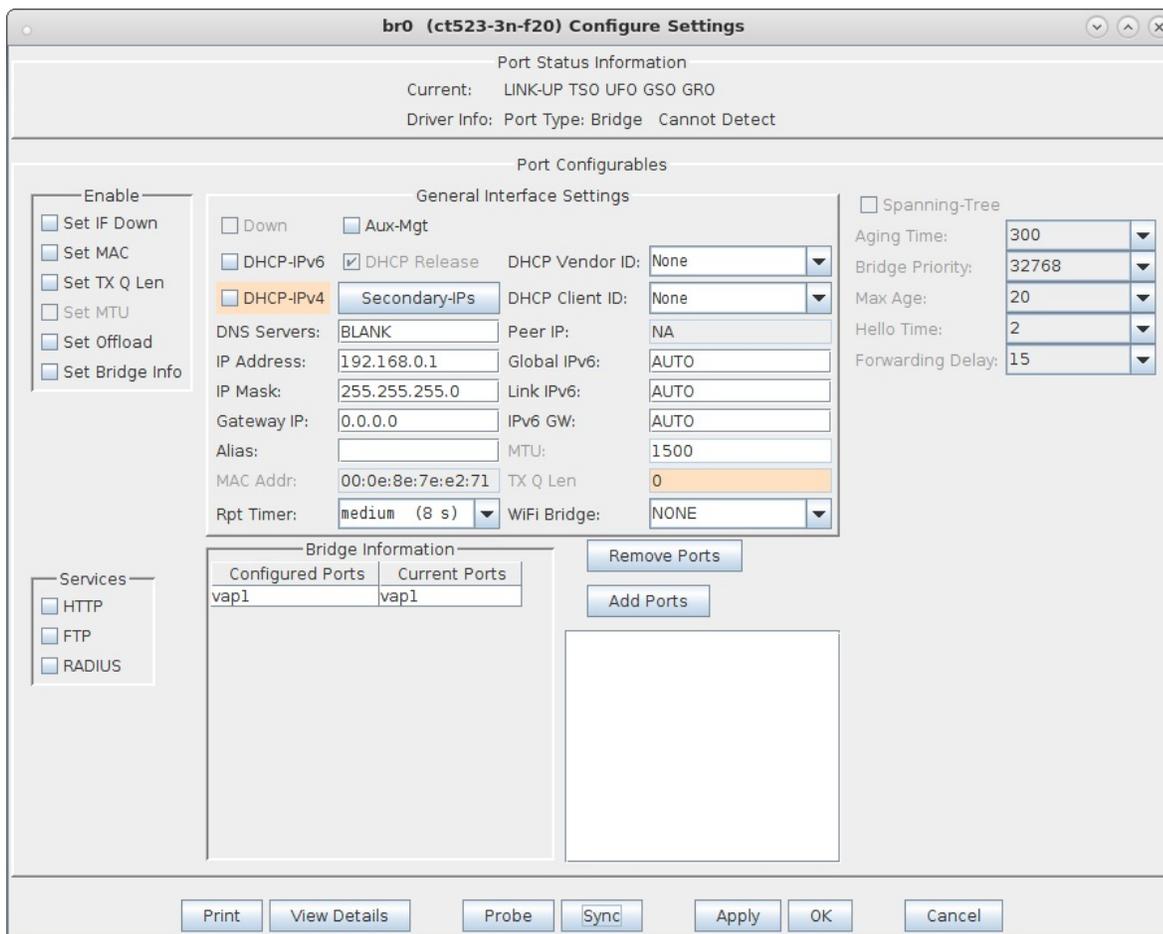
Remove Ports

Add Ports

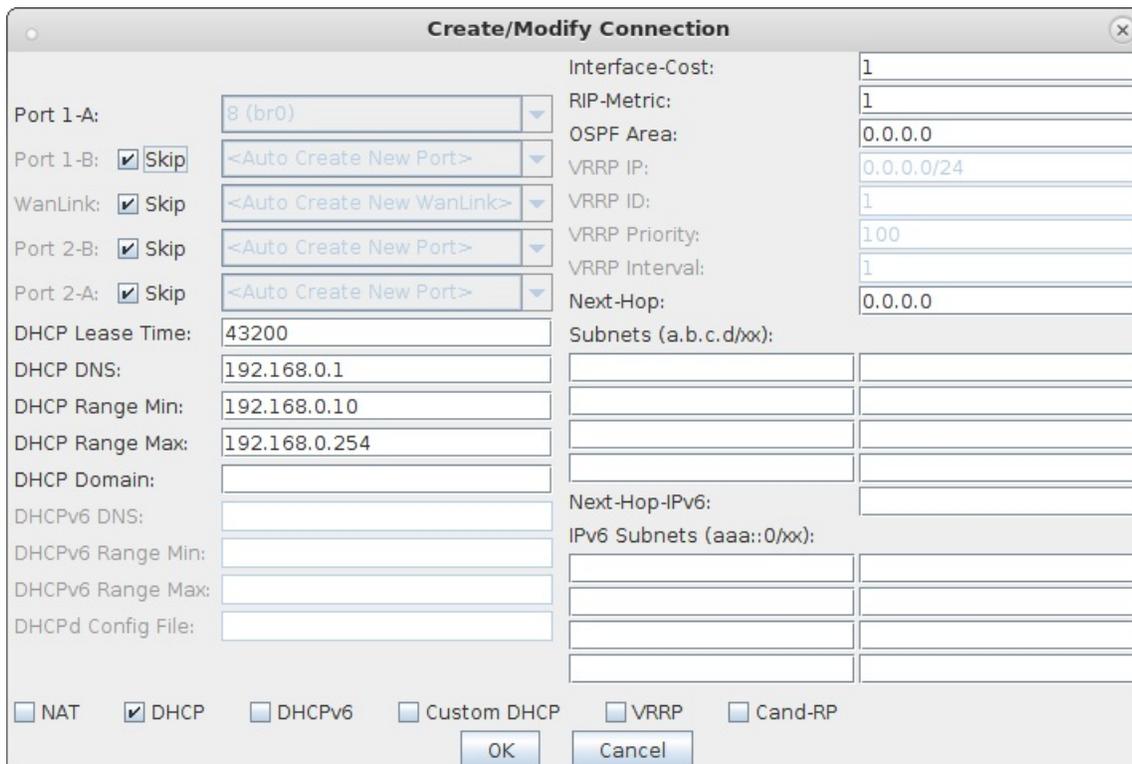
vap1

Print | View Details | Probe | Sync | Apply | OK | Cancel

C. Select Sync to verify vap1 is a configured and current bridge member.



D. Go to Netsmith, right-click the bridge and select Modify to add DHCP service. Select the DHCP checkbox at the bottom, then fill in the DHCP Lease Time, DHCP DNS, DHCP Range Min, DHCP Range Max and DHCP Domain if needed, then select OK.



- E. Go to Netsmith, right-click in a free area and select New Router and select OK. Then drag the bridge br0 into the virtual router and select Netsmith Apply.

For more information see [Virtual Router with DHCP Cookbook \(skip the wanlink portion\)](#)

3. Add a RADIUS server to the bridge device.
- A. Go to Netsmith, right-click the bridge and select Modify Port to add RADIUS service.
 - B. Select the RADIUS checkbox, then select OK.

br0 (ct523-3n-f20) Configure Settings

Port Status Information
Current: LINK-UP TSO UFO GSO GRO
Driver Info: Port Type: Bridge Cannot Detect

