Commissioned by
Redpine Signals, Inc.

IoT Wi-Fi & Bluetooth Power Consumption

Redpine Signals vs Cypress Semiconductor, Qualcomm Tech. & Texas Instruments

EXECUTIVE SUMMARY

The ever-growing Internet of Things (IoT) relies heavily on battery power. Unlike mobile phones and tablets, IoT devices such as doorbells, smart locks and remote sensors cannot easily be recharged. Other devices like wearables have very small battery sizes imposing tighter power constraints. Thus, prolonging battery life by minimizing power consumption becomes a critical concern in IoT.

Redpine Signals commissioned Tolly to evaluate two of their IoT SoCs, the RS9116 and the RS14100 and compare their power consumption with competing IoT offerings from Cypress Semiconductor, Qualcomm Technologies and Texas Instruments. Tests run in an RF chamber included Wi-Fi and Bluetooth Low Energy (BLE) scenarios and benchmarked power consumption in Wi-Fi Standby Associated Mode, while running a secure TCP stack (with and without co-channel traffic) and in a multi-protocol scenario using BLE.

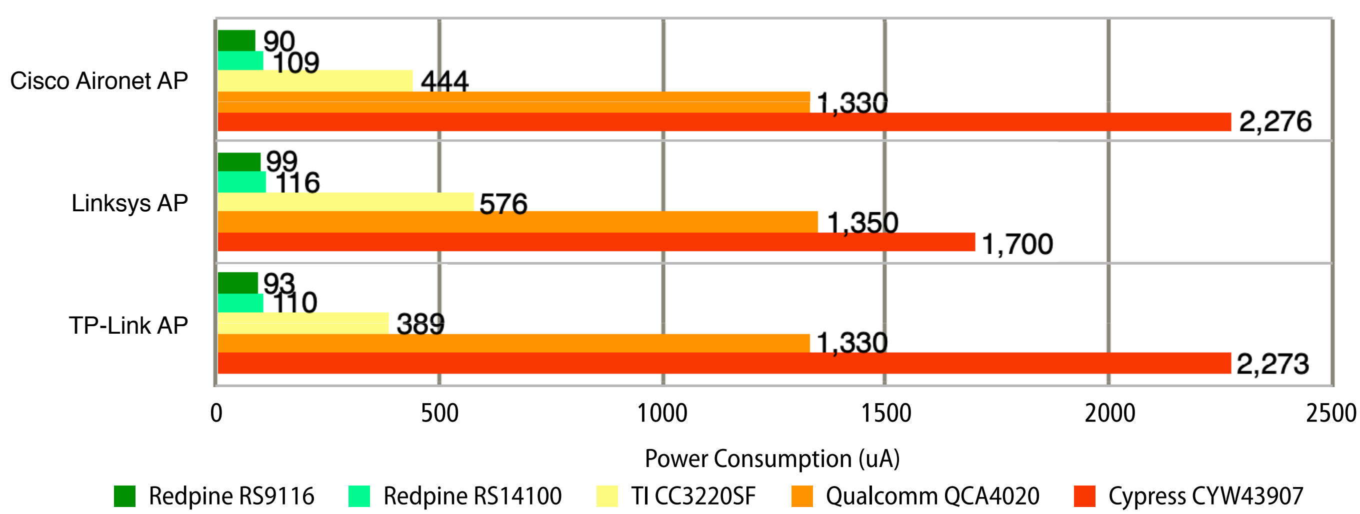
The power consumption of the Redpine Signals solutions was dramatically lower than the competition in every test scenario. ...<continued on next page>

THE BOTTOM LINE

The Redpine Signals SoCs delivered dramatically lower power consumption than the competing chips in all tests:

1. 4x to 25x lower in Wi-Fi standby mode tests
2. 18x to 22x lower in Wi-Fi TCP + TLS tests
3. 10x to 15x lower in multi-protocol Wi-Fi + Bluetooth Low Energy (BLE) tests
4. Projected improvement in battery life for smart lock application: 3 years with Redpine chips (greater than 3x improvement) compared to 9 months using competitor chips.

