TEST REPORT
Tolly.

#216147
November 2016

Commissioned by
Ruijie Networks Co., Ltd.

Ruijie Networks AP740-I

802.11ac Wave 2 Rate/Range Comparative Performance Evaluation
Versus Cisco Systems, New H3C and Ruckus Wireless

EXECUTIVE SUMMARY

The advent of high-availability wireless as has led to an increase in personal devices such as smartphones, tablets and of course, the portable computer, which all allow users to connect from anywhere within the office. All these different ways to connect ultimately means that there are many devices - usually several per person - competing for the same wireless bandwidth.

802.11ac "Wave 2" is an addendum to the original standard that uses multi-user, multiple-input/multiple output (MU-MIMO) technology to increase wireless LAN throughput.

Ruijie Networks Co., Ltd. commissioned Tolly to evaluate their AP740-I 802.11ac Wave 2 access point's performance and features. The AP740-I provides three radios and delivered 1.329Gbps throughput. The MU-MIMO feature provided a 165% performance gain over Wave 1. Ruijie's X-Sense 4 smart antenna technology showed better coverage than the competitors, and supported up to 117 clients streaming one HD video with acceptable experience at the same time.

THE BOTTOM LINE

The Ruijie Networks' AP740-I 802.11ac Wave 2 Access Point:

1   Delivered consistently higher throughput than competitors' APs in all locations in coverage tests

2   Delivered the highest throughput numbers Tolly has validated thus far, with up to 1.178Gbps throughput with one 5GHz HT80 radio and 1.329Gbps with all three radios in one AP

3   Delivered 2.65 times of throughput with the MU-MIMO feature turned on as with it turned off

4   Supported 117 clients streaming one 720p HD video with acceptable experience at the same time

Coverage Tests - 802.11ac Wave 2 AP Performance
Single 3x3:3 Client TCP Downstream Throughput, 5GHz, 80MHz Bandwidth
(as reported by IxChariot 7.10)
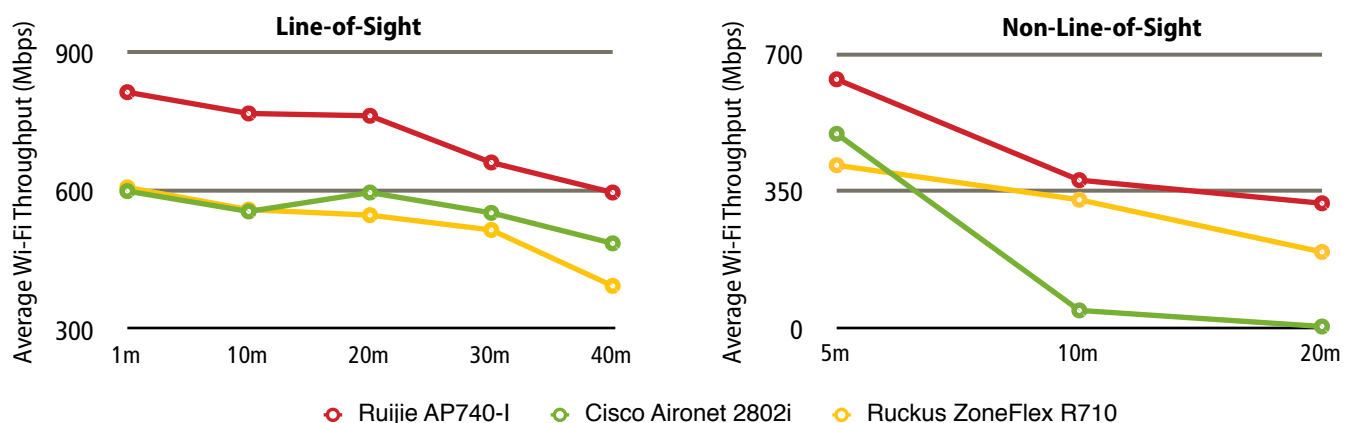
Note: One Apple MacBook Pro Retina 13 inches early 2015 model was used as the 802.11ac 3x3:3 client. See Figure 5 for the test environment.

Source: Tolly, August 2016

Figure 1

Test Results

Coverage Tests

Single client downstream throughput from 1 meter to 40 meters was tested to evaluate each access point's coverage performance. All devices were tested at line-of-sight locations (no obstructions between the AP and the client) and non-line-of-sight locations (with obstructions between the AP and the client).

Line-Of-Sight Coverage Test

The Ruijie AP740-I outperformed the Cisco Aironet 2802i and Ruckus ZoneFlex R710 at all test locations with a 20% to 51% throughput advantage. See Figure 1 and Table 2 for details.

