

# CARNet Wi-Fi Independent Test Results

Access Points Comparison

May 2015



## EXECUTIVE SUMMARY

Croatian Academic and Research Network (CARNet) recently conducted independent Wi-Fi performance testing, showcasing the world's top 802.11ac and 802.11n access points (APs) within a real world high-capacity, high interference classroom environment.

Using industry standard test tools, 19 APs were stressed within several progressive testing scenarios that included 12, 23, 36, and 60 clients, increasing number of clients for each throughput test.

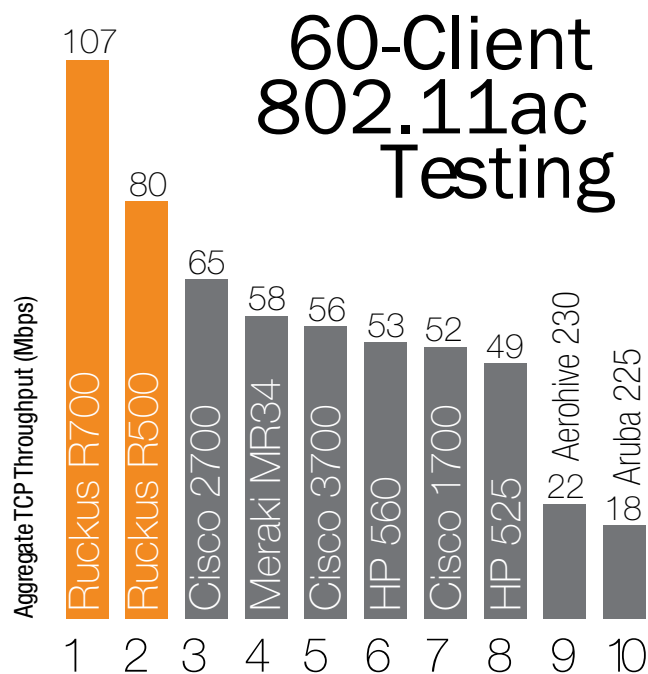
Maximum aggregate TCP throughput to a mix of 802.11ac and 802.11n clients that included one- two- three-stream mobile and laptop devices. Each test was run three times with the highest result recorded.

Vendors were invited to actively participate in the testing with the latest publicly available code for the device under test (DUT) and the option to choose their own channels and channel width for testing, with no encryption required.

The results of the exhaustive testing found that Ruckus Smart Wi-Fi APs consistently outperformed all DUTs, taking top marks in almost every test scenario.

## TEST HIGHLIGHTS

- 19 enterprise class 802.11ac and 802.11n access points stressed in progressive test environment
- Mix of .11ac and .11n single, dual and three-stream clients within the classroom
- Each AP tested on the other side of a 5dB drywall
- Increasing number of clients (12, 23, 36 and 60) used with each test run three times
- Highest aggregate TCP throughput recorded using latest IxChariot test suite
- Only publicly available code allowed



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### Dual-Band Devices Under Test

