SR9 / Mikrotik Study PMP

900 MHz Network Performance Investigation

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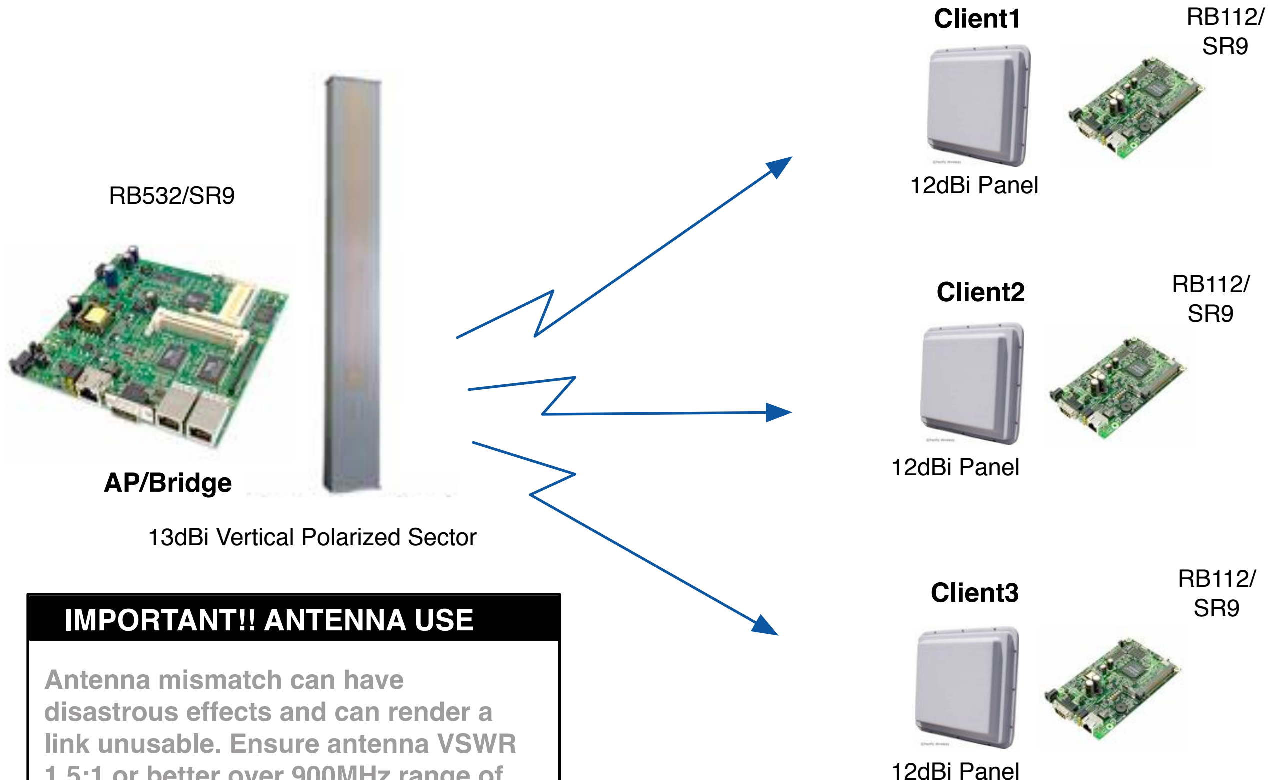
Study Overview

Point-to-MultiPoint networks based on Mkrotik™ RB532/RB112/RouterOS™ paired with Ubiquiti SuperRange9 900MHz radio cards have been created to characterize real-life performance expectations. The effects of varying signal levels, antenna selection, network scaling, in-band and out of and noise, and wireless settings upon network and throughput performance will be investigated.

Network Setup

Testing location was Ubiquiti Networks Labs in Silicon Valley, CA. A RB532 board with SR9 was placed at the far corner of the lab connected to a vertically polarized 13dBi Sector Antenna from PacWireless. Three client RB112/SR9 radios were setup across the room each enclosed in a 900MHz vertically polarized 12dBi Rootenna from PacWireless. To model path loss in later testing, attenuators were introduced before the antenna.