Port Configurables

Enable

- Set IF Down
- Set MAC
- Set TX Q Len
- Set MTU
- Set Offload
- Set Bridge Info

General Interface Settings

Down Aux-Mgt

DHCP-IPv6 DHCP Release DHCP Vendor ID: None

DHCP-IPv4 Secondary-IPs DHCP Client ID: None

DNS Servers: BLANK Peer IP: NA

IP Address: 192.168.0.1 Global IPv6: AUTO

IP Mask: 255.255.255.0 Link IPv6: AUTO

Gateway IP: 0.0.0.0 IPv6 GW: AUTO

Alias: MTU: 1500

MAC Addr: 00:0e:8e:7e:e2:71 TX Q Len: 0

Rpt Timer: medium (8 s) WiFi Bridge: NONE

Spanning-Tree

Aging Time: 300

Bridge Priority: 32768

Max Age: 20

Hello Time: 2

Forwarding Delay: 15

Bridge Information

Configured Ports	Current Ports
vap1	vap1

Remove Ports

Add Ports

Services

- HTTP
- FTP
- RADIUS

Print View Details Probe Sync Apply OK Cancel

- C. Setup the following configuration files to start the RADIUS service. You will need to create these files, but the certificate files can be created by running the `lf_kinstall` script with the `--do_radius` option.

/etc/hostapd.radius_clients

```
0.0.0.0/0 lanforge
```

/etc/hostapd.eap_user

```
"dot11r.user" PEAP  
"dot11r.user" MSCHAPV2 "!!dot11r123" [2]
```

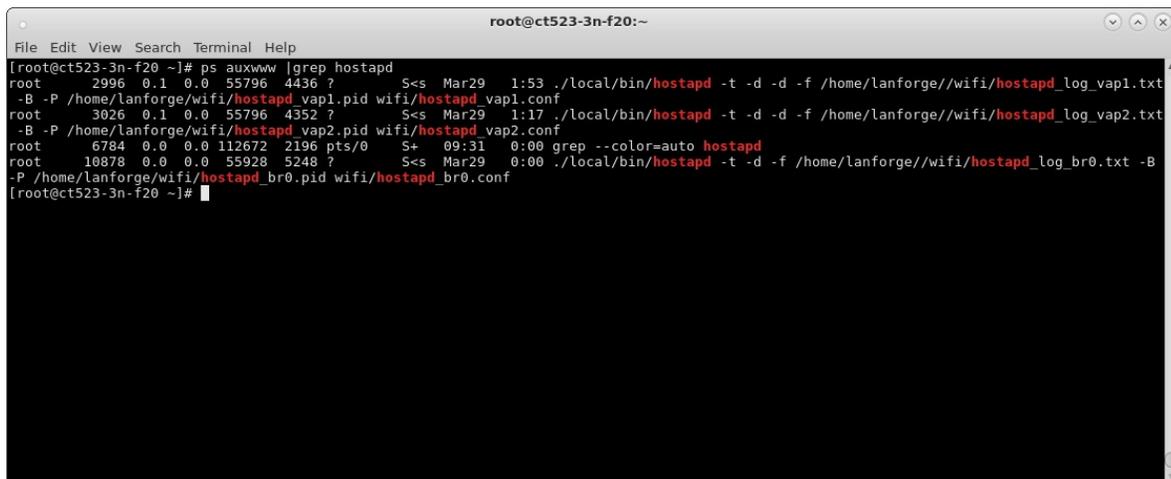
/home/lanforge/wifi/hostapd_br0.conf

```
interface=br0  
driver=wired  
logger_syslog=-1  
logger_syslog_level=2  
logger_stdout=-1  
logger_stdout_level=2  
ctrl_interface=/var/run/hostapd  
ctrl_interface_group=0  
eapol_key_index_workaround=0  
eap_server=1  
eap_user_file=/etc/hostapd.eap_user  
server_id=ct523-3n-f20 #Your server_id will be different.  
radius_server_auth_port=1812  
radius_server_clients=/etc/hostapd.radius_clients  
  
ca_cert=/etc/raddb/certs/ca.pem  
server_cert=/etc/raddb/certs/server.pem  
private_key=/etc/raddb/certs/server.key  
private_key_passwd=lanforge
```