IoT Power Consumption: Wi-Fi Standby Associated Mode
As Reported by Keysight Technologies N6705B DC Power Analyzer
uA @ 3.3V (Lower numbers are better)



Notes: Tests conducted using vendor evaluation kits. AP DTIM set to 3. All testing using 2.4GHz band. See Table 2 for AP details.

Source: Tolly, December 2018

Figure 1

Platforms Tested

Two Redpine Signals SoCs were evaluated. The RS9116 is an IoT Wireless Connectivity SoC that provides Wi-Fi, BT and BLE capabilities and is used in conjunction with third-party microprocessors. The RS14100 SoC integrates the microcontroller in addition to the Wi-Fi, BT and BLE functions. The Redpine Signals platforms were tested along with: Cypress Semiconductor CYW943907, Qualcomm QCA4020 and Texas Instruments (TI) CC3220SF. See Table 2 for version levels tested.

Access Points Tested

Although all access points (APs) are standards-based, the interaction between APs and clients is apparently not identical. The difference in activity is reflected in different power consumption profiles when platforms are tested with different APs. Tests were run using common models from Cisco, Linksys and TP-Link. See Table 2 for details of the APs.

Test Results

Wi-Fi Standby Associated Mode Test

This test measured the power consumption of the test platform when associated with an AP in standby mode.

Three different APs were used for this test. Each AP was tested with three different DTIM settings: 1, 3, and 10. The DTIM setting's significance is explained in the Test Methodology section. In short, the higher the DTIM period, the lower the drain on a battery.

Redpine Signals, Inc.

RS9116 & RS14100

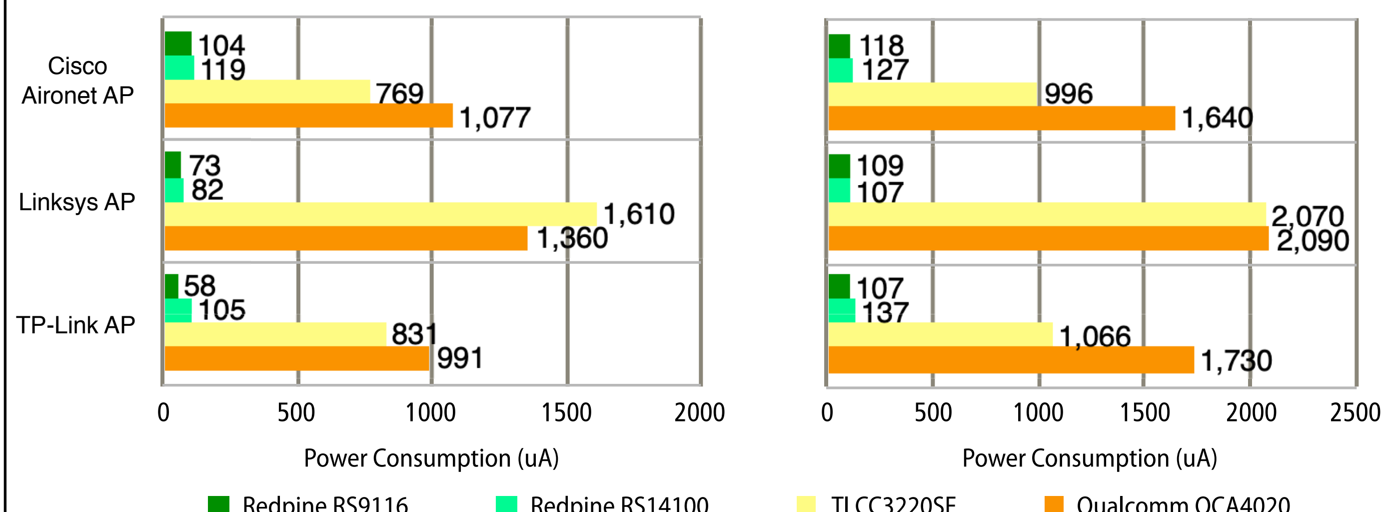
IoT Wi-Fi & Bluetooth Power Consumption

Tested December 2018

A total of 40 tests were run. Figure 1 illustrates the results with the common DTIM setting of 3. Full results can be found in Table 1. The Linksys AP does not support any DTIM setting lower than three and thus could not run the test of DTIM=1.