Point to Multi-Point



IMPORTANT!! ANTENNA USE

Antenna mismatch can have disastrous effects and can render a link unusable. Ensure antenna VSWR 1.5:1 or better over 900MHz range of operation. Please see Appendix for further study and recommendations. It is critical that VSWR of antenna/cable is controlled to repeat the following results.

Point to MultiPoint Testing Introduction

Testing Procedure

Using NetIQ Chariot, a throughput script was run which stresses equal amount of TCP/IP traffic in each direction of the link. Each test was was completed over a 5 minute period. There are some noticable inconsisentices in some of the graphs due to random noise nature of the environment and multi-path effects due indoor testing. Also important to note is that throughput is often limited by the CPU (not the wireless link) and both throughput pairs in the graphs must be combined for total throughput representation.

In addition to throughput testing, loop time for the completion of a full script iteration was also recorded. Using throughput, response time, and the max limited datarate, a robustness factor was calculated using the following formula.

$$\text{Robustness Factor} = \frac{\text{Throughput (Mbps)}}{\text{Looptime(Sec.)}+[\text{DataRate(Mbps)} / \text{Channel(MHz)}]}$$

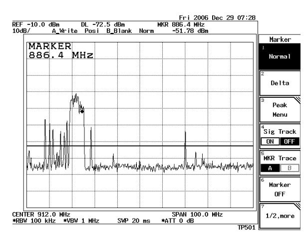
Note, the robustness factor calculation should be taken lightly as it does not take into account significant factors including: a.) processor speed limited throughput and b.) all testing was confined to low to mid signal levels -- insufficient to successfully utilize higher data rates. In this case however, it is useful in showing the effects of using different data rates in mid and low link cases which we believe are critical to understand as they will often be the signal levels seen when operators use 900MHz in situations where higher frequencies were not successful.

How We Chose Testing Conditions

In the Point to Point study (should be referenced before reading this document), we were able to categorize and draw conclusions on different test configurations fairly efficiently. When introducing multipoint testing to our test environments, there were suddenly an infinite amount of scenarios we could create with the expanding number of clients (variables). In order to make this study as useful as possible to the end user, we used the following rules to limit the configuration scenarios to what we believe most accurately models real life deployment.

SIGNAL LEVELS: In this study, all signal levels were confined to low and mid ranges to model typical deployment scenarios and in an effort to keep the study efficient. For mid range, we used a -70dBm signal level and for low range, a -85dBm signal level. Note, these signal levels will not show the highest potential performance of the SR9/Mikrotik solution which will require higher signal levels. For those results, please consult the Point to Point study. To achieve lower signal levels in our test environment, attenuators were placed in line with the client antennas.

NOISE ENVIORNMENT: All testing was performed with radiated links through antennas. This was done to observe the network in the presence of fairly high ambient noise in and around the 900-928MHz ISM band in Silicon Valley, CA and to incorporate antenna effects. The spectrum analyzer plot of ambient noise is shown to the right.

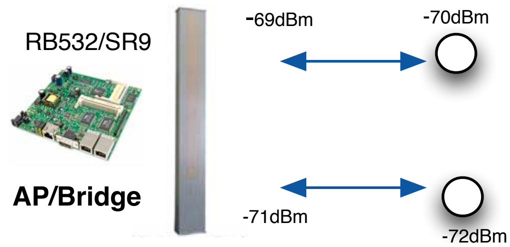


WIRELESS SETTINGS: We primarily concentrated our test cases with mid to high data rates on 5, 10, 20MHz channel settings. In each case, we started with aggressive settings and lowered the rates as we saw improvement. In each case, we tried to find the best compromise between throughput and robustness.