Non-Line-Of-Sight Coverage Test

Both with smart antennas, the Ruijie AP740-I provided constantly higher throughput than Ruckus ZoneFlex R710 at all test locations with a 15% to 64% advantage. Cisco Aironet 2802i's performance dropped significantly in the non-line-of-sight test. The performance advantage of the Ruijie AP740-I over the Cisco 2802i was from 28% to multiple times greater.

Ruijie's X-Sense 4 smart antenna technology showed a significant advantage when there were obstructions between the AP and the client. See Figure 1 and Table 2 for results. See Figure 5 for the test environment.

Ruijie Networks

AP740-I

802.11ac Wave 2 Performance/ Coverage Evaluation
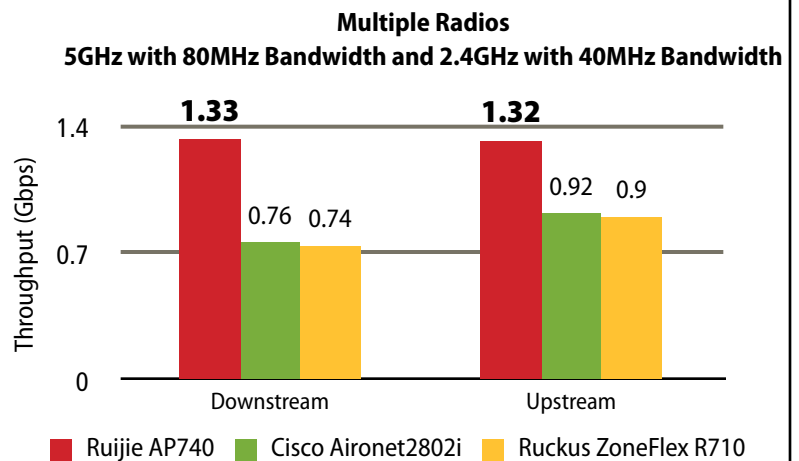
Tested August 2016

Maximum Throughput

Single Radio Performance

The Ruijie AP740-I access point has three radios. The three radios can work as two 2.4GHz radios and one 5GHz radio (4x4:4 802.11ac Wave 2) or one 2.4GHz radio and

---

Maximum TCP Throughput per Access Point Test - 802.11ac Wave 2
(As reported by Ixia IxChariot 7.10)

Single Radio: Ruijie AP740-I Result
4x4:4 5GHz with 80MHz Bandwidth, Unidirectional

1.178Gbps

Multiple Radios
5GHz with 80MHz Bandwidth and 2.4GHz with 40MHz Bandwidth

Throughput (Gbps)

	Downstream	Upstream
Ruijie AP740	1.33	1.32
Cisco Aironet2802i	0.76	0.92
Ruckus ZoneFlex R710	0.74	0.9

■ Ruijie AP740 ■ Cisco Aironet2802i ■ Ruckus ZoneFlex R710

Notes: Ruijie AP740-I supports three radios. In the multiple radios test, the three radios were configured as one 5GHz HT80 802.11ac Wave 2 radio, one 5GHz HT80 802.11ac Wave 1radio, and one 2.4GHz 802.11n radio. Cisco Aironet supports two radios. The two radios were configured as one 5GHz HT80 802.11ac Wave 2 radio and one 2.4GHz HT40 802.11n radio. Cisco 2802i's two radios can also both work in 5GHz mode which may improve the performance. Using both radios as 5GHz limit the coverage and client types. So it may not fit some customer scenarios. Ruckus ZoneFlex supports two radios. The two radios were configured as one 5GHz HT80 802.11ac Wave 2 radio and one 2.4GHz HT40 802.11n radio.

Source: Tolly, August 2016

Figure 2

two 5GHz radios (one 802.11ac Wave 1 and one 4x4:4 Wave 2).

The 4x4:4 5GHz 802.11ac Wave 2 radio provides the maximum performance out of the three radios. Tolly engineers verified that the 5GHz radio of the Ruijie AP740-I provided 1.178Gbps unidirectional throughput in the HT80 mode (80MHz bandwidth). See Figure 2.

The Wave 2 radio can also work in the HT160 (160MHz bandwidth). When the 4x4:4 5GHz radio worked in the HT160 mode, it provided up to 1.078Gbps unidirectional throughput.

Multiple Radios Performance

The Ruijie AP740-I had three radios. Tolly engineers configured them as one 2.4GHz radio and two 5GHz radios. The Cisco Aironet and the Ruckus ZoneFlex R710 each had two radios (one configured as 2.4GHz and one as 5GHz).

With one client connected to each radio, Tolly engineers tested the maximum upstream and downstream throughput

that each AP could provide - choosing the best result of three runs in a shielded box.