Redpine RS9116 Results

In the tests with Cisco Aironet, which were representative of the other APs,



Notes: Tests conducted using vendor evaluation kits. AP DTIM set to 3. All testing using 2.4GHz band. See Table 2 for AP details.

Source: Tolly, December 2018

Figure 2

the Redpine Signals RS9116 consumed 90 uA. In the same test, the Cypress platform consumed 2,276 uA which is 25x the power consumption of the Redpine platform. (In the test with the Linksys AP, the Cypress consumption was 1,700 uA. Better, but still more than 17x the Redpine RS9116 power consumption in the same test scenario.)

The Qualcomm power consumption of 1,330 uA in the Cisco scenario is nearly 15x that of the Redpine RS9116.

TI's power consumption was 444 uA. While better than Cypress and Qualcomm, TI's power draw was still 4.93x that of the Redpine RS9116.

Results were similar across other DTIM settings with the Redpine RS9116 power consumption always lower than competing vendors.

Redpine RS14100 Results

The results for the Redpine RS14100 were similarly low and, again, lower than all competitors. Once again referencing the Cisco Aironet scenario, the Redpine 14100 power consumption was 109 uA.

The Cypress platform consumed more than 20x the power of the Redpine 14100, the Qualcomm platform consumed 12x and the TI platform consumed 4x that of the Redpine.

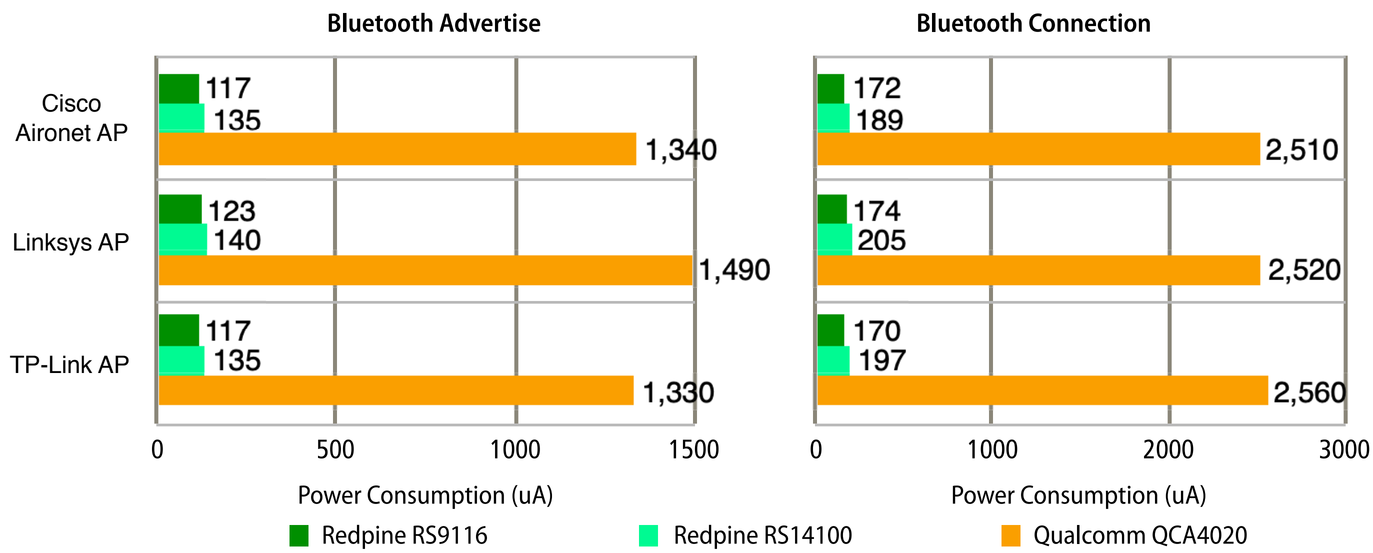
Results were similar across other DTIM settings with the Redpine RS14100 power consumption always lower than competing vendors.

TCP + TLS (Secure) Connection

This test measured the power consumption of the test platform when a connection was active through an AP with the TCP stack active and a Transport Layer Security (TLS) connection active. This scenario simulates the conditions where the platform would be in secure communication with a cloud application and is a typical usage profile of IoT devices. [1]

Two traffic variations were tested. In one, there was no other traffic on the AP from other clients. In the other scenario, a steady stream of traffic 70Mbps was running between another client and the same test AP. This test was conducted with all three APs but only with DTIM=3. Full results can be found both in Figure 2 and Table 1.

