

AN1287: RS9116N Wi-Fi Roaming Application Note

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1 Abstract

This Document helps the user with the Bgscan and Roaming features supported by the RS9116N driver. It also describes the procedure to enable Bgscan and Roaming using RS9116N driver.

2 Introduction

RS9116N Open Source Driver (OSD) is a SoftMAC driver which interacts with the Linux wireless MAC layer, i.e., MAC80211. The driver is a group of simple and efficient kernel modules which currently supports RS9116N chipsets and it can be ported to any embedded platform in-addition to x86 platform.

Background scanning helps to get the information about surrounding AP's in the vicinity of STA. This information helps the STA to roam between the APs. The document explains the steps to enable Background scanning & Roaming with OSD driver in STA mode.

3 Terminology (Acronyms/Abbreviations)

1. NL80211 - nl80211 is the new 802.11 netlink interface public header.
2. Bgscan - Background scanning
3. AP - Access Point
4. STA - Station DUT
5. EVB - Evaluation Board
6. EVK – Evaluation Kit

4 Requirements

- RS9116N EVK – Refer to the sample product link of our module given below:
 - <https://www.silabs.com/wireless/wi-fi/rs9116-wi-fi-transceiver-modules>
- WLAN driver – RS9116N n-Link Open Source Driver. Available at below link.
 - <https://www.silabs.com/wireless/wi-fi/rs9116-wi-fi-transceiver-modules>
- Linux PC (kernel version v2.6.38 – v5.3)
- At least two Access points

5 Background Scanning

In the earlier days, the data transfer between the STA and AP is limited to particular range based upon type of standard. If the STA crosses beyond the range, there may be a loss of data and immediate connection to another nearest AP is not possible because there is no background scanning. In order to avoid the loss of data / reduce data loss during the STA is in mode of mobility, background scan was implemented.

Functional Description: The mobility of station makes the signal strength weak and it may sometimes leads to disconnection from AP. In order to avoid data loss, STA must have nearby network report to connect to better AP prior to disconnect from existing AP. This is called BG SCANNING.

Scanning: There are two types of scanning.

1. Active scanning
2. Passive scanning

Active scanning will be done in normal channels and passive scanning should be done in DFS channels of 5GHz due to meet regulatory rules.

Note:

Background scan is implemented in firmware and is controlled by the driver with an IOCTL called "set_bgscan_params". The arguments that are given in the command line, starts the scanning procedure and station may scan available APs before they make decision to roam.

6 Roaming

Roaming, in the context of an 802.11 wireless network, is the process of a client moving an established Wi-Fi network association from one access point to another access point within the same Extended Service Set (ESS) without losing connectivity.

Driver will monitor the RSSI of connected AP and Changes the connection to AP, if connected AP's RSSI crosses the subjected threshold values.

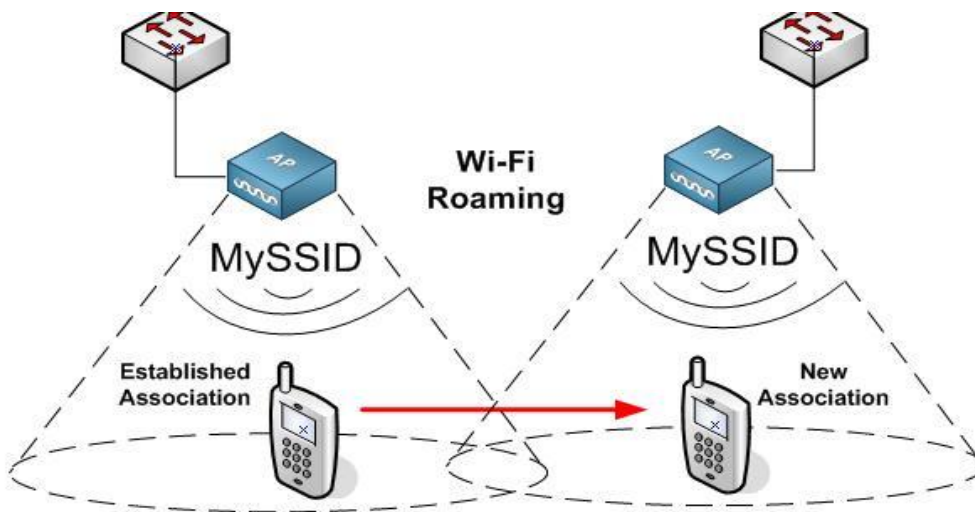


Figure 1: Roaming

It is the legacy roaming in which no roam time optimization method is used.