The Ruijie AP740-I provided up to 1.329Gbps aggregated downstream throughput or 1.32Gbps aggregated upstream throughput. These results are the highest downstream and upstream throughput results for one AP in all WLAN tests Tolly has performed to date (August 2016).

In comparison, the Ruijie AP740-I provided 74% higher downstream throughput and 43% higher upstream throughput than Cisco Aironet 2802i. The Ruijie AP740-I also provided 80% higher downstream throughput and 47% higher upstream throughput than Ruckus ZoneFlex R710. See Figure 2.

Multi-User MIMO (MU-MIMO)

One key new feature for the 802.11ac Wave 2 standard is Multi-user MIMO (MU-MIMO) which make the AP be able to communicate with multiple clients at the

same time. Without using MU-MIMO, one radio of the AP can only communicate with one client at a time slot. The MU-MIMO feature is expected to improve the AP's performance in multi-client environment.

In order to evaluate the efficiency of the MU-MIMO feature in the Ruijie, Cisco and Ruckus APs, Tolly engineers used 3 clients to connect to the 5GHz 802.11ac Wave 2 radio and test the throughput with and without the MU-MIMO feature enabled.

With the MU-MIMO feature enabled, Ruijie AP740-I's performance was up to 2.65 times as the performance with the MU-MIMO feature disabled. For Cisco and Ruckus, the result was 1.09 times and 1.75 times. Ruijie AP740-I's MU-MIMO feature had much greater performance gain than Cisco and Ruckus APs'. See Figure 3.
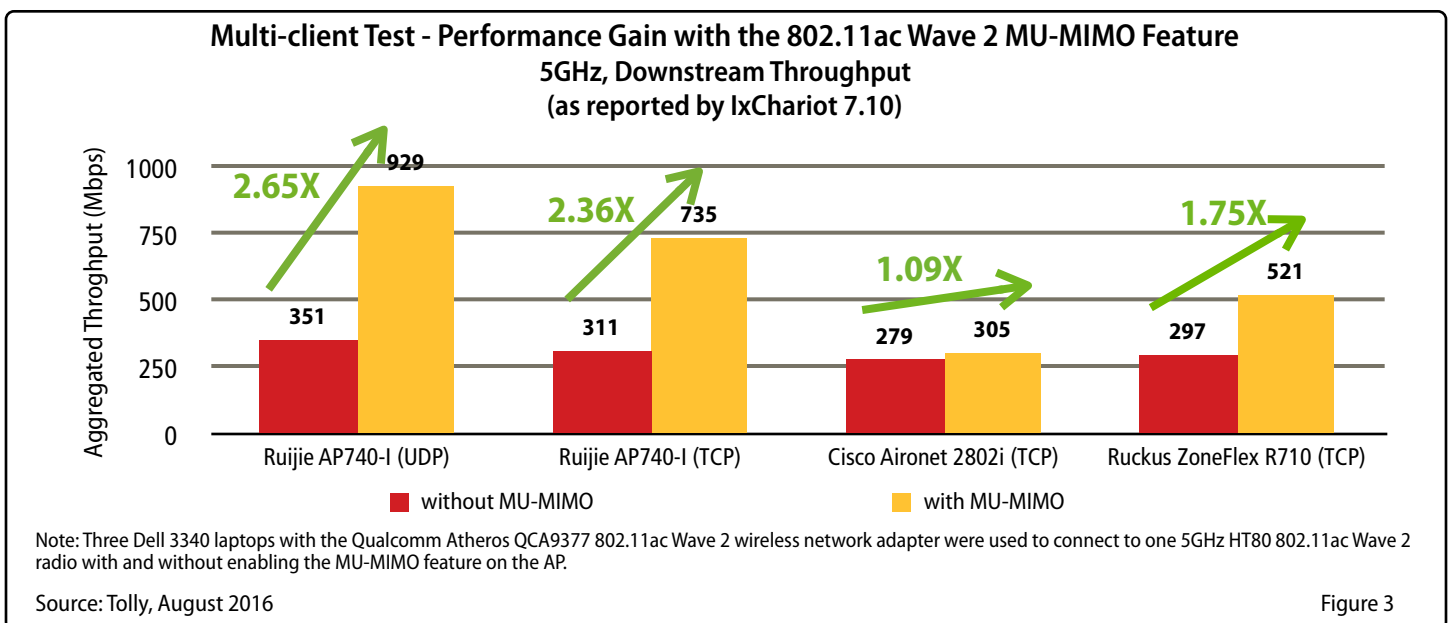

Multi-client Test - Performance Gain with the 802.11ac Wave 2 MU-MIMO Feature
5GHz, Downstream Throughput
(as reported by IxChariot 7.10)

Note: Three Dell 3340 laptops with the Qualcomm Atheros QCA9377 802.11ac Wave 2 wireless network adapter were used to connect to one 5GHz HT80 802.11ac Wave 2 radio with and without enabling the MU-MIMO feature on the AP.