| VENDOR   | MODEL      | PHY      | Tx/Rx:SS | RESULT      | RANK* |
|----------|------------|----------|----------|-------------|-------|
| Aerohive | 121        | 802.11n  | 2x2:2    | 38.16 Mbps  | 15    |
| Aerohive | 230        | 802.11ac | 3x3:3    | 42.68 Mbps  | 14    |
| Aerohive | 330        | 802.11n  | 3x3:3    | 54.45 Mbps  | 13    |
| Aruba    | 225        | 802.11ac | 3x3:3    | 67.84 Mbps  | 8     |
| Cisco    | 1700       | 802.11ac | 3x3:2    | 54.50 Mbps  | 12    |
| Cisco    | 2700       | 802.11ac | 3x4:3    | 83.56 Mbps  | 6     |
| Cisco    | 3700       | 802.11ac | 4x4:3    | 76.21 Mbps  | 7     |
| HP       | 430        | 802.11n  | 3x3:2    | 61.43 Mbps  | 10    |
| HP       | 525        | 802.11ac | 2x2:2    | 37.67 Mbps  | 16    |
| HP       | 560        | 802.11ac | 3x3:3    | 65.09 Mbps  | 9     |
| Meraki   | MR34       | 802.11ac | 3x3:3    | 56.00 Mbps  | 11    |
| Ruckus   | 7372       | 802.11n  | 2x2:2    | 91.27 Mbps  | 4     |
| Ruckus   | 7982       | 802.11n  | 3x3:3    | 85.23 Mbps  | 5     |
| Ruckus   | R300       | 802.11n  | 2x2:2    | 95.24 Mbps  | 3     |
| Ruckus   | R500       | 802.11ac | 2x2:2    | 122.16 Mbps | 2     |
| Ruckus   | R700       | 802.11ac | 3x3:3    | 137.00 Mbps | 1     |
| Ubiquiti | Uni-Fi Pro | 802.11n  | 2x2:2    |             | n/a   |
| Xirrus   | XR520      | 802.11n  | 2x2:2    |             | n/a   |
| Xirrus   | XR430      | 802.11n  | 3x3:3    |             | na    |

\* Results from 36 (distributed) client testing.  
(n/a= access points that were unable to complete tests)



All enterprise Wi-Fi manufacturers were invited to bring in their choice of APs, without limitation as to what type or how many APs could be tested in a single day. Each of the following vendors chose to send an engineer to the tests with equipment in hand: Aerohive, Cisco, HP, and Ruckus. Each vendor was also given a test cycle to prove that their AP is working as desired and had the opportunity to optimize their configuration for performance.

Downlink throughput tests, using a 1MB file transferred and the latest version of IxChariot, were conducted, in order, from a single AP to 13, 23, 36, 60, and 36 (distributed) clients. For the 36 (distributed) test, the client devices were spread into a 270° arc pattern. All 60 clients were associated to the AP being tested prior to each test starting. Band balancing of clients could be performed automatically by the AP or manually by the on-site technical staff. Five different test were run with the best result from the three tests recorded:

**Test 1:** 13 clients (a mix of 802.11ac and 802.11n)

**Test 2:** add 10 802.11n clients

**Test 3:** add 13 802.11n clients

**Test 4:** add 24 802.11n clients

**Test 5:** spread 36 clients into a 270° arc pattern

### CARNET

CARNet is a public institution that facilitates the progress of individuals and society through the use of new information technologies. Primary and secondary educational institutions are able to take advantage of CARNet services, which include information and communication technologies and their application in education network and infrastructure. CARNet includes:

- Over 240 academic community members
- Over 1,380 primary and secondary education schools
- Over 2,320 connected locations through the CARNet network

For more information please visit: <http://www.carnet.hr/en>



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## Participation

| Manufacturer | Model      | PHY      | Dual-Band | TxR:SS |
|--------------|------------|----------|-----------|--------|
| Aerohive     | 121        | 802.11n  | Y         | 2x2:2  |
| Aerohive     | 230        | 802.11ac | Y         | 3x3:3  |
| Aerohive     | 330        | 802.11n  | Y         | 3x3:3  |
| Aruba        | 225        | 802.11ac | Y         | 3x3:3  |
| Cisco        | 1700       | 802.11ac | Y         | 3x3:2  |
| Cisco        | 2700       | 802.11ac | Y         | 3x4:3  |
| Cisco        | 3700       | 802.11ac | Y         | 4x4:3  |
| HP           | 430        | 802.11n  | Y         | 3x3:2  |
| HP           | 525        | 802.11ac | Y         | 2x2:2  |
| HP           | 560        | 802.11ac | Y         | 3x3:3  |
| Meraki       | MR34       | 802.11ac | Y         | 3x3:3  |
| Ruckus       | 7372       | 802.11n  | Y         | 2x2:2  |
| Ruckus       | 7982       | 802.11n  | Y         | 3x3:3  |
| Ruckus       | R300       | 802.11n  | Y         | 2x2:2  |
| Ruckus       | R500       | 802.11ac | Y         | 2x2:2  |
| Ruckus       | R700       | 802.11ac | Y         | 3x3:3  |
| Ubiquiti     | Uni-Fi Pro | 802.11n  | Y         | 2x2:2  |
| Xirrus       | XR520      | 802.11n  | Y         | 2x2:2  |
| Xirrus       | XR4430     | 802.11n  | Y         | 3x3:3  |