This process consists of 3 phases:

1. **Scanning:** As the device moves away from the AP to which it is connected and the RSSI (Received Signal Strength Indicator) values begin to drop below certain levels, the client device sends out probe packets to identify AP alternatives. Upon discovery of accessible APs, the device then selects its next AP based on certain criteria, as defined by the device itself.
2. **Authentication:** During this phase, the client device sends an authentication request to the new AP and waits for a response from the AP to approve or reject the request.
3. **Re-association:** Upon approval by the new AP, the client sends a re-association request and waits for a response. Once the re-association is complete, client device connects to new AP.

7 Configuration Steps Required for Roaming

7.1 Configuration Parameters in .config File

Download the supplicant from https://w1.fi/wpa_supplicant/

Extract the supplicant using the following command.

```
# tar xvf wpa_supplicant-2.6.tar.gz
# cd wpa_supplicant-2.6/wpa_supplicant
# cp defconfig .config
```

Make sure the following parameters are enabled in the supplicant configuration file (.config)

```
CONFIG_DRIVER_NL80211=y
CONFIG_BGSCAN_SIMPLE=y
NL80211_CMD_ROAM=y
CONFIG_LIBNL20=y
CONFIG_LIBNL32=y
CONFIG_WPS2=y
CONFIG_BGSCAN=y
```

Save the configuration file and exit.

Compile the supplicant using "make" command in the following path.

```
# cd wpa_supplicant-2.6/wpa_supplicant
# make clean
# make
```

After successful compilation the supplicant executable will be found in the same path. Copy the supplicant executable to the driver release folder.

```
# cp wpa_supplicant RS9116.NB0.NL.GNU.LNX.OSD.a.b.c.d/rsi.
```

7.1.1 Access Point Configuration:

All the AP's using for Roaming must have below similar configuration's.

1. Same SSID
2. Same Password
3. Same Security mode
4. Same band(2.4GHz/5GHz)
5. Same Channel width(20Mhz/40Mhz)

7.2 Configuring Bgscan Parameters in sta_settings.conf File

Background scanning and roaming can be verified using wpa_supplicant. It is recommended to use supplicant version greater than 2.6 for better performance in roaming.

To use this facility, user needs to ensure the flag **CONFIG_BGSCAN_SIMPLE** is enabled in the supplicant build configuration file (.config).

Note:

If user does not require bgscan he has to disable bgscan in the supplicant config and should not include above configurations in the wpa_supplicant.conf file. This cannot be done if the user is connected through network manager.

To enable Bgscan and Roaming add '**bgscan="simple: 10:-45:100"**' in the network block of sta_settings.conf file. Wpa_supplicant behavior for background scanning can be specified by configuring a bgscan module. These modules are responsible for requesting background scans for the purpose of roaming within an ESS (i.e., within a single network block with all the APs using the same SSID).

The bgscan parameter uses the below format:

"<bgscan module name> :< module parameters>"

```
bgscan="simple :< short bgscan interval in seconds> :< signal strength threshold>: <long interval>"
```

This line should be present either inside a network block or outside of all network blocks based on the requirement.

Bgscan parameter has three configurable parameters.

1. short bgscan interval,
2. signal strength threshold,
3. long bgscan interval in seconds.

If the signal strength of connected AP is stronger/better than "signal strength threshold" supplicant will perform a bgscan for every "long interval" and if the signal is worse, it will perform a scan every "short bgscan interval".

Please see the example network block:

```
network={
  ssid= "Range"
  key_mgmt= WPA-PSK
  psk=<passphrase specified in the Access Point>
  proto=WPA2
  pairwise=CCMP
  group =CCMP
  #bgscan="simple:<short bgscan interval in seconds>:<signal strength
  threshold>:<long interval in seconds>"
  bgscan="simple:10:-45:100"
  priority=1
}
```

After configuring the network block, follow the below steps:

- 1) Start the RS9116N module in STA mode and connect to AP [For starting RS9116N module in STA mode, please refer section 4. Installing the nlink Driver in RS9116N Open Source Driver Technical Reference Manual
- 2) Run the supplicant to connect the STA to nearest AP.
`./wpa_supplicant -i <Interface_name> -D nl80211 -c sta_settings.conf -dddt > log1 &`
- 3) Check the connection of the STA with “iwconfig” or “`./wpa_cli -i <interface> status`”.
Example: `./wpa_cli -i wifi0 status`