Source: Tolly, August 2016   Figure 3

High Density Video Playback

Engineers configured the three radios of Ruijie AP740-I as one HT40 2.4GHz radio, one HT80 5GHz Wave 1 radio, and one HT80 5GHz Wave 2 radio.

Tolly engineers verified that the Ruijie AP740-I was able to support 117 clients simultaneously streaming one 720p HD video with acceptable experience with mixed 802.11n, 802.11ac Wave 1 and 802.11ac Wave 2 clients.

The H3C WA4330 is an 802.11ac Wave 1 AP which also supports 3 radios. In the same test environment with the same clients, the H3C WA4330 AP supported 70 clients streaming one 720p HD video with acceptable experience at the same time. See Figure 4.

While the above tests were run with the default number of spatial streams that each AP supports. Tolly engineers also configured the AP to only support one spatial stream in order to match the e-bag scenario in schools. Students in a classroom use tablets to stream the class video at the same time. Most tablets on the market only support one spatial stream.

In the one spatial stream test, Ruijie AP740-I supported 90 clients streaming one 720p HD video at the same time with acceptable experience while the Cisco 2802i supported 59 clients and the Ruckus R710 supported 43 clients. See Figure 4.

High Availability

The Ruijie AP740-I provides two uplink ports, both with powered device capability to receive power from the PoE ports of a power sourcing equipment (e.g. PoE switch). Also, the two uplinks can work as a Link Aggregation Group (LAG) for load balancing and high availability.

When one uplink or port fails, the AP740-I can still work properly with the other uplink for both power and data transmission.

Frequency Spectrum Scan

The Ruijie AP740-I supports three radios. Administrators can configure two of them for user network access (one 2.4GHz radio and one 5GHz 802.11ac Wave 2 radio) and use the third one for frequency spectrum scan (FSS).

Tolly engineers verified that while the third radio was scanning, the single client performance for the 2.4GHz radio and the 5GHz radio was not affected.
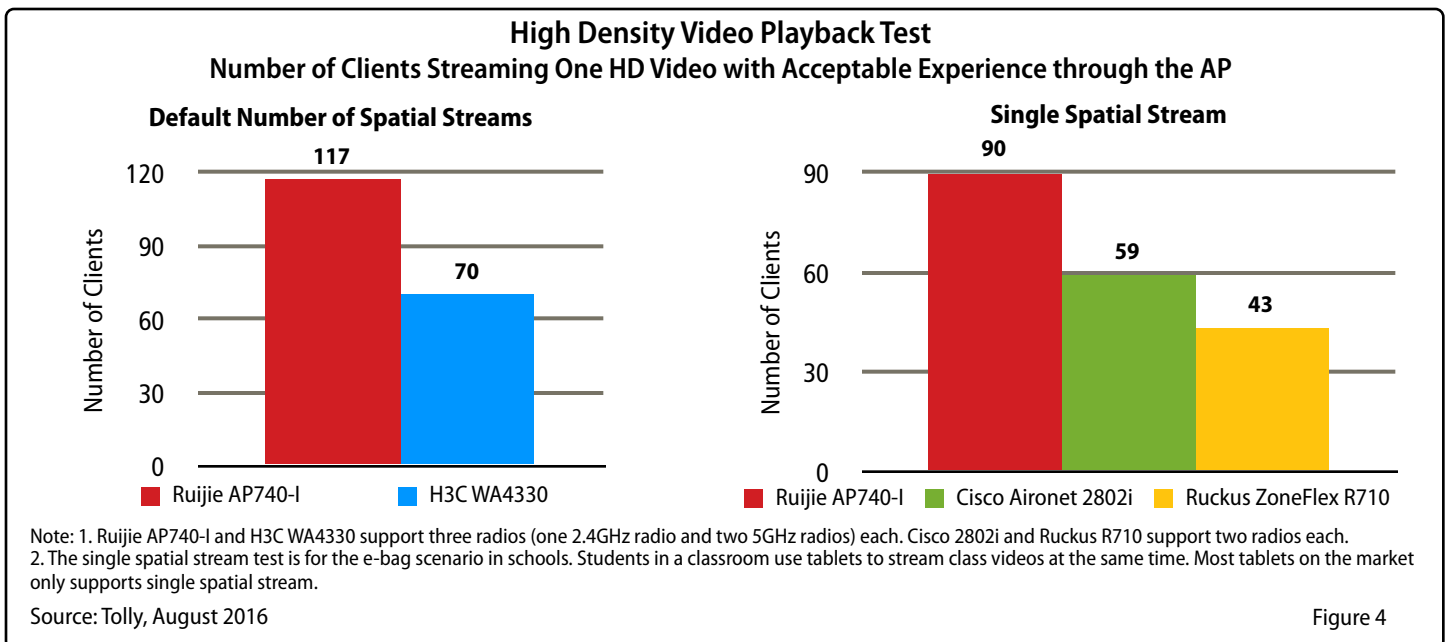
Test Methodology

Test Environment

For details of the WLAN systems under test, see Table 1. The maximum throughput tests, MU-MIMO tests, and Frequency Spectrum Scan tests were run in a shielded box to avoid other interferences.