IoT Power Consumption: Low-Power Multi-Protocol WLAN + Bluetooth (BLE)
As Reported by Keysight Technologies N6705B DC Power Analyzer
uA @ 3.3V (Lower numbers are better)



Notes: Tests conducted using vendor evaluation kits. AP DTIM set to 3. All testing using 2.4GHz band. See Table 2 for AP details.

Source: Tolly, December 2018

Figure 3

[1] The Cypress platform was not included because power consumption in early tests was overly high.

Complete Power Consumption Test Results

as reported by Keysight N6705B DC Power Analyzer

Vendor	Solution Under Test	WLAN Standby Associated Mode Test (2.4GHz) by AP and DTIM Setting (uA)								
		DTIM 1			DTIM 3			DTIM 10		
		Linksys	TP-Link	Cisco Aironet	Linksys	TP-Link	Cisco Aironet	Linksys	TP-Link	Cisco Aironet
Redpine Signals	RS9116	N/A[1]	254.1	247.2	98.8	93.2	90.2	49.3	40.6	40.5
	RS14100	N/A[1]	292.0	284.7	116.2	110.1	108.9	52.1	48.1	47.2
Cypress Semi.	CYW43907	N/A[1]	2,930	3,810	1,700	2,273	2,276	2,570	1,927	3,480
Qualcomm	QCA4020	N/A[1]	2,540	2,460	1,350	1,330	1,330	929.2	972.6	920
TI	CC3220SF	N/A[1]	817.4	680.6	576.0	388.6	443.8	348.8	304.2	251

Vendor	Solution Under Test	TCP/IP + TLS Connection (2.4GHz) by AP with DTIM=3 Setting (uA)					
		Linksys		TP-Link		Cisco Aironet	
		No Co-channel Traffic	70Mbps Co-channel	No Co-channel Traffic	70Mbps Co-channel Traffic	No Co-channel Traffic	70Mbps Co-channel
Redpine Signals	RS9116	72.6	109	57.6	107.4	104.2	118
	RS14100	82	107.3	104.6	136.7	118.7	126.8
Qualcomm	QCA4020	1,360	2,090	991	1,730	1,077	1,640
TI	CC3220SF	1,610	2,070	830.7	1,066	768.5	996

Vendor	Solution Under Test	Low-Power Multi-Protocol WLAN (2.4GHz) by AP with DTIM=3 Setting + Bluetooth (uA)					
		Linksys		TP-Link		Cisco Aironet	
		Advertise	Connection	Advertise	Connection	Advertise	Connection
Redpine Signals	RS9116	123.3	174.2	117.1	170.3	116.8	171.7
	RS14100	139.9	205.4	134.7	196.9	134.6	189.2
Qualcomm	QCA4020	1,490	2,520	1,330	2,560	1,340	2,510

Note: uA @ 3.3V. 1) Linksys does not support a DTIM setting of 1.

Source: Tolly, December 2018

Table 1

The scenario using the Linksys AP demonstrated product differences most significantly and, thus, will be referenced here for both Redpine platforms.

Redpine RS9116 Results

In this test with Linksys, the Redpine Signals RS9116 consumed 73 uA with no co-channel traffic and 109 uA with co-channel traffic. In the same test, the Qualcomm platform consumed 1,360 uA and 2,090 uA. This was more than 18x and 19x the respective Redpine results.

In the same test, the TI platform consumed 1,610 uA and 2,070 uA. This was 22x and 19x the respective Redpine results.

Both Qualcomm and TI demonstrated somewhat lower power consumption in the tests with Cisco and TP-Link but both still drew far more power power than the Redpine RS9116.

Redpine RS14100 Results

In this test with Linksys, the Redpine Signals RS14100 consumed 82 uA with no co-channel traffic and 107 uA with co-channel traffic. In the same test, the Qualcomm platform consumed 16.5x and 19.5x the respective Redpine results.

In the same test, the TI platform consumed than 19.6x and 19x the respective Redpine RS14100 results.