The sample output of this command is

```
wifi0 IEEE 802.11bgn ESSID:"Range" Nickname:""
Mode:Managed Frequency:2.412 GHz Access Point: 38:A4:ED:DE:BB:06
Bit Rate:39 Mb/s Tx-Power=16 dBm Sensitivity=1/0
RTS thr:off Fragment thr:off
Encryption key:****-**** Security mode:restricted
Power Management:off
Link Quality=80/80 Signal level=-28 dBm Noise level:0 dBm
Rx invalid mwid:0 Rx invalid crypt:0 Rx invalid frag:0
Tx excessive retries:0 Invalid misc:0 Missed beacon:0
```

7.3 Configuring background scan parameters through debugfs

For Bgscan, f/w requires some of the parameters to be configured. Default values are configured if user doesn't configure them through debugfs. Below commands are used to configure bgscan params.

- 1) To verify the bgscan status and parameters

```
# cat /sys/kernel/debug/phy<X>/bgscan
```

- 2) To enable background scan and configure its parameters from debugfs:

```
# echo 1 10 10 20 20 100 1 3 1 6 11 > /sys/kernel/debug/phy<X>/bgscan
```

The input parameters of the background scan command are explained below.

- **<background_enable>**: To enable the background scan.
- **<bgscan_threshold>**: The Background scan threshold is referred to as the RSSI Upper Threshold. At every background scan interval, the n-Link® module decides whether to initiate or not to initiate a background scan based on the connected Access Point's RSSI. The module initiates a background scan if the RSSI of the connected Access Point is below this threshold. The input value should be the absolute value in dBm.
- **<rss_i_tolerance_threshold>**: If the difference between the current RSSI value of the connected Access Point and the RSSI value of the Access Point from the previous background scan is greater than the RSSI Tolerance Threshold, then the module performs a background scan. Assigning a large value to this field will eliminate this method of triggering background scans.
- **<periodicity>**: This parameter specifies the interval between the background scans. The unit of this field is seconds. Setting the value of this field as 0 will disable background scans.

- **<active_scan_duration>**: This parameter determines the duration of the active scan in each channel during the Background scan process. The recommended value for this parameter is 20ms for quicker Background scan operation and uninterrupted throughput. The maximum allowed value for this parameter is 255ms.
- **<passive_scan_duration>**: This parameter determines the duration of the passive scan in each DFS channel. If an active scan is enabled in a DFS channel and a beacon or probe response is received during that period, the module converts the passive scan into an active scan and waits through the duration specified by the <active_scan_duration> parameter. During a passive scan, if any beacon is received in a channel, then the recommended value for this parameter will be 100ms. The active scan in DFS channel can be enabled through Background scan probe request. Active scanning will be performed only if channel switch IE (Information Element) is not present in the received beacon or probe response packets. The maximum allowed value for this parameter is 255ms.
- **<two_probe_enable>**: If this feature is enabled, the Client sends two probe requests to the Access Point. This is useful when scanning is carried out in channels with high traffic. The valid values are
 - a. 0 – Disable
 - b. 1 – Enable
- **<num_of_bgscan_channels>**: Specifies the number of Background scan channels. The n-Link® module supports up to 24 channels.
- **<channels_to_scan>**: The list of channels in which Background scan has to be performed.

The command initializes background scanning in the driver, for the channels specified. It also takes signal strength threshold and periodicity values specified as input. These will decide at what signal strength threshold to start bgscan and at what interval those need to be repeated, irrespective of signal strength threshold

- 3) To disable background scan which is happening in channels provided through debugfs.

```
# echo 0 > /sys/kernel/debug/phy<X>/bgscan
```

- 4) For checking the list of bgscan channels configured to device use below command. This will display the list of bgscan channels configured to device with DFS indication also.

```
# cat /sys/kernel/debug/phy<X>/bgscan
```

The command initializes background scanning in the driver, for the channels specified. It also takes signal strength threshold and periodicity values specified as input. These will decide at what signal strength threshold to start bgscan and at what interval those need to be repeated, irrespective of signal strength threshold.

7.4 Configure Connection Quality Monitoring (cqm) rssi and hysteresis using iw Command

To know more about iw tool, refer to the section [Configuration Using CFG80211](#).

```
$iw dev <devname> cqm rssi <threshold|off> [<hysteresis>]
Set connection quality monitor RSSI threshold.
Example:
$iw dev wlan0 cqm rssi -45 4
```

To know more about Background Scan and Set Parameters configuration, refer to the section [Background Scan & Roaming](#) in RS9116N Open Source Driver Technical Reference Manual.