The High Density Video Playback test was run in a room with all the clients in the same room.

The coverage tests were run in a dormitory building. See Figure 5.

All APs functioned in local forwarding mode.

High Density Video Playback Test
Number of Clients Streaming One HD Video with Acceptable Experience through the AP

Note: 1. Ruijie AP740-I and H3C WA4330 support three radios (one 2.4GHz radio and two 5GHz radios) each. Cisco 2802i and Ruckus R710 support two radios each.
2. The single spatial stream test is for the e-bag scenario in schools. Students in a classroom use tablets to stream class videos at the same time. Most tablets on the market only supports single spatial stream.

Source: Tolly, August 2016   Figure 4

Coverage Tests

One Apple MacBook Pro Retina 13 inches early 2015 model with 3x3:3 capability was used as the client. All three APs used one 5GHz HT80 radio on channel 157. All APs were mounted to the ceiling at the same location. The high performance throughput TCP script in IxChariot was used for line-of-sight tests. The throughput TCP script in IxChariot was used for non-line-of-sight tests. 20 downstreams were used in each test.

Maximum Throughput

The maximum throughput tests were run in a shielded box. Ruijie AP740-I's transmission power was set to 5%; Cisco 2802i's power level was set to 6; Ruckus R710's power was set to -10dB.

Single Radio Performance

As there was no 4x4:4 802.11ac Wave 2 client available at the test time, engineers used two Ruijie AP740-I to bridge traffic using the 4x4:4 802.11ac Wave 2 5GHz HT80/HT160 radio in channel 161. Each AP had two clients connected with wired connections. The clients then passed through traffic across the two APs to evaluate the wireless performance of the APs.

Multiple Radios Performance

Ruijie AP740-I supports three radios. The three radios were configured as one 5GHz HT80 802.11ac Wave 2 radio in channel 157, one 5GHz HT80 802.11ac Wave 1 radio in channel 36, and one 2.4GHz 802.11n radio in channel 1. Cisco 2802i supports two radios. The two radios were configured as one 5GHz HT80 802.11ac radios in channel 157 and one 2.4GHz HT40 802.11n radio in channel 1. Cisco 2802i's two radios

can also both work in 5GHz mode which may improve the performance. Using both radios as 5GHz limits the coverage and client types. Thus, that configuration may not fit some customer scenarios. Ruckus R710 supports two radios. The two radios were configured as one 5GHz HT80 802.11ac Wave 2 radio on channel 157 and one 2.4GHz HT40 802.11n radio on channel 1.

One Apple MacBook Pro Retina 13 inches early 2015 model was used to connect to the 5GHz radio. One desktop PC with the ASUS AC66 wireless adapter was used to connect to the 2.4GHz radio. One Dell laptop with the Qualcomm Atheros QCA9377 adapter was used to connect to the extra Ruijie 5GHz radio. There was no available client with HT160 support at the time of test. So HT160 was not used in the test for any of the APs.