## Client Devices

A real-world mix (60 total) of mobile devices, tablets, and laptops, each with varying Wi-Fi specifications and operating systems, were used.

| Qty | Manufacturer & Model   | 802.11n | 802.11ac | 20MHz | 40MHz | 80MHz | 1SS | 2SS | 3SS | 802.11h |
|-----|------------------------|---------|----------|-------|-------|-------|-----|-----|-----|---------|
| 1   | Samsung S-SM-T230      | Y       |          | Y     |       |       | Y   |     |     | Y       |
| 1   | Samsung S-SM-T235      | Y       |          | Y     | Y     |       | Y   | Y   |     | Y       |
| 2   | Samsung S-SM-T700      | Y       | Y        | Y     | Y     | Y     | Y   | Y   |     | Y       |
| 1   | Samsung S-SM-T705      | Y       | Y        | Y     | Y     | Y     | Y   | Y   |     | Y       |
| 1   | Samsung S-SM-T800      | Y       | Y        | Y     | Y     | Y     | Y   |     |     | Y       |
| 1   | Samsung S-SM-T805      | Y       | Y        | Y     | Y     | Y     | Y   |     |     | Y       |
| 1   | Samsung S-SM-N910C     | Y       | Y        | Y     | Y     | Y     | Y   | Y   |     | Y       |
| 1   | Samsung S-SM-P600      | Y       | Y        | Y     | Y     |       | Y   | Y   |     | Y       |
| 6   | Samsung N8000          | Y       |          | Y     | Y     |       | Y   |     |     | Y       |
| 4   | iPad 3                 | Y       |          | Y     | Y     |       | Y   |     |     | Y       |
| 1   | iPad 4                 | Y       |          | Y     | Y     |       | Y   |     |     | Y       |
| 1   | MacBook Pro 15" (2011) | Y       |          | Y     | Y     |       | Y   | Y   | Y   | Y       |
| 10  | Lenovo X200 laptops    | Y       |          | Y     | Y     |       | Y   | Y   | Y   |         |
| 14  | Lenovo T400 laptops    | Y       |          | Y     | Y     |       | Y   | Y   | Y   |         |
| 15  | HP Pro Tablet 610 G1   | Y       |          | Y     | Y     |       | Y   | Y   |     | Y       |



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## Testing Environment

APs were placed outside of a classroom, separated from the client devices within the classroom by a single drywall with a measured loss of 5dB. The classroom measured 12 meters (~39 feet) by 10 meters (~33 feet). Each vendor was given a test cycle to prove that their AP is working as desired and had the opportunity to optimize their configuration for performance.

## Evaluation Criteria

Criteria to be evaluated included throughput maximized to all test clients. Downlink throughput tests, using a 1MB file transferred using the latest version of IxChariot, were conducted, in order, from a single AP, to 13, 23, 36, 60, and 36 (distributed). For the 36 (distributed) test, the client devices were spread into a 270° arc pattern. All 60 clients were associated to the AP being tested prior to each test starting. Band balancing of clients could be performed automatically by the AP or manually by the on-site technical staff.

## The Rules

- Tests must be run in order: 13, 23, 36, 60, 36 (distributed).
- Each vendor was given a trial run, if requested.
- If a TCP session to a client fails in any test, that test is considered to have failed and the AP under test does not progress to the next round of testing (with a higher number of clients).
- Each test was run three times, and the highest number (in Mbps) was recorded.
- Each vendor can choose its own channel(s) and channel width for testing.