Note: Use only open source supplicant for roaming using NL80211. Latest supplicant is recommended (wpa_supplicant 2.6)

7.5 Illustration of Roaming

Let us say, two AP's are configured with same SSID, security and password. After executing the `bgscan` IOCTL, STA is connected to one AP which has better signal strength (In the figure below: AP (98:FC:11:E6:27:0B) with signal strength -26dBm).

```
Every 0.1s: iwconfig:./wpa_cli scan_res | grep roam

rpine0    no wireless extensions.

virbr0-nic no wireless extensions.

lo        no wireless extensions.

virbr0    no wireless extensions.

enp0s3l6  no wireless extensions.

wlp0s20f0u10 IEEE 802.11bgn ESSID:"roam_test" Nickname:""
  Mode:Managed Frequency:2.462 GHz Access Point: 98:FC:11:E6:27:0B
  Bit Rate:65 Mb/s Tx-Power=10 dBm Sensitivity=1/0
  RTS thr:off Fragment thr:off
  Encryption key:**** Security mode:restricted
  Power Management:off
  Link Quality=80/80 Signal level=-25 dBm Noise level:0 dBm
  Rx invalid nwid:0 Rx invalid crypt:0 Rx invalid frag:0
  Tx excessive retries:0 Invalid misc:0 Missed beacon:0

78:11:dc:34:84:ae 2462 -40 [WPA2-PSK-CCMP][WPS][ESS] roam_test
98:fc:11:e6:27:0b 2462 -26 [WPA2-PSK-CCMP+TKIP][WPS][ESS] roam_test
```

Figure 2: Connected to AP-1

When the signal strength of the AP is weaker, STA will try to connect to another AP which has better signal strength (In the figure below: AP (78:11:dc:34:84:ae) with signal strength -26dBm).

```
Every 0.1s: iwconfig:./wpa_cli scan_res | grep roam

rpine0    no wireless extensions.

virbr0-nic no wireless extensions.

lo        no wireless extensions.

virbr0    no wireless extensions.

enp0s3l6  no wireless extensions.

wlp0s20f0u10 IEEE 802.11bgn ESSID:"roam_test" Nickname:""
  Mode:Managed Frequency:2.462 GHz Access Point: 78:11:DC:34:84:AE
  Bit Rate:65 Mb/s Tx-Power=10 dBm Sensitivity=1/0
  RTS thr:off Fragment thr:off
  Encryption key:**** Security mode:restricted
  Power Management:off
  Link Quality=80/80 Signal level=-25 dBm Noise level:0 dBm
  Rx invalid nwid:0 Rx invalid crypt:0 Rx invalid frag:0
  Tx excessive retries:0 Invalid misc:0 Missed beacon:0

78:11:dc:34:84:ae 2462 -26 [WPA2-PSK-CCMP][WPS][ESS] roam_test
98:fc:11:e6:27:0b 2462 -32 [WPA2-PSK-CCMP+TKIP][WPS][ESS] roam_test
```