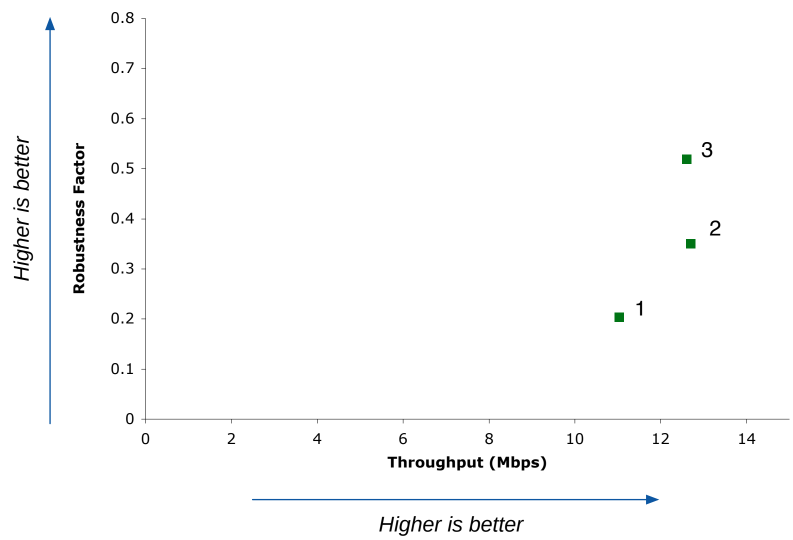
Test Group 1

2 Client Network with Mid Signal Levels

Frequency	912MHz
Mode	802.11b/g
Channel	20MHz
Rate	Variable
Operation	AP/Bridge
Signal(RX)	-70dBm



Test	Settings	Throughput (Mbps)	LoopTime(sec)	Robustness Factor
1	20MHz, Auto DataRate	11.032	0.298	0.203
2	20MHz, 36Mbps max limited	12.700	0.251	0.350
3	20MHz, 24Mbps max limited	12.600	0.253	0.520



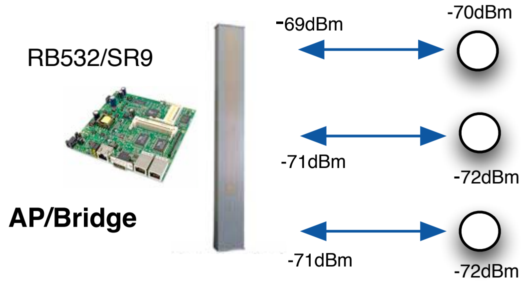
Conclusions / Observations

The auto-rate setting appears to have some problems at these signal levels. This agrees with our findings in the PtP study. As the maximum data rate is lowered, we see the network becomes more robust. However, it is important to note that the improved robustness going from 36Mbps to 24Mbps, does not appear to be real looking at the throughput graphs in the appendix -- they are both fairly smooth. In this case, the auto-rate algorithm of the driver might be working correctly and selecting 24Mbps in both cases or the throughput is processor limited.

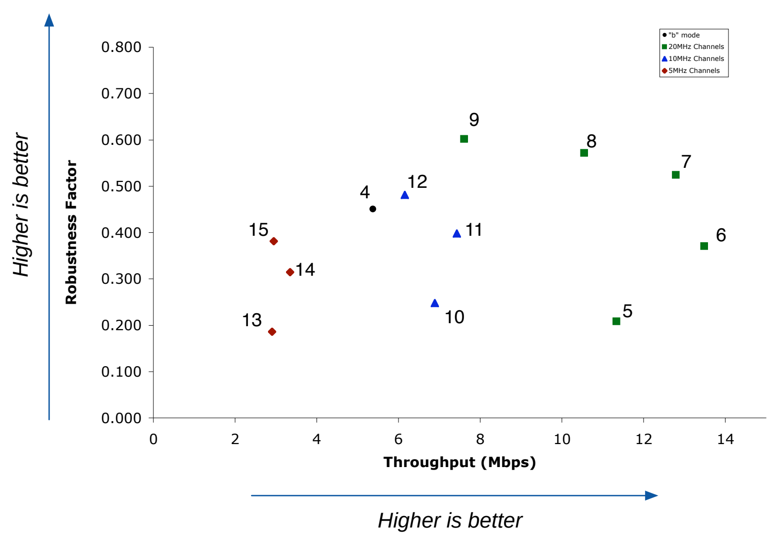
Test Group 2

3 Client Network with Mid Signal Links

Frequency	912MHz
Mode	802.11b/g
Channel	20MHz
Rate	Variable
Operation	AP/Bridge
Signal(RX)	-70dBm