As noted earlier, both Qualcomm and TI demonstrated somewhat lower power consumption in the tests with Cisco and TP-Link APs but, again, both still drew far more power than the Redpine RS14100.

Low-Power Multi-Protocol WLAN + Bluetooth (BLE)

This test measured the power consumption of the test platform when the platform under test was connected both to a WLAN AP and a Bluetooth device using Bluetooth Low Energy (BLE) mode. This scenario simulates a condition that would occur when BLE connectivity to a local device (e.g. smartphone or tablet) would be use in addition to or in lieu of a Wi-Fi connection.[2]

Solutions Under Test

Vendor & Platform	Firmware/Software/SDK Version
Redpine Signals RS9116	1.0.6 (WiSeConnect)
Redpine Signals RS14100	1.0.6
Cypress Semiconductor CYW43907	WICED Version : 6.0.1.5 WLAN firmware: W10, Version : 7.15.168.101 (r674438) FWID 01-13cae12
Qualcomm QCA4020	SDK version 2.0.1
Texas Instruments CC3220SF	Host Driver Version: 2.0.1.15 Build Version 3.3.0.0.31.2.0.0.0.2.2.0.4

Access Points (APs) Under Test

Vendor & Model	Firmware Version
Cisco Aironet 802.11n Dual band Access point : AIR-LAP1262N-E-K9	15.2(2)JA
Linksys E3000	1.0.04
TP-Link TL WR741N	3.16.5 Build 130329 Rel.62825n

Source: Tolly, December 2018

Table 2

[2] The TI platform under test did not provide Bluetooth connectivity and, thus, was not tested.

Two variations were tested. In one, the BLE was "Advertising" (looking for connection).In the other scenario, a connection was made between the platform under test and the Bluetooth device.

This test was conducted with all three APs but only with DTIM=3. Full results can be found both in Figure 3 and Table 1.

Lower Power Consumption = Longer Battery Life

Lower Wi-Fi Connected mode power consumption directly translates to longer battery life. But how low is low-enough and what are the potential gains in battery life? To answer this -we consider two scenarios to illustrate the gains in battery life due to the measured lower Wi-Fi Connection power:

Scenario-1: Wearable Application

Consider a Wearable with 100mAh Li-Ion rechargeable battery connected securely to cloud application(s) (TCP, TLS) providing notifications, etc., in the absence of a smart phone. Battery life without Wi-Fi cloud connectivity is 2 weeks => average power consumption of: 100mAh/ (2*7*24h) = 297uA.

Taking the numbers from Figure-2 for Linksys AP the battery life of the wearable with Wi-Fi included is:

With **Redpine RS9116**: 297uA + 73uA = 370uA. Battery life of wearable including RS9116 Wi-Fi TCP+TLS = 100mAh /370uA = 270 hours = **11.2 days**

With **TI CC3220SF:** 297uA + 1610uA = 1907uA. Battery life of wearable including CC3220SF Wi-Fi TCP+TLS = 100mAh /1907uA = 52 hours = **2.2 days .**

Scenario-2: Smart Lock Application

Consider a Smart Lock with 4x AA cells providing 1500mAh @ 6V . The battery life of the Smart lock without Wi-Fi connectivity is 5 years => average power consumption of rest of the Smart lock electronics is 1500mAh/ (5*365*24h) = 34.2uA.

The Smart lock can remain connected to AP with 1 second sleep intervals. Taking the Standby associated numbers from Table-1 for TP-Link AP for DTIM=10 (1 second sleep between Wi-Fi beacon receptions) the battery life of the Smart Lock with Wi-Fi included is:

With **Redpine RS9116**: 40.6uA @ 3.3V = 24.8uA @ 6V (assuming 90% efficiency step down regulator from 6V down to 3.3V) => total current of Lock = 24.8uA + 34.2uA = 59uA. Battery life of Lock including RS9116 Wi-Fi with 1 Second connected sleep = 1500mAh /59uA = 25423 hours = **2 years and 11 months**

With **TI CC3220SF**: 306.2uA @ 3.3V = 187.1uA @ 6V (assuming 90% efficiency step down regulator from 6V down to 3.3V) => total current of Lock = 187.1uA + 34.2uA = 221.3uA. Battery life of Lock including CC3220SF Wi-Fi with 1 Second connected sleep = 1500mAh /221.3uA = 6778 hours = **9 months**.