Coverage Test Environment
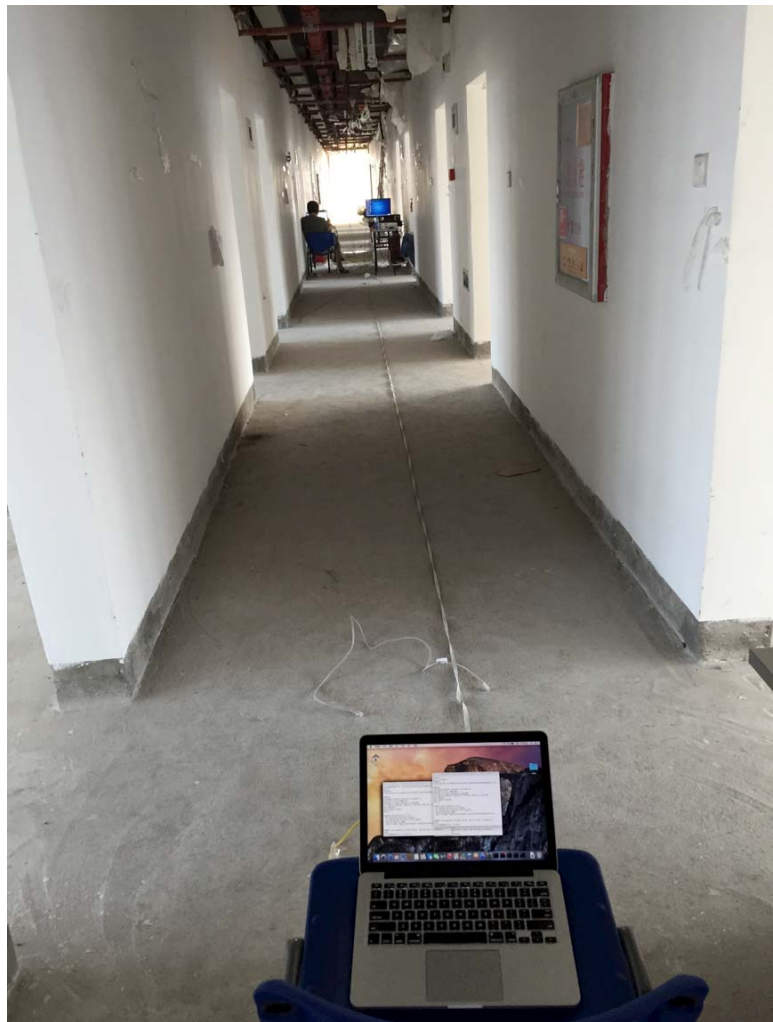
Note: The AP was mounted on the ceiling of the hallway. For line-of-sight tests, the client was in the hallway. For non-line-of-sight tests, the client was placed in the room adjacent to the hallway.

Source: Tolly, August 2016

Figure 5

High Density Video Playback Test

120 clients including Apple MacBook Pro, Apple MacBook Air, Dell laptops with the Qualcomm Atheros QCA9377 adapter, desktops with the ASUS AC66 adapter, netbooks with USB wireless adapters were used to cover 802.11ac Wave 2 MU-MIMO clients, 802.11ac Wave 1 single, dual or triple spatial streams clients, as well as some 802.11n clients. Each client used the VideoLAN (VLC) player to stream the same 720p video from a VLC server.

Systems Under Test

Vendor	Model	Version
Ruijie Networks Co., Ltd.	AP740-I (802.11ac Wave 2 AP)	AC_RGOS 11.1(5)
Cisco Systems, Inc.	AIR-AP2802I-C-K9 (802.11ac Wave 2 AP)	8.3.102.0
Ruckus Wireless, Inc.	ZoneFlex R710 (802.11ac Wave 2 AP)	100.2.0.0.336
New H3C Group	WA4330 (802.11ac Wave 1 AP)	Comware version 5.20, release 2509P39

Source: Tolly, August 2016

Table 1

Coverage Tests - 802.11ac Wave 2 Performance - Detailed Results of Figure 1
Single 3x3:3 Client TCP Downstream Throughput, 5GHz, 80MHz Bandwidth
(as reported by IxChariot 6.70)

Line-of-sight Throughput (Mbps)

	1m	10m	20m	30m	40m
Ruijie AP740-I	813	767	762	661	596
Cisco Aironet 2802i	599	555	596	552	486
Ruckus ZoneFlex R710	607	559	547	515	394

Non-line-of-sight Throughput (Mbps)

	5m	10m	20m
Ruijie AP740-I	634	377	318
Cisco Aironet 2802i	495	45	4
Ruckus ZoneFlex R710	415	327	194

Source: Tolly, August 2016

Table 2

About Ruijie Networks

Ruijie Networks (stock code SZ:002396) is a leading network solution supplier of China. We focus on customer benefits and strive to improve the network application experience of our customers through continuous technological innovation. Ruijie Networks provides end-to-end network solutions for telecom carriers, financial services, government agencies, education and enterprises to create values for customer networks.

Ruijie Networks has 38 branches with sales and service covering Asia, Europe, North America, and South America. Currently, we have more than 3,100 employees, of which 1,600 are R&D engineers working in five R&D centers located in Fuzhou, Beijing, Shanghai, Chengdu, and Tianjin.

Ruijie Networks is the only company of data communication to be certified as an innovative enterprise in China. Every year, 15% of sales income is invested in R&D, and 30% of R&D funds in high-tech pre-research. In 2000, Ruijie Networks introduced the first domestic-made modularized switch and the full suite of gigabit switches, which promotes the successful rise of indigenous network brands in China. In 2011, Ruijie Networks rolled out China's first cloud-computing data center switch family, which makes Ruijie Networks a pioneer on the cloud-computing network platform. With continuous improvement on the innovative road of independent R&D, Ruijie Networks leads and promotes the development of cutting-edge network technologies in China.
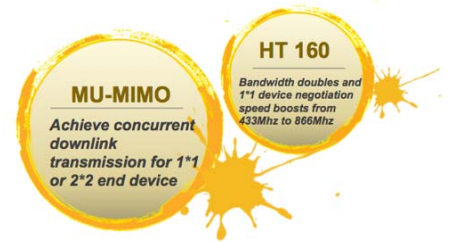
In the network economy era, we believe that each progress in network technology changes people's life, work, and education. Future-oriented, Ruijie Networks embraces the missions of promoting network technology development, achieving technology and application convergence, and advancing social progress, thereby helping our customers and partners benefit from the new era.