- D. Verify that there are three hostapd processes running with the command:

```
ps auxww |grep hostapd
```

which should show something similar to the following:



```
root@ct523-3n-f20:~  
File Edit View Search Terminal Help  
[root@ct523-3n-f20 ~]# ps auxww |grep hostapd  
root    2996  0.1  0.0  55796  4436 ?        Ss   Mar29   1:53  ./local/bin/hostapd -t -d -f /home/lanforge/wifi/hostapd_log_vap1.txt  
-B -P /home/lanforge/wifi/hostapd_vap1.pid wifi/hostapd_vap1.conf  
root    3026  0.1  0.0  55796  4352 ?        Ss   Mar29   1:17  ./local/bin/hostapd -t -d -f /home/lanforge/wifi/hostapd_log_vap2.txt  
-B -P /home/lanforge/wifi/hostapd_vap2.pid wifi/hostapd_vap2.conf  
root    6784  0.0  0.0  112672  2196 pts/0    S+  09:31   0:00  grep --color=auto hostapd  
root    10878 0.0  0.0  55928  5248 ?        Ss   Mar29   0:00  ./local/bin/hostapd -t -d -f /home/lanforge/wifi/hostapd_log_br0.txt -B  
-P /home/lanforge/wifi/hostapd_br0.pid wifi/hostapd_br0.conf  
[root@ct523-3n-f20 ~]#
```

4. Create a second bridge device for the second virtual access point, `vap2`. Each `vap` in the 802.11r network requires its own bridge so that the bridge device receive logic can correctly process packets from each `vap` during fast-transition client roaming.

- A. Go to Netsmith, right-click in a free area, select New Bridge, enter Quantity 1 and a Bridge Name, then select Apply. Sync Netsmith to view the new bridge.

Create VLANs on Port:

1 MAC-VLAN 802.1Q-VLAN Redirect Bridge GRE Tunnel
 WiFi STA WiFi VAP WiFi Monitor WiFi Virtual Radio

2 Shelf: 1 Resource: 1 (ct523-3n-f20) Port: 1 (eth1)

3 VLAN ID: DHCP-IPv4
Parent MAC: 00:90:0b:2d:6a:83 DHCP Client ID: None
MAC Addr: IP Address: Global IPv6: AUTO
Quantity: 1 IP Mask or Bits: Link IPv6: AUTO
Gateway IP: IPv6 GW: AUTO
Bridge Name: br1 #2 Redir Name:
STA ID: SSID:
WiFi AP: Key/Phrase:
 WPA WPA2 WEP

4 Down

Apply Cancel Ready

- B. Right-click the new bridge and select Modify Port to add vap2 as a bridge member.

br1 (ct523-3n-f20) Configure Settings

Port Status Information
Current: LINK-UP PROBE-ERROR TSO UFO GSO GRO
Driver Info: Port Type: Bridge Driver: bridge(2.3) Bus: N/A

Port Configurables

Enable

- Set IF Down
- Set MAC
- Set TX Q Len
- Set MTU
- Set Offload
- Set Bridge Info

Services

- HTTP
- FTP
- RADIUS

General Interface Settings

Down Aux-Mgt

DHCP-IPv6 DHCP Release DHCP Vendor ID: None
 DHCP-IPv4 Secondary-IPs DHCP Client ID: None
DNS Servers: BLANK Peer IP: NA
IP Address: 0.0.0.0 Global IPv6: AUTO
IP Mask: 0.0.0.0 Link IPv6: AUTO
Gateway IP: 0.0.0.0 IPv6 GW: AUTO
Alias: MTU: 1500
MAC Addr: 00:0e:8e:cb:fc:48 TX Q Len: 0
Rpt Timer: medium (8 s) WiFi Bridge: NONE

Spanning-Tree
Aging Time: 300
Bridge Priority: 32768
Max Age: 20
Hello Time: 2
Forwarding Delay: 15

Bridge Information

Configured Ports	Current Ports
vap2	vap2

Remove Ports
Add Ports

Print View Details Probe Sync Apply OK Cancel

5. Each bridge will share a connection to a redirect device (rdd) pair so that FT messages can be sent and received.

- A. In Netsmith, right-click in a free area and select New Connection to create an rdd pair. Select **Skip** for Port 1-B, WanLink and Port 2-B then select OK. Select Netsmith Apply after creating the new connection.