Source: Redpine Signals

Test results were quite similar across the three APs. The TP-Link results will be referenced in this discussion.

Redpine RS9116 Results

In this test with TP-Link, the Redpine Signals RS9116 consumed 117 uA with the Bluetooth "Advertise" and 189 uA with a Bluetooth "Connection." In the same test, the Qualcomm platform consumed 1,330 uA and 2,090 uA. This was more than 11x and 15x the respective Redpine results.

Redpine RS14100 Results

In this test with TP-Link, the Redpine Signals RS9116 consumed 135 uA with the Bluetooth "Advertise" and 197 uA with a Bluetooth "Connection." In the same test, the Qualcomm platform consumed 9.85x and 13x the respective Redpine results.

Test Setup & Methodology

Overview

IoT Platforms

All testing was focused on board-level, platform capabilities rather than complete systems. All testing was conducted in an RF chamber using developer kits from each vendor. See Table 2 for details of board models and levels.

WLAN Access Points

Testing focused on power consumption as the IoT platforms interacted with WLAN networks. AP settings as well as AP models will impact results. Thus, three common APs from Cisco Systems, Linksys (a division of Belkin), and TP-Link were chosen for testing. See Table 2 for details on specific models and firmware versions. All WLAN testing was done using 2.4GHz mode.

DTIM Settings

The delivery traffic indication message (DTIM) setting for an AP impacts how frequently a connected device will "wake up" and, thus, will impact power consumption. In short, the higher the DTIM setting the longer the period between "wake up" packets for the client. Higher DTIM means longer battery life.

Bluetooth

IoT devices may require communicating with a nearby device via Bluetooth in addition to WLAN or as a fall-back should the WLAN AP or connection become unavailable. Thus, one test scenario included testing for both WLAN and the newer, energy-saving mode introduced as Bluetooth 4.0 and known as Bluetooth Low Energy or BLE.

Power Measurement

All power consumption measurements were taken using a Keysight Technologies N6705B DC Power Analyzer. That device ran Agilent 14585A Control and Analysis Software for DC Power Analyzer (v1.0.0.1).

Wi-Fi Standby Associated Mode Test

In this test, each system under test associated with an AP in standby mode. Power consumption was measured for 30 seconds and the average consumption was recorded. Results were recorded as microamperes (uA)..

Three different APs were used for this test. Each AP was tested with three different DTIM settings: 1, 3, and 10. The Linksys AP does not support any DTIM setting lower than three and thus could not run the test of DTIM=1.

TCP + TLS (Secure) Connection

This test simulated a scenario where the IoT platform would have a secure TCP connection through AP to a cloud application. This test was run with each AP configured with a DTIM setting of 3. The test was run for five minutes with application keep alive packets being sent every 55 seconds to the server.

Engineers ran two scenarios. In the first, there was no other traffic active on the AP. In the second, there was 70Mbps of co-channel traffic running between a different associated client and the AP. An open source traffic generator was used to generate the co-channel traffic to emulate real world dense or congested wireless environments. The Cypress Semiconductor platform was not used in this test.

Low-Power Multi-Protocol WLAN + Bluetooth (BLE)

This test simulated a scenario where the IoT platform would also have a Bluetooth Low Energy (BLE) connection in addition to being associated with an AP.

This test was run with each AP configured with a DTIM setting of 3. The test was run for 30 seconds.

Engineers ran two scenarios. In the first, the IoT platform would send BLE "Advertising" messages. In the second, the IoT platform would "Connect" to the Bluetooth device. This test was only run on the Redpine Signals and Qualcomm platforms.

About Tolly

The Tolly Group companies have been delivering world-class IT services for nearly 30 years. Tolly is a leading global provider of third-party validation services for vendors of IT products, components and services.

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About Redpine Signals

Redpine Signals, Inc., is a global semiconductor and system solutions company founded in 2001 and headquartered in San Jose, California. It is focused on innovative development of ultra-low power and high-performance wireless and MCU products for next-generation IoT, wearable, home automation, medical, industrial and automotive applications.

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