Figure 3: Connected to AP-2 with Better Signal Strength

8 Test Procedure

8.1 Block Diagram

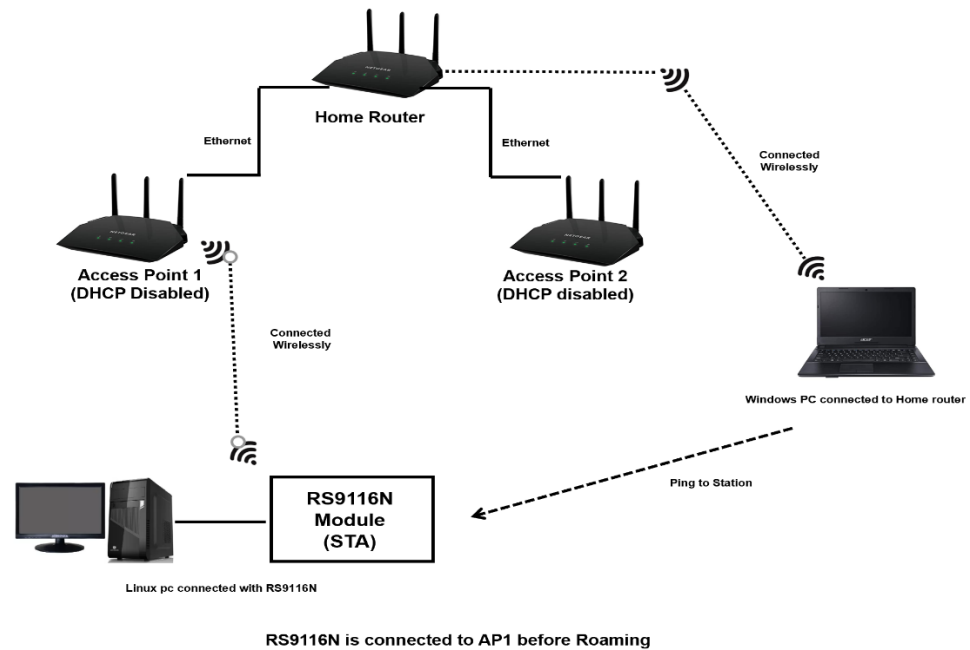


Figure 4: Before Roaming (STA Connected to AP1)

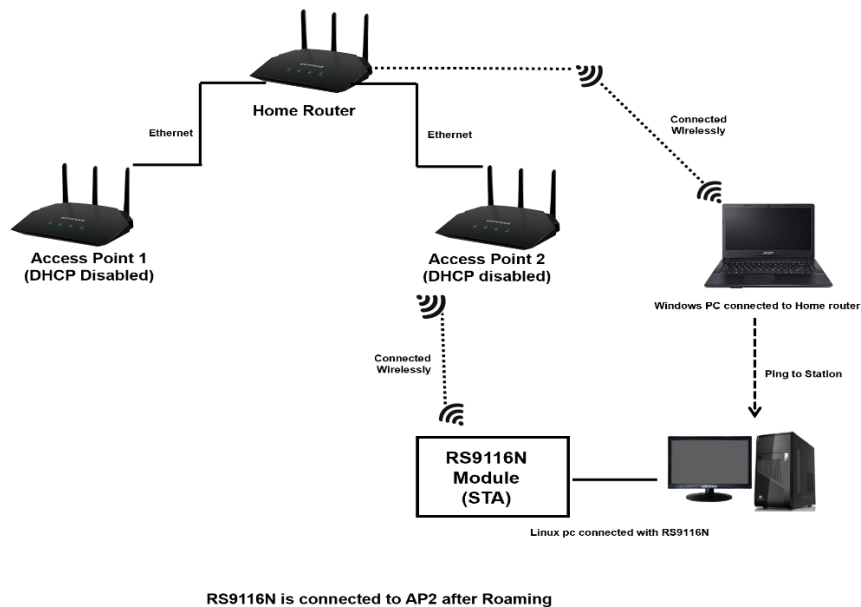


Figure 5: After Roaming (STA Connected to AP2)

8.2 Description

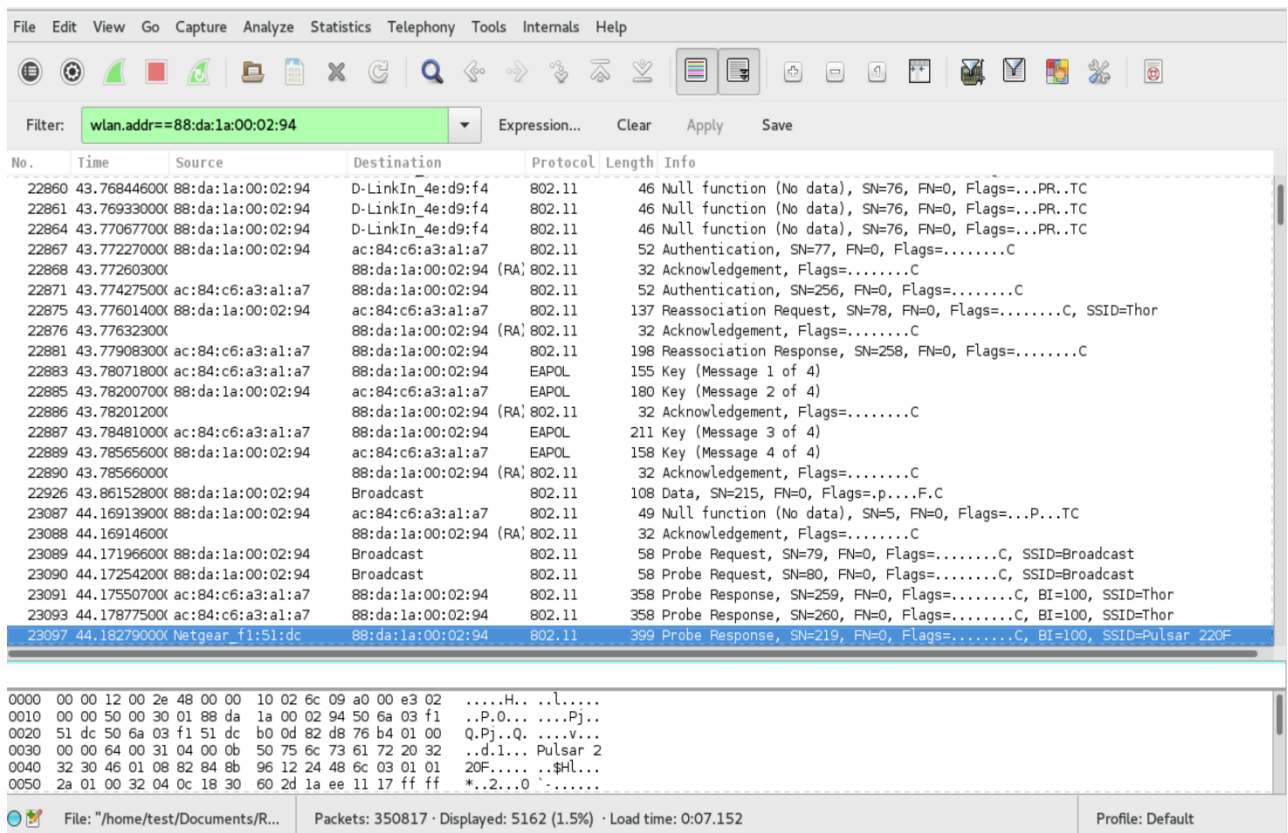
This test procedure is used to calculate the switchover time of Roaming.