Source: Ruijie Networks, August 2016

About Ruijie Networks AP740-I 802.11ac Wave 2 Access Point

The RG-AP740-I AP tops the class by supporting 802.11ac Wave 2 with a collection of first-rate features:

•	Tri-radio, Dual-band Design: The AP supports 2.4G+5G+2.4G or 2.4G+5G+5G operating modes and concurrent 802.11ac Wave 2, 802.11ac Wave 1 and 802.11n. The two main radios deliver up to 1,733Mbps and 800Mbps. The whole AP hence speeds up the performance to up to 2.966Gbps.

•	MU-MIMO Support: The Multi-User MIMO feature, which is one of the milestone technologies of 802.11ac Wave 2, enables wireless communication among a set of end users. The RG-AAP740-I AP implements an industry-leading design with 4 spatial streams, supporting 4x4 SU-MIMO and 4x4 MU-MIMO.

•	HT160 Support: The 802.11ac Wave 2 ready AP deploys 160 MHz channel bandwidths (contiguous 80+80) or 80+80 MHz channel bonding (discontiguous 80+80), multiplying the access speed of one-spatial-stream devices.

HT 160

Bandwidth doubles and 1*1 device negotiation speed boosts from 433Mhz to 866Mhz

MU-MIMO

Achieve concurrent downlink transmission for 1*1 or 2*2 end device

•	"X-Sense 4" Dual-mode Reflector Antenna: By supporting automatic antenna switching, the RG-AP740-I AP offers Wave 1 and Wave 2 devices the best user experience. Under the Wave 1 mode, the AP implements "X-Sense 3" algorithm to achieve signal follow your move. By dynamic antenna selection, the AP enhances the signal strength based on the location of the end device and maximizes the performance 3 times better than general AP. The best signal strength is thereby available in every corner under wireless coverage. There is no need to worry about the radiation level. The enhanced signal is used to compensate for the loss along the transmission path or wall penetration. For the Wave 2 mode, the reflector feature of the antenna is enabled to largely improve the isolation level among antennas. The feature does not only make channel evaluation and user grouping more efficient, but proactively controls the antenna direction during beam formation for boosting the beam formation efficiency. The MU-MIMO performance is hence greatly upgraded, delivering a better and more stable throughput performance for end users.

Wave 1 Mode	**Wave 2 Mode**
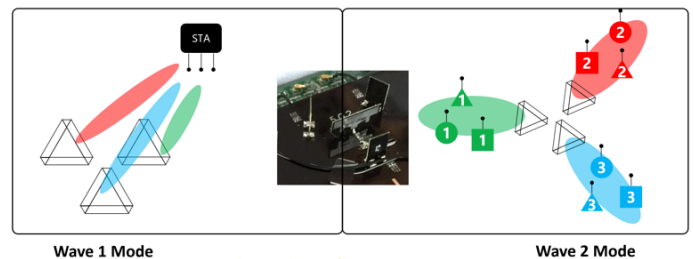
Dual-mode Reflector Antenna ideally works with 802.11ac Wave 2
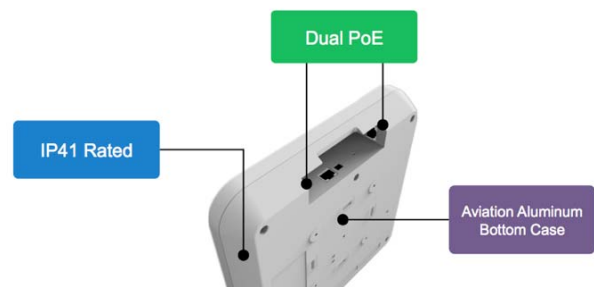
•	Carrier-class Design: The IP41 rated AP deploys a totally enclosed design for absolute dustproof performance. The case prevents erosion by dripping or condensation to maximize the AP life cycle. In addition, the dual Ethernet ports design of RG-AP740-I AP not only solves the problem of interface data backup, but also provides flexible networking modes for the network which requires intranet and Internet isolation. Both Ethernet ports support PoE for power backup and load power feature. PoE switch (non-PoE+) can be deployed for dual power supply to save network investment cost. An aviation aluminum bottom case is used here with a zero cooling hole design. The aluminum case achieves high-efficiency cooling with strong adaptability at the same time.