- B. Right-click and select Modify Port br0, then add rddVR0 to br0, select Add Ports then select Apply. Your rddVRX numbering may differ depending on what other Netsmith objects are created.

- C. Right-click and select Modify Port br1, then add rddVR1 to br1, select Add Ports then select Apply. Your rddVRX numbering may differ depending on what other Netsmith objects are created.

br1 (ct523-3n-f20) Configure Settings

Port Status Information
 Current: LINK-UP PROBE-ERROR TSO UFO GSO GRO
 Driver Info: Port Type: Bridge Driver: bridge(2.3) Bus: N/A

Port Configurables

Enable

- Set IF Down
- Set MAC
- Set TX Q Len
- Set MTU
- Set Offload
- Set Bridge Info

General Interface Settings

Down Aux-Mgt

DHCP-IPv6 DHCP Release DHCP Vendor ID: None

DHCP-IPv4 DHCP Client ID: None

DNS Servers: BLANK Peer IP: NA

IP Address: 0.0.0.0 Global IPv6: AUTO

IP Mask: 0.0.0.0 Link IPv6: AUTO

Gateway IP: 0.0.0.0 IPv6 GW: AUTO

Alias: MTU: 1500

MAC Addr: 00:0e:8e:cb:fc:48 TX Q Len: 0

Rpt Timer: medium (8 s) WiFi Bridge: NONE

Spanning-Tree

Aging Time: 300

Bridge Priority: 32768

Max Age: 20

Hello Time: 2

Forwarding Delay: 15

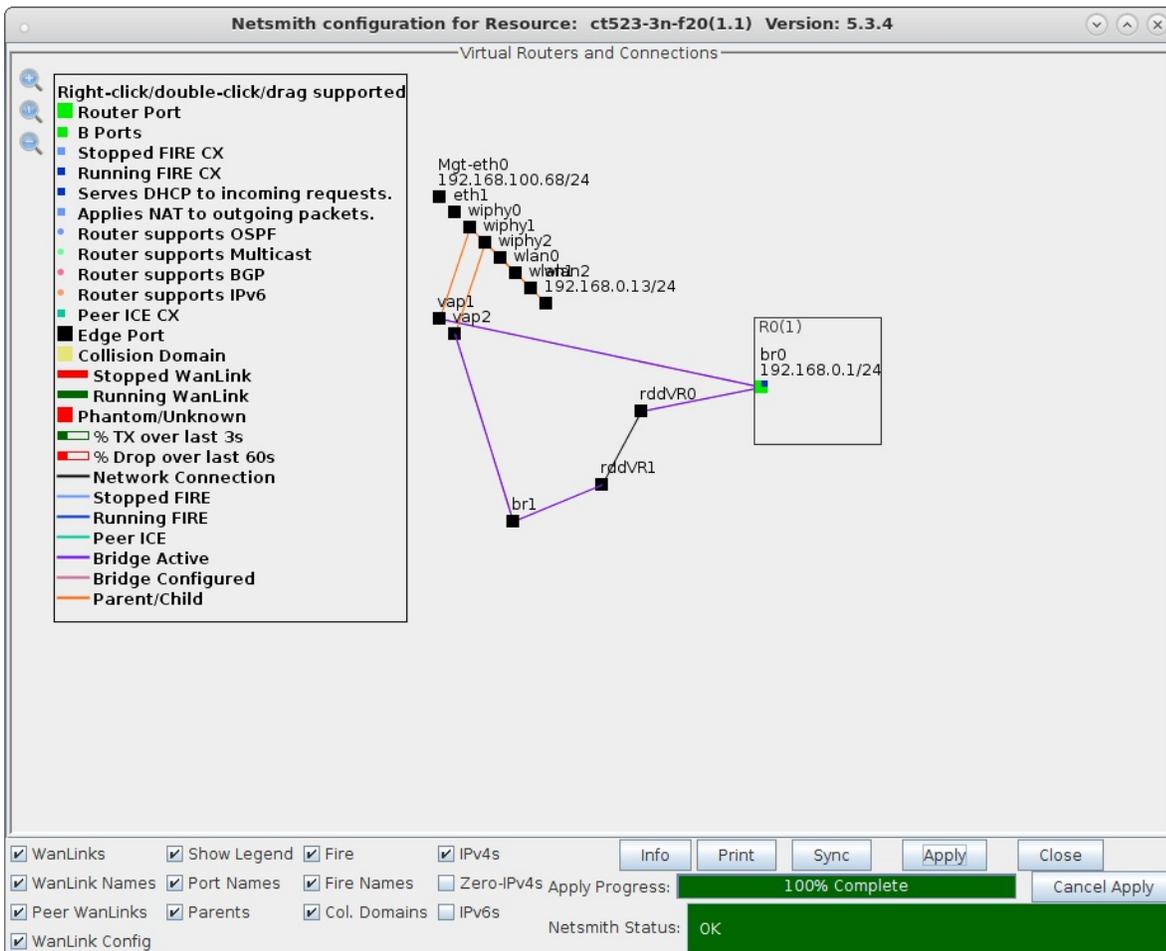
Services

- HTTP
- FTP
- RADIUS

Bridge Information

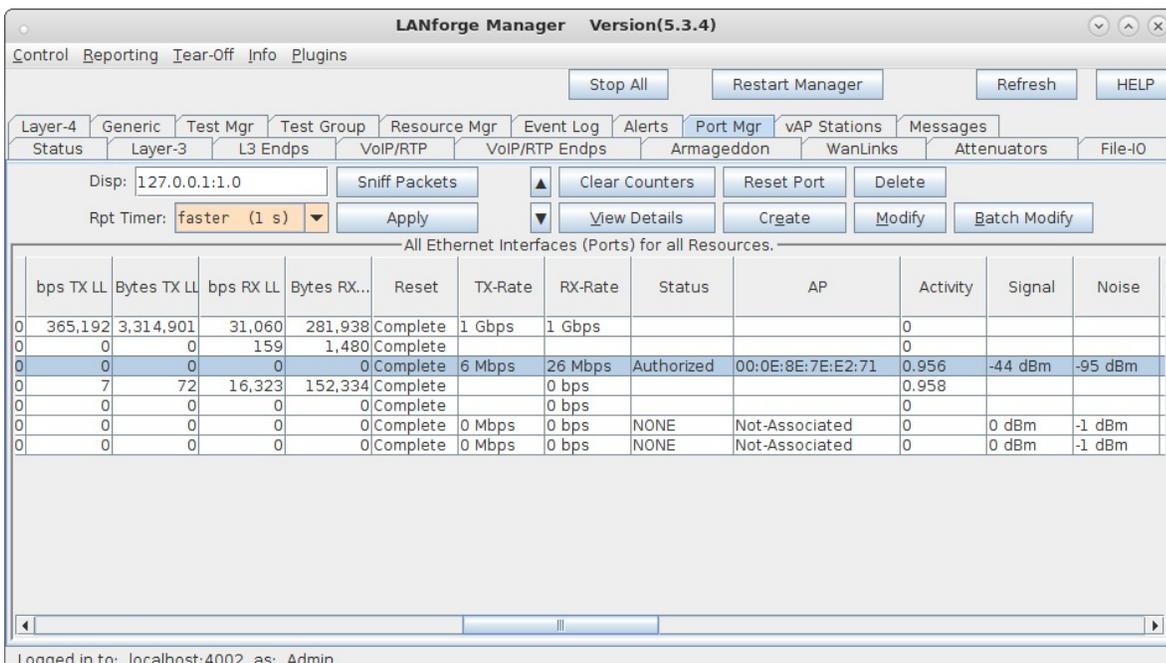
Configured Ports	Current Ports
vap2	vap2
rddVR1	rddVR1

D. The final Netsmith display should show the two bridged virtual access points connected by a rdd pair



6. Connect clients and force them to roam from vap to vap. This can be accomplished with a wpa_cli command for one or two clients or the Mobility Plugin Script for many clients. If the system under test is not able to force a roam, a variable attenuator on each vap radio may help induce a client to roam as the signal strength from vap to vap is varied.