8.3 Procedure

1. Connect the both Access points, AP1 and AP2 to Home router with ethernet cables.
2. Disable the DHCP server in both AP1 and AP2.
3. Configure the both access points with same SSID's, Password, Security, Band and channel width.
4. Now, connect RS9116N module to Linux PC and configure it in STA(client) mode.
5. Establish the connection between STA and AP1, configure the background scan as mentioned in the above section (Follow the procedure for Roaming mentioned in the section 7 [Configuration steps required for roaming](#)).
6. Obtain IP address to STA, by dhclient command and start ping from Windows PC connected wirelessly to home router to STA.
7. When STA switches from AP1 to AP2, roaming is happened and the ping will continue with some timeouts.
8. Now, calculate the switchover time from AP1 to AP2.

8.4 Results

- Switchover time from AP1 to AP2 is ~100ms.



The image shows a Wireshark packet capture interface. The top menu bar includes File, Edit, View, Go, Capture, Analyze, Statistics, Telephony, Tools, Internals, and Help. Below the menu is a toolbar with various icons. The filter bar shows the filter: wlan.addr==88:da:1a:00:02:94. The packet list pane shows a list of packets with columns for No., Time, Source, Destination, Protocol, Length, and Info. The packet details pane shows the selected packet (No. 23097) with its structure and data. The packet bytes pane shows the raw data in hexadecimal and ASCII.

