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>
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.

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.

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,
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.

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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

### WLAN Standby Associated Mode Test (2.4GHz) by AP and DTIM Setting (uA)

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Solution Under Test</th>
<th>DTIM 1</th>
<th>DTIM 3</th>
<th>DTIM 10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Linksys</td>
<td>TP-Link</td>
<td>Cisco Aironet</td>
<td>Linksys</td>
</tr>
<tr>
<td>Redpine Signals</td>
<td>RS9116</td>
<td>N/A</td>
<td>254.1</td>
<td>98.8</td>
</tr>
<tr>
<td></td>
<td>RS14100</td>
<td>N/A</td>
<td>292.0</td>
<td>116.2</td>
</tr>
<tr>
<td>Cypress Semi.</td>
<td>CYW43907</td>
<td>N/A</td>
<td>2,930</td>
<td>1,700</td>
</tr>
<tr>
<td>Qualcomm</td>
<td>QCA4020</td>
<td>N/A</td>
<td>2,540</td>
<td>1,350</td>
</tr>
<tr>
<td>TI</td>
<td>CC3220SF</td>
<td>N/A</td>
<td>817.4</td>
<td>576.0</td>
</tr>
</tbody>
</table>

### TCP/IP + TLS Connection (2.4GHz) by AP with DTIM=3 Setting (uA)

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Solution Under Test</th>
<th>No Co-channel Traffic</th>
<th>70Mbps Co-channel</th>
<th>No Co-channel Traffic</th>
<th>70Mbps Co-channel</th>
<th>No Co-channel Traffic</th>
<th>70Mbps Co-channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redpine Signals</td>
<td>RS9116</td>
<td>72.6</td>
<td>109</td>
<td>57.6</td>
<td>107.4</td>
<td>104.2</td>
<td>118</td>
</tr>
<tr>
<td></td>
<td>RS14100</td>
<td>82</td>
<td>107.3</td>
<td>104.6</td>
<td>136.7</td>
<td>118.7</td>
<td>126.8</td>
</tr>
<tr>
<td>Qualcomm</td>
<td>QCA4020</td>
<td>1,360</td>
<td>2,090</td>
<td>991</td>
<td>1,730</td>
<td>1,077</td>
<td>1,640</td>
</tr>
<tr>
<td>TI</td>
<td>CC3220SF</td>
<td>1,610</td>
<td>2,070</td>
<td>830.7</td>
<td>1,066</td>
<td>768.5</td>
<td>996</td>
</tr>
</tbody>
</table>

### Low-Power Multi-Protocol WLAN (2.4GHz) by AP with DTIM=3 Setting + Bluetooth (uA)

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Solution Under Test</th>
<th>Linksys</th>
<th>TP-Link</th>
<th>Cisco Aironet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Advertise</td>
<td>Connection</td>
<td>Advertise</td>
<td>Connection</td>
</tr>
<tr>
<td>Redpine Signals</td>
<td>RS9116</td>
<td>123.3</td>
<td>174.2</td>
<td>117.1</td>
</tr>
<tr>
<td></td>
<td>RS14100</td>
<td>139.9</td>
<td>205.4</td>
<td>134.7</td>
</tr>
<tr>
<td>Qualcomm</td>
<td>QCA4020</td>
<td>1,490</td>
<td>2,520</td>
<td>1,330</td>
</tr>
</tbody>
</table>

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

Source: Tolly, December 2018
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.  

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**Table 2**

### Solutions Under Test

<table>
<thead>
<tr>
<th>Vendor &amp; Platform</th>
<th>Firmware/Software/SDK Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redpine Signals RS9116</td>
<td>1.0.6 (WiSeConnect)</td>
</tr>
<tr>
<td>Redpine Signals RS14100</td>
<td>1.0.6</td>
</tr>
<tr>
<td>Qualcomm QCA4020</td>
<td>SDK version 2.0.1</td>
</tr>
<tr>
<td>Texas Instruments CC3220SF</td>
<td>Host Driver Version: 2.0.1.15 Build Version 3.3.0.0.31.2.0.0.0.2.2.0.4</td>
</tr>
</tbody>
</table>

### Access Points (APs) Under Test

<table>
<thead>
<tr>
<th>Vendor &amp; Model</th>
<th>Firmware Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cisco Aironet 802.11n Dual band Access point : AIR-LAP1262N-E-K9</td>
<td>15.2(2)JA</td>
</tr>
<tr>
<td>Linksys E3000</td>
<td>1.04</td>
</tr>
<tr>
<td>TP-Link TL WR741N</td>
<td>3.16.5 Build 130329 Rel.62825n</td>
</tr>
</tbody>
</table>

Source: Tolly, December 2018

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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 μA with the Bluetooth “Advertise” and 189 μA with a Bluetooth “Connection.” In the same test, the Qualcomm platform consumed 1,330 μA and 2,090 μA. 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 μA with the Bluetooth “Advertise” and 197 μA 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 (μA).

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

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You can reach the company by E-mail at sales@tolly.com, or by telephone at +1 561.391.5610.

Visit Tolly on the Internet at: http://www.tolly.com

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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