Test	Settings	Throughput (Mbps)	LoopTime(sec)	Robustness Factor
4	20MHz, b mode	5.369	0.896	0.451
5	20MHz, Auto	11.339	0.459	0.208
6	20MHz, 36Mbps max limited	13.483	0.357	0.371
7	20MHz, 24Mbps max limited	12.787	0.376	0.525
8	20MHz, 18Mbps max limited	10.545	0.456	0.571
9	20MHz, 12Mbps max limited	7.605	0.632	0.602
10	10MHz, Auto	6.887	0.785	0.248
11	10MHz, 36Mbps max limited	7.425	0.653	0.398
12	10MHz, 24Mbps max limited	6.153	0.784	0.481
13	5MHz, Auto	2.902	2.101	0.186
14	5MHz, 36Mbps max limited	3.348	1.640	0.315
15	5MHz, 24Mbps max limited	2.944	1.716	0.382



Conclusions and Observations

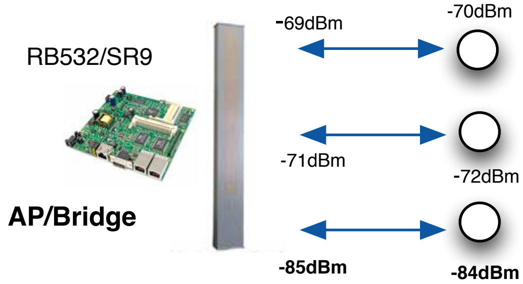
It is clear that limiting the maximum data rate is beneficial to both throughput and robustness. For the 20MHz case at these signal levels, it is important to limit the maximum data rate to 36Mbps or below. It is clear that there does not appear to be much benefit for reducing the rates below 24Mbps.

For the 10MHz and 5MHz channel, the robustness factor is a much more useful figure. It is clear that in these narrower channel modes, robustness and throughput significantly increase when data rates are max limited to 36Mbps. Robustness can further be improved moving down to 24Mbps. These conclusions do agree with the throughput charts in the Appendix.

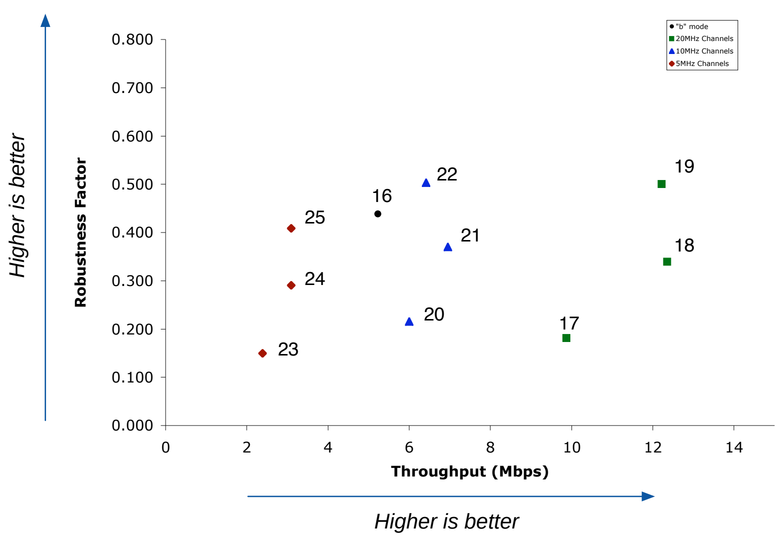
Test Group 3

3 Client Network with Mid x2 and Weak x1 Signal Links

Frequency	912MHz
Mode	802.11b/g
Channel	20MHz
Rate	Variable
Operation	AP/Bridge
Signal(RX)	-70dBm to -85dBm