No.	Time	Source	Destination	Protocol	Length	Info
22860	43.768446000	88:da:1a:00:02:94	D-LinkIn_4e:d9:f4	802.11	46	Null function (No data), SN=76, FN=0, Flags=...PR..TC
22861	43.769330000	88:da:1a:00:02:94	D-LinkIn_4e:d9:f4	802.11	46	Null function (No data), SN=76, FN=0, Flags=...PR..TC
22864	43.770677000	88:da:1a:00:02:94	D-LinkIn_4e:d9:f4	802.11	46	Null function (No data), SN=76, FN=0, Flags=...PR..TC
22867	43.772270000	88:da:1a:00:02:94	ac:84:c6:a3:a1:a7	802.11	52	Authentication, SN=77, FN=0, Flags=.....C
22868	43.772603000	88:da:1a:00:02:94	88:da:1a:00:02:94 (RA)	802.11	32	Acknowledgement, Flags=.....C
22871	43.774275000	ac:84:c6:a3:a1:a7	88:da:1a:00:02:94	802.11	52	Authentication, SN=256, FN=0, Flags=.....C
22875	43.776014000	88:da:1a:00:02:94	ac:84:c6:a3:a1:a7	802.11	137	Reassociation Request, SN=78, FN=0, Flags=.....C, SSID=Thor
22876	43.776323000	88:da:1a:00:02:94	88:da:1a:00:02:94 (RA)	802.11	32	Acknowledgement, Flags=.....C
22881	43.779083000	ac:84:c6:a3:a1:a7	88:da:1a:00:02:94	802.11	198	Reassociation Response, SN=258, FN=0, Flags=.....C
22883	43.780718000	ac:84:c6:a3:a1:a7	88:da:1a:00:02:94	EAPOL	155	Key (Message 1 of 4)
22885	43.782007000	88:da:1a:00:02:94	ac:84:c6:a3:a1:a7	EAPOL	180	Key (Message 2 of 4)
22886	43.782012000	88:da:1a:00:02:94	88:da:1a:00:02:94 (RA)	802.11	32	Acknowledgement, Flags=.....C
22887	43.784810000	ac:84:c6:a3:a1:a7	88:da:1a:00:02:94	EAPOL	211	Key (Message 3 of 4)
22889	43.785656000	88:da:1a:00:02:94	ac:84:c6:a3:a1:a7	EAPOL	158	Key (Message 4 of 4)
22890	43.785660000	88:da:1a:00:02:94	88:da:1a:00:02:94 (RA)	802.11	32	Acknowledgement, Flags=.....C
22926	43.861528000	88:da:1a:00:02:94	Broadcast	802.11	108	Data, SN=215, FN=0, Flags=p....F.C
23087	44.169139000	88:da:1a:00:02:94	ac:84:c6:a3:a1:a7	802.11	49	Null function (No data), SN=5, FN=0, Flags=...P...TC
23088	44.169146000	88:da:1a:00:02:94	88:da:1a:00:02:94 (RA)	802.11	32	Acknowledgement, Flags=.....C
23089	44.171966000	88:da:1a:00:02:94	Broadcast	802.11	58	Probe Request, SN=79, FN=0, Flags=.....C, SSID=Broadcast
23090	44.172542000	88:da:1a:00:02:94	Broadcast	802.11	58	Probe Request, SN=80, FN=0, Flags=.....C, SSID=Broadcast
23091	44.175507000	ac:84:c6:a3:a1:a7	88:da:1a:00:02:94	802.11	358	Probe Response, SN=259, FN=0, Flags=.....C, BI=100, SSID=Thor
23093	44.178775000	ac:84:c6:a3:a1:a7	88:da:1a:00:02:94	802.11	358	Probe Response, SN=260, FN=0, Flags=.....C, BI=100, SSID=Thor
23097	44.182790000	Netgear_fl:51:dc	88:da:1a:00:02:94	802.11	399	Probe Response, SN=219, FN=0, Flags=.....C, BI=100, SSID=Pulsar 220F

0000 00 00 12 00 2e 48 00 00 10 02 6c 09 a0 00 e3 02H..l....
0010 00 00 50 00 30 01 88 da 1a 00 02 94 50 6a 03 f1 ..P.O...Pj..
0020 51 dc 50 6a 03 f1 51 dc b0 0d 82 d8 76 b4 01 00 Q.Pj..Q.v..
0030 00 00 64 00 31 04 00 0b 50 75 6c 73 61 72 20 32 ..d.l... Pulsar 2
0040 32 30 46 01 08 82 84 8b 96 12 24 48 6c 03 01 01 20F.....\$HL..
0050 2a 01 00 32 04 0c 18 30 60 2d 1a ee 11 17 ff ff *.2...0`.....

File: "/home/test/Documents/R... Packets: 350817 · Displayed: 5162 (1.5%) · Load time: 0:07.152 Profile: Default

9 Troubleshooting

- Make sure you are enabling bgscan in STA mode only.
- Make sure all the AP's SSID, password, band, channel width and security mode should be same in case of roaming.
- The parameters given in the example command are only for reference. You can change the values based on your application.
- Make sure of the COEX and DRIVER modes for corresponding STA mode that you intended to use.
 - COEX MODE =1 - Wi-Fi ALONE
 - COEX MODE =5 - Wi-Fi STA+BT classic
 - COEX MODE =9 - Wi-Fi STA+BT LE
 - COEX MODE =13 - Wi-Fi STA+BT classic +BT LE (All possible modes for STA)
- Make sure, "CFG80211 and MAC 80211" and "Bluetooth subsystem" is enabled in the Target platform's kernel. Please refer our RS9116N Open Source Driver Technical Reference Manual.
- Use latest wpa supplicant version 2.6 or above.