## The RF Environment

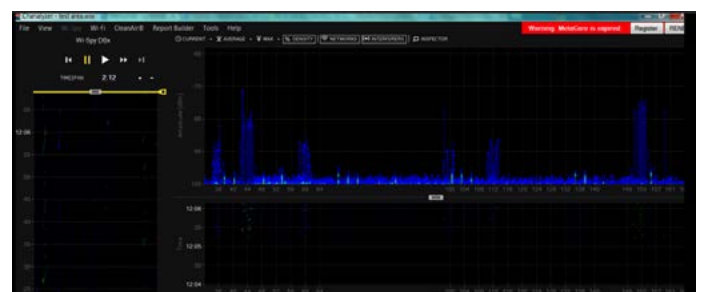
No effort was made to “clean up” the RF environment, as real-world deployments have to deal with random, and often uncontrollable, levels of modulated and unmodulated interference. CARNet’s dual-band Wi-Fi network and 2.4GHz motion sensors remained operational during the test.

Before the test began, MetaGeek’s Wi-Spy DBx spectrum analysis USB dongle and Chanalyzer software showed was used to view the 2.4GHz ISM band and 5GHz UNII bands. Illustrations are below.

### 2.4GHz before the test began.



### 5GHz before the test began.



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## TEST RESULTS

### Test #1 – 13 Clients Test

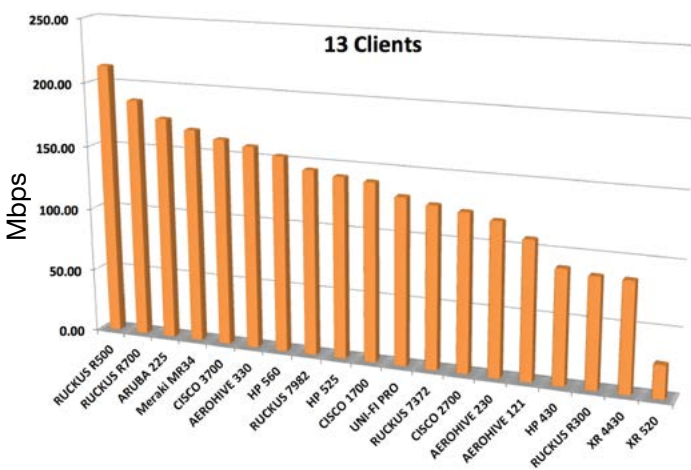
The clients used in the test are shown in the chart below.

| Client #      | Type               | PHY            | Dual-Band? |
|---------------|--------------------|----------------|------------|
| Client 1      | Samsung S-SM-T230  | 802.11n 1x1:1  | Yes        |
| Client 2      | Samsung S-SM-T235  | 802.11n 2x2:2  | Yes        |
| Clients 3-4   | Samsung S-SM-T700  | 802.11ac 2x2:2 | Yes        |
| Client 5      | Samsung S-SM-T705  | 802.11ac 2x2:2 | Yes        |
| Client 6      | Samsung S-SM-T800  | 802.11ac 1x1:1 | Yes        |
| Client 7      | Samsung S-SM-T805  | 802.11ac 1x1:1 | Yes        |
| Client 8      | Samsung S-SM-N910C | 802.11ac 2x2:2 | Yes        |
| Client 9      | Samsung S-SM-P600  | 802.11ac 2x2:2 | Yes        |
| Clients 10-13 | Samsung N8000      | 802.11n 1x1:1  | Yes        |

The full list of numeric ranking and throughput is shown below.