Test	Settings	Throughput (Mbps)	LoopTime(sec)	Robustness Factor
16	20MHz, b mode	5.227	0.924	0.438
17	20MHz, Auto	9.875	0.525	0.181
18	20MHz, 36Mbps max limited	12.356	0.408	0.339
19	20MHz, 24Mbps max limited	12.221	0.417	0.501
20	10MHz, Auto	5.996	0.862	0.215
21	10MHz, 36Mbps max limited	6.952	0.798	0.370
22	10MHz, 24Mbps max limited	6.415	0.751	0.503
23	5MHz, Auto	2.384	2.413	0.150
24	5MHz, 36Mbps max limited	3.096	1.669	0.290
25	5MHz, 24Mbps max limited	3.093	1.570	0.409



Conclusions and Observations

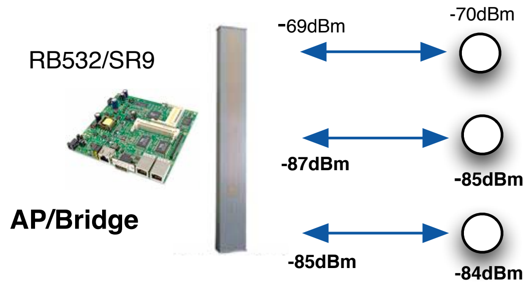
The most notable observation shows that when one of the clients signal level was weakened to the -85dBm range, the cases that were not max data rate limited further degraded in both throughput and robustness.

Overall, the other cases did not show significant performance differences from the previous test group suggesting that a weak link will not affect network scaling if the datarates are correctly limited. However, we see the start of a trend where limiting maximum data rates becomes more crucial to maintaining robustness/ scalability of the network.

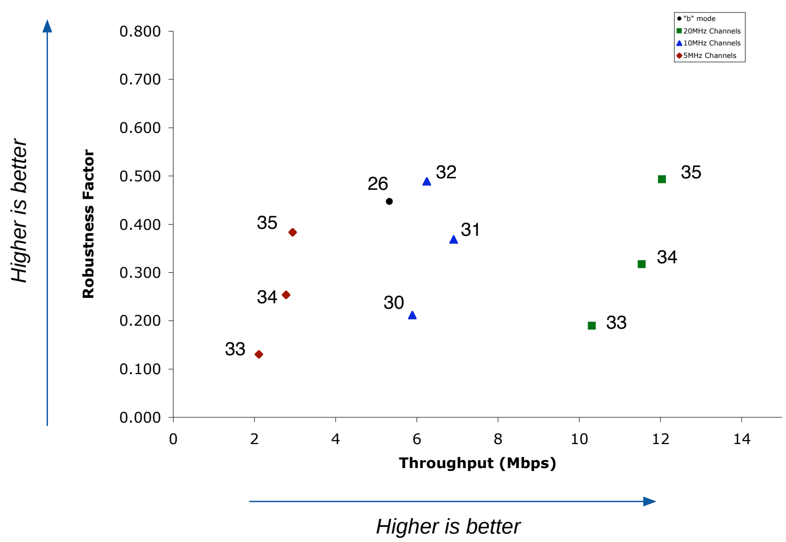
Test Group 4

3 Client Network with Mid x1 and Low x2 Signal Links

Frequency	912MHz
Mode	802.11b/g
Channel	20MHz
Rate	Variable
Operation	AP/Bridge
Signal(RX)	-70dBm to -85dBm