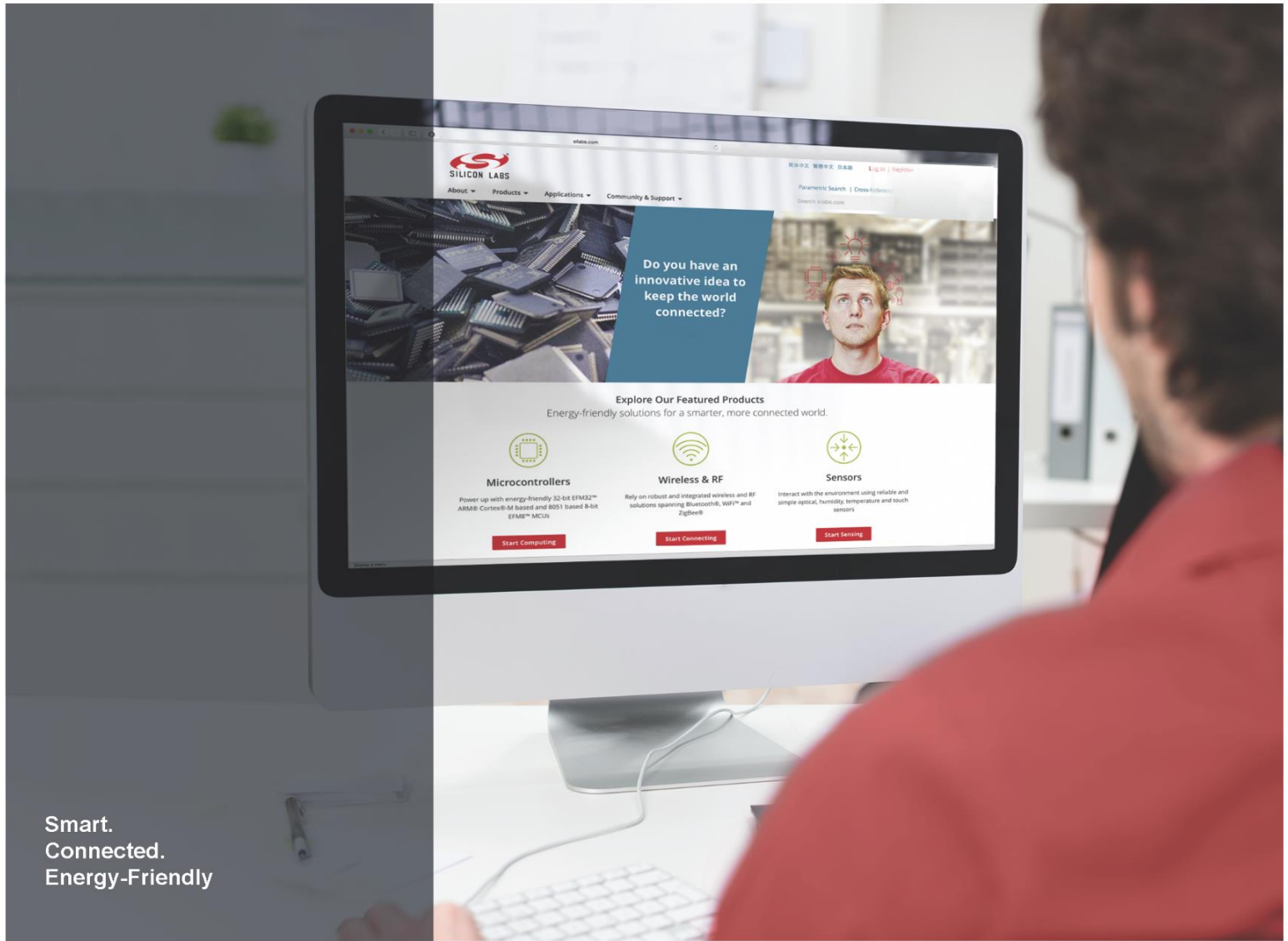
10 References and Related Documentation

- Refer to our RS9116N Open Source Driver Technical Reference Manual which is part of our driver source package available at the link below:

<https://www.silabs.com/wireless/wi-fi/rs9116-wi-fi-transceiver-modules>

11 Revision History

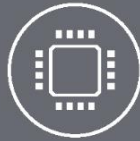
Revision No	Version No	Date	History/Comments
1	Initial Version	February, 2019	Initial document
2	Secondary version	August, 2020	Changed the Driver link
3	0.1	August 7, 2020	Initial Review.
4	0.2	August 13, 2020	Review#2
5	0.3	September 6, 2020	Review#3
6	0.4	October 16, 2020	Updated OSD related changes. Updated references.



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