| Ranking | Manufacturer | AP Model   | Result (Mbps) |
|---------|--------------|------------|---------------|
| 1       | Ruckus       | R500       | 213.26        |
| 2       | Ruckus       | R700       | 187.69        |
| 3       | Aruba        | 225        | 175.00        |
| 4       | Meraki       | MR34       | 168.19        |
| 5       | Cisco        | 3700       | 162.66        |
| 6       | Aerohive     | 330        | 158.92        |
| 7       | HP           | 560        | 153.48        |
| 8       | Ruckus       | 7982       | 144.87        |
| 9       | HP           | 525        | 141.74        |
| 10      | Cisco        | 1700       | 139.89        |
| 11      | Ubiquiti     | Uni-Fi Pro | 130.78        |
| 12      | Ruckus       | 7372       | 126.80        |
| 13      | Cisco        | 2700       | 123.82        |
| 14      | Aerohive     | 230        | 119.52        |
| 15      | Aerohive     | 121        | 108.10        |
| 16      | HP           | 430        | 89.06         |
| 17      | Ruckus       | R300       | 86.00         |
| 18      | Xirrus       | XR4300     | 85.58         |
| 19      | Xirrus       | XR520      | 25.90         |

### Test #1 – 13 Clients Results



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### Test #2 – 23 Clients Test

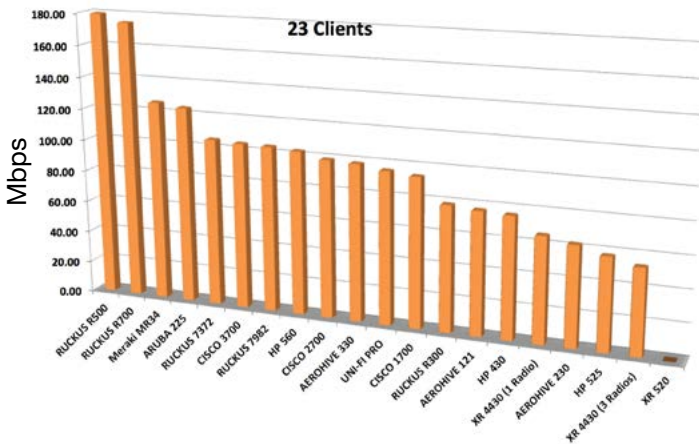
The additional clients added for this test are shown in the chart below.

| Client #      | Type              | PHY           | Dual-Band? |
|---------------|-------------------|---------------|------------|
| Client 14     | Samsung N8000     | 802.11n 1x1:1 | Yes        |
| Client 15-16  | iPad 3            | 802.11n 1x1:1 | Yes        |
| Clients 17-23 | HP Pro Tablet 610 | 802.11n 2x2:2 | Yes        |

The full list of numeric ranking and throughput is shown below.

| Ranking | Manufacturer | AP Model         | Result (Mbps) |
|---------|--------------|------------------|---------------|
| 1       | Ruckus       | R500             | 179.59        |
| 2       | Ruckus       | R700             | 174.92        |
| 3       | Meraki       | MR34             | 126.30        |
| 4       | Aruba        | 225              | 124.09        |
| 5       | Ruckus       | 7372             | 105.73        |
| 6       | Cisco        | 3700             | 104.67        |
| 7       | Ruckus       | 7982             | 104.36        |
| 8       | HP           | 560              | 103.03        |
| 9       | Cisco        | 2700             | 99.41         |
| 10      | Aerohive     | 330              | 98.66         |
| 11      | Ubiquiti     | Uni-Fi Pro       | 95.94         |
| 12      | Cisco        | 1700             | 94.17         |
| 13      | Ruckus       | R300             | 78.90         |
| 14      | Aerohive     | 121              | 77.29         |
| 15      | HP           | 430              | 76.27         |
| 16      | Xirrus       | XR4430 (1 radio) | 66.15         |
| 17      | Aerohive     | 230              | 62.74         |
| 18      | HP           | 525              | 58.00         |

### Test #2 – 23 Clients Results





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### Test #3 – 36 Clients Test