A. Client connected to vap1.



B. Client roams to vap2.

```

root@ct521-1ac-f20:/home/lanforge
File Edit View Search Terminal Help
[root@ct521-1ac-f20 lanforge]# wpa_cli -i sta1 scan
OK
[root@ct521-1ac-f20 lanforge]# wpa_cli -i sta1 roam 00:0e:8e:cb:fc:48 DS
OK
[root@ct521-1ac-f20 lanforge]# █

```

LANforge Manager Version(5.3.4)

Control Reporting Tear-Off Info Plugins

Stop All Restart Manager Refresh HELP

Layer-4 Generic Test Mgr Test Group Resource Mgr Event Log Alerts Port Mgr vAP Stations Messages

Status Layer-3 L3 Endps VoIP/RTP VoIP/RTP Endps Armageddon WanLinks Attenuators File-I/O

Disp: 127.0.0.1:1.0 Sniff Packets Clear Counters Reset Port Delete

Rpt Timer: faster (1 s) Apply View Details Create Modify Batch Modify

All Ethernet Interfaces (Ports) for all Resources.

	bps TX LL	Bytes TX LL	bps RX LL	Bytes RX...	Reset	TX-Rate	RX-Rate	Status	AP	Activity	Signal	Noise
0	190,631	6,996,062	17,399	583,995	Complete	1 Gbps	1 Gbps			0		
0	0	0	197	4,440	Complete					0		
0	11	133	14	161	Complete	6 Mbps	6 Mbps	Authorized	00:0E:8E:CB:FC:48	1.024	-42 dBm	-95 dBm
0	62	811	6,521	263,346	Complete		0 bps			1.025		
0	0	0	0	0	Complete		0 bps			0		
0	0	0	0	0	Complete	0 Mbps	0 bps	NONE	Not-Associated	0	0 dBm	-1 dBm
0	0	0	0	0	Complete	0 Mbps	0 bps	NONE	Not-Associated	0	0 dBm	-1 dBm

Logged in to: localhost:4002 as: Admin

C. Client roams back to vap1.

```
root@ct521-1ac-f20:/home/lanforge
File Edit View Search Terminal Help
[root@ct521-1ac-f20 lanforge]# wpa_cli -i sta1 scan
OK
[root@ct521-1ac-f20 lanforge]# wpa_cli -i sta1 roam 00:0e:8e:7e:e2:71 DS
OK
[root@ct521-1ac-f20 lanforge]#
```

LANforge Manager Version(5.3.4)

Control Reporting Tear-Off Info Plugins

Stop All Restart Manager Refresh HELP

Layer-4 Generic Test Mgr Test Group Resource Mgr Event Log Alerts Port Mgr vAP Stations Messages

Status Layer-3 L3 Endps VolP/RTP VolP/RTP Endps Armageddon WanLinks Attenuators File-I/O