Dual PoE

IP41 Rated

Aviation Aluminum Bottom Case

Source: Ruijie Networks, August 2016

Ruijie Patented Leading "X-Sense 4" Smart Antenna Technology
Information provided by vendor, not necessarily verified by Tolly

The RG-AP740-I flagship AP implements the latest "X-Sense 4" Dual-mode Reflector Antenna for an unsurpassed 802.11ac Wave 2 experience. The smart antenna supports automatic switching between Wave 1 and Wave 2 modes. The Wave 1 mode guarantees the best signal experience with ease regardless of the end device location. The Wave 2 mode, on the other hand, enables the reflector feature of the antenna. It does not only make channel evaluation and user grouping more efficient, but gives beam formation a boost by proactively controlling the antenna. In addition, the "X-Sense 4" antenna fully supports 802.11ac Wave 2 features including MU-MIMO and HT160 (80+80), redefining the high-speed wireless standard.

User Signal Tracking

Dynamic signal strength tuned according to end user location

+10dBi
+4dBi

X-Sense 4
X-Sense 3
Dual-mode Reflector Antenna
802.11ac Wave 2
X-Sense
Customized for Mobile Devices
20%+ Better Coverage
Dynamic Antenna Matrix
Fixed Radiation

X-Sense AP 802.11ac Series

AP520(DA)
802.11ac Wave 1
Up to 1.167Gbps, 2 SS
Directional Antenna

AP530-I
802.11ac Wave 1
Up to 1.9Gbps, 3 SS
"X-Sense 3" Antenna

AP720-I
802.11ac Wave 2
Up to 1.267Gbps/2.4Gbps, 2 SS
Satellite AP Expansion

AP740-I
802.11ac Wave 2
Up to 2.966Gbps, 4 SS
"X-Sense 4" Antenna

Source: Ruijie Networks, August 2016

About Tolly

The Tolly Group companies have been delivering world-class IT services for more than 25 years. Tolly is a leading global provider of third-party validation services for vendors of IT products, components and services.

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

Interaction with Competitors

In accordance with Tolly's Fair Testing Charter, Tolly personnel invited representatives from Cisco Systems, H3C Technologies Co., Ltd., and Ruckus Wireless to participate in the testing. Cisco, H3C and Ruckus did not respond to the invitation.

For more information on the
Tolly Fair Testing Charter, visit:

http://www.tolly.com/FTC.aspx

Terms of Usage

This document is provided, free-of-charge, to help you understand whether a given product, technology or service merits additional investigation for your particular needs. Any decision to purchase a product must be based on your own assessment of suitability based on your needs. The document should never be used as a substitute for advice from a qualified IT or business professional. This evaluation was focused on illustrating specific features and/or performance of the product(s) and was conducted under controlled, laboratory conditions. Certain tests may have been tailored to reflect performance under ideal conditions; performance may vary under real-world conditions. Users should run tests based on their own real-world scenarios to validate performance for their own networks.

Reasonable efforts were made to ensure the accuracy of the data contained herein but errors and/or oversights can occur. The test/ audit documented herein may also rely on various test tools the accuracy of which is beyond our control. Furthermore, the document relies on certain representations by the sponsor that are beyond our control to verify. Among these is that the software/ hardware tested is production or production track and is, or will be, available in equivalent or better form to commercial customers. Accordingly, this document is provided "as is," and Tolly Enterprises, LLC (Tolly) gives no warranty, representation or undertaking, whether express or implied, and accepts no legal responsibility, whether direct or indirect, for the accuracy, completeness, usefulness or suitability of any information contained herein. By reviewing this document, you agree that your use of any information contained herein is at your own risk, and you accept all risks and responsibility for losses, damages, costs and other consequences resulting directly or indirectly from any information or material available on it. Tolly is not responsible for, and you agree to hold Tolly and its related affiliates harmless from any loss, harm, injury or damage resulting from or arising out of your use of or reliance on any of the information provided herein.

Tolly makes no claim as to whether any product or company described herein is suitable for investment. You should obtain your own independent professional advice, whether legal, accounting or otherwise, before proceeding with any investment or project related to any information, products or companies described herein. When foreign translations exist, the English document is considered authoritative. To assure accuracy, only use documents downloaded directly from Tolly.com. No part of any document may be reproduced, in whole or in part, without the specific written permission of Tolly. All trademarks used in the document are owned by their respective owners. You agree not to use any trademark in or as the whole or part of your own trademarks in connection with any activities, products or services which are not ours, or in a manner which may be confusing, misleading or deceptive or in a manner that disparages us or our information, projects or developments.

216147-spvhjfs3-yx-2016-11-22-VerG