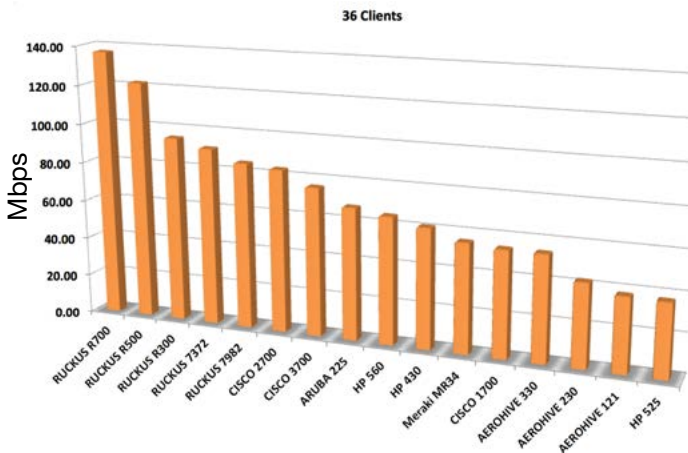
The additional clients added for this test are shown in the chart below.

| Client #     | Type                   | PHY           | Dual-Band? |
|--------------|------------------------|---------------|------------|
| Client 24-25 | iPad 3                 | 802.11n 1x1:1 | Yes        |
| Client 26    | iPad 4                 | 802.11n 1x1:1 | Yes        |
| Client 27    | Samsung N8000          | 802.11n 1x1:1 | Yes        |
| Client 28    | MacBook Pro 15" (2011) | 802.11n 3x3:3 | Yes        |
| Client 29-36 | HP Pro Tablet 610      | 802.11n 2x2:2 | Yes        |

The full list of numeric ranking and throughput is shown below.

| Ranking | Manufacturer | AP Model | Result (Mbps) |
|---------|--------------|----------|---------------|
| 1       | Ruckus       | R700     | 137.00        |
| 2       | Ruckus       | R500     | 122.16        |
| 3       | Ruckus       | R300     | 95.24         |
| 4       | Ruckus       | 7372     | 91.27         |
| 5       | Ruckus       | 7982     | 85.23         |
| 6       | Cisco        | 2700     | 83.56         |
| 7       | Cisco        | 3700     | 76.21         |
| 8       | Aruba        | 225      | 67.84         |
| 9       | HP           | 560      | 65.09         |
| 10      | HP           | 430      | 61.43         |
| 11      | Meraki       | MR34     | 56.00         |
| 12      | Cisco        | 1700     | 54.50         |
| 13      | Aerohive     | 330      | 54.45         |
| 14      | Aerohive     | 230      | 42.68         |
| 15      | Aerohive     | 121      | 38.16         |
| 16      | HP           | 525      | 37.67         |

### Test #3 – 36 Clients Results



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### Test #4 – 60 Clients Test

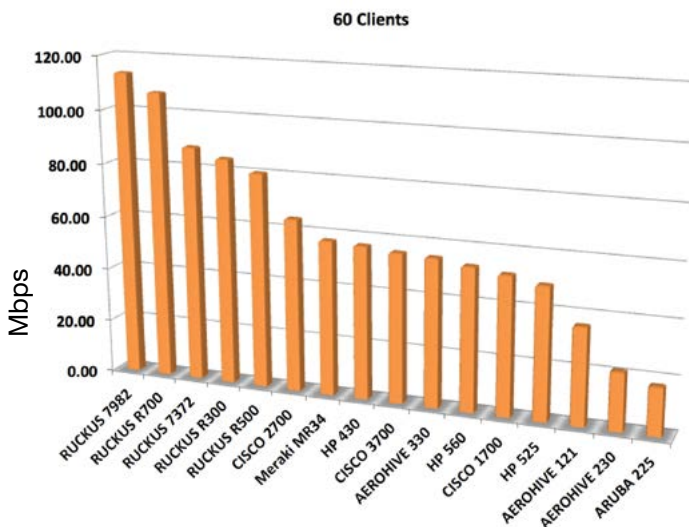
The additional clients added for this test are shown in the chart below

The full list of numeric ranking and throughput is shown below.