Test	Settings	Throughput (Mbps)	LoopTime(sec)	Robustness Factor
26	20MHz, b mode	5.326	0.904	0.447
27	20MHz, Auto	10.315	0.479	0.189
28	20MHz, 36Mbps max limited	11.541	0.439	0.317
29	20MHz, 24Mbps max limited	12.040	0.417	0.493
30	10MHz, Auto	5.890	0.885	0.211
31	10MHz, 36Mbps max limited	6.910	0.744	0.369
32	10MHz, 24Mbps max limited	6.245	0.774	0.489
33	5MHz, Auto	2.114	2.706	0.130
34	5MHz, 36Mbps max limited	2.779	1.949	0.254
35	5MHz, 24Mbps max limited	2.944	1.677	0.383



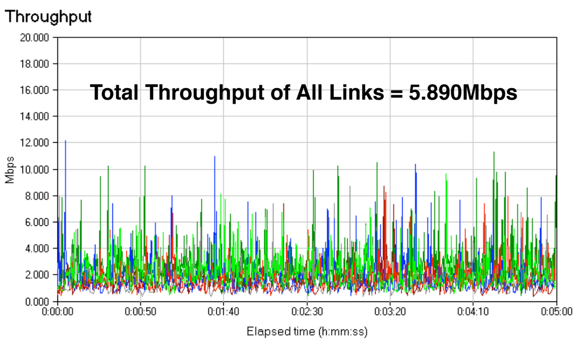
Conclusions and Observations

Dropping two clients now to weaker links shows a slight overall decrease in throughput and robustness. It now appears that a 24Mbps max limited data rate becomes a better throughput/robustness compromise where as in the previous test group (higher signal levels), the 36Mbps max limited setting showed better performance.

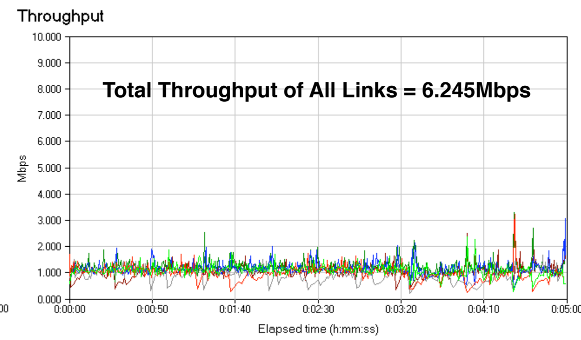
Overall, the data shows that dropping a second client to a lower signal level does not substantially degrade performance and we can conclude that a SR9 based network with lower signal links can still be robust and scalable.

Final Conclusions and Observations

1.) Lower signal levels and narrow bandwidth links benefit from limiting Data Rates: This conclusion was reached in the point to point study and holds even more true in the point-to-multipoint case especially when dealing with increased number of clients and lower signal levels.



10MHz, Auto data rate. clients at -85dBm,-85dBm,-70dBm



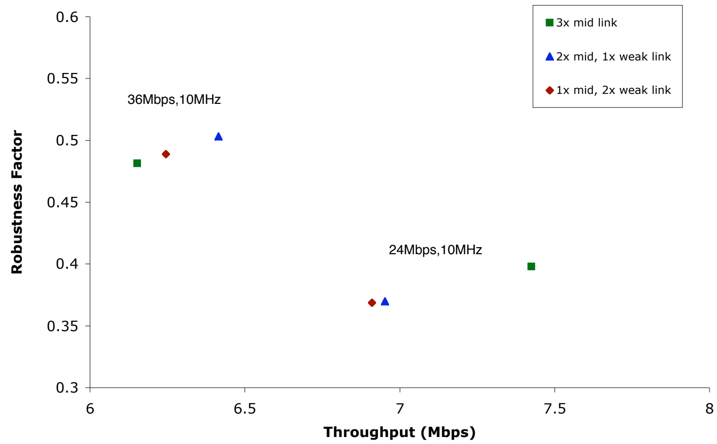
Same network with data rates max limited to 24Mbps

It is clear that max limiting data rates to 24Mbps in the example above improves the overall throughput and significantly improves robustness of the network. It is difficult to determine if this is a noise issue or a driver / auto-rate algorithm issue, or (most likely) a combination of both. It is strongly recommended to lock in the maximum data rates to 36Mbps (and