Disp: 127.0.0.1:1.0 Sniff Packets Clear Counters Reset Port Delete

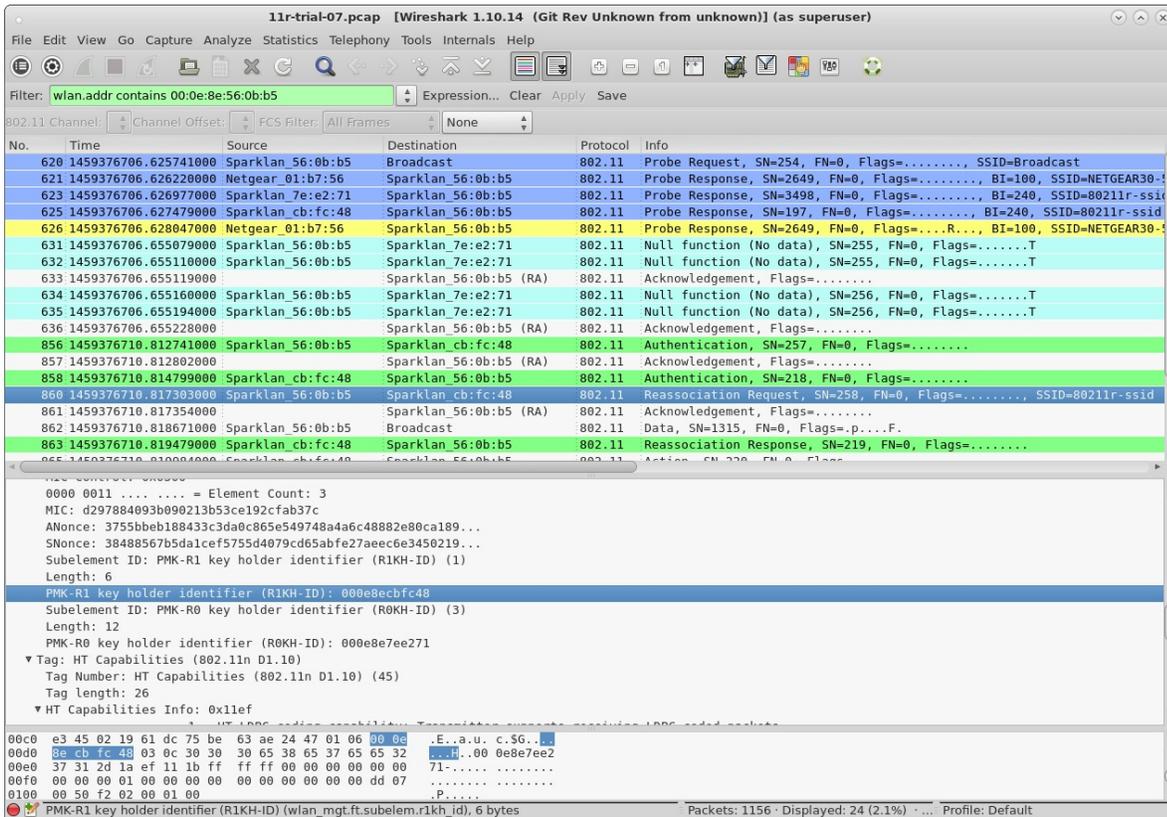
Rpt Timer: medium (8 s) Apply View Details Create Modify Batch Modify

All Ethernet Interfaces (Ports) for all Resources.

bps TX LL	Bytes TX LL	bps RX LL	Bytes RX...	Reset	TX-Rate	RX-Rate	Status	AP	Activity	Signal	Noise
12,636,...	2,417,8...	154,186	26,860,...	Complete	1 Gbps	1 Gbps			0		
0	1,548	225	79,550	Complete	1 Gbps	1 Gbps			0		
0	0	0	245	Complete	0 bps	0 bps			0		
899	812,653	6,937	11,203,...	Complete	0 bps	0 bps			0		
0	0	0	0	Complete	0 Mbps	0 bps	NONE	Not-Associated	0	0 dBm	-1 dBm
0	0	0	0	Complete	0 Mbps	0 bps	NONE	Not-Associated	0	0 dBm	-1 dBm
681	7,337	851	19,599	Complete	175.5 M...	26 Mbps	Authorized	00:0E:8E:7E:E2:71	1.199	-44 dBm	-95 dBm

Logged in to: localhost:4002 as: Admin

E. A wireless capture of over-the-air packets shows the transition.



F. Output graph of the Mobility Plugin script of several roaming stations.