### Test #4 – 60 Clients Results

| Client #     | Type               | PHY           | Dual-Band? |
|--------------|--------------------|---------------|------------|
| Client 37-46 | Lenovo X200 laptop | 802.11n 3x3:3 | Yes        |
| Client 47-60 | Lenovo T400 laptop | 802.11n 3x3:3 | Yes        |

| Ranking | Manufacturer | AP Model | Result (Mbps) |
|---------|--------------|----------|---------------|
| 1       | Ruckus       | 7982     | 113.65        |
| 2       | Ruckus       | R700     | 107.06        |
| 3       | Ruckus       | 7372     | 87.85         |
| 4       | Ruckus       | R300     | 84.50         |
| 5       | Ruckus       | R500     | 80.25         |
| 6       | Cisco        | 2700     | 64.48         |
| 7       | Meraki       | MR34     | 57.70         |
| 8       | HP           | 430      | 57.06         |
| 9       | Cisco        | 3700     | 55.68         |
| 10      | Aerohive     | 330      | 55.17         |
| 11      | HP           | 560      | 53.35         |
| 12      | Cisco        | 1700     | 51.66         |
| 13      | HP           | 525      | 49.28         |
| 14      | Aerohive     | 121      | 36.14         |
| 15      | Aerohive     | 230      | 21.52         |
| 16      | Aruba        | 225      | 17.78         |





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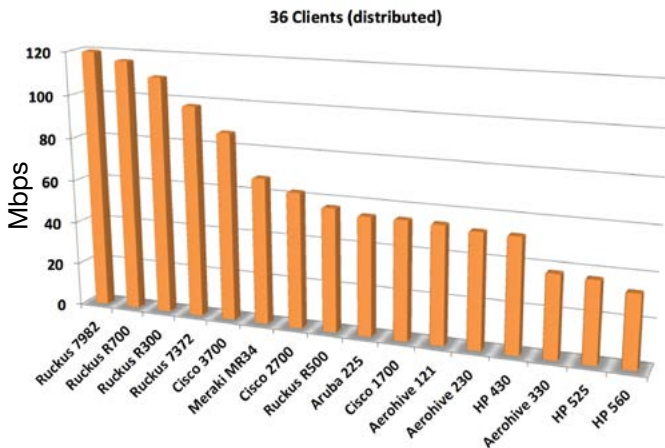


### Test #5 – 36 Clients (distributed) Test

The same clients were used for this test as were used with the standard 36 client test. The difference is that the client devices were spread around in a 270 degree arc shape so that APs would have to alternate speaking to clients in various directions.

The full list of numeric ranking and throughput is shown below.

### Test #5 – 36 Clients (distributed) Results



| Ranking | Manufacturer | AP Model | Result (Mbps) |
|---------|--------------|----------|---------------|
| 1       | Ruckus       | R7982    | 120.00        |
| 2       | Ruckus       | R700     | 116.42        |
| 3       | Ruckus       | R300     | 110.00        |
| 4       | Ruckus       | 7372     | 98.00         |
| 5       | Cisco        | 3700     | 86.95         |
| 6       | Meraki       | MR34     | 67.76         |
| 7       | Cisco        | 2700     | 62.67         |
| 8       | Ruckus       | R500     | 57.19         |
| 9       | Aruba        | 225      | 54.91         |
| 10      | Cisco        | 1700     | 54.84         |
| 11      | Aerohive     | 121      | 54.36         |
| 12      | Aerohive     | 230      | 52.85         |
| 13      | HP           | 430      | 52.53         |
| 14      | Aerohive     | 330      | 38.00         |
| 15      | HP           | 525      | 37.30         |
| 16      | HP           | 560      | 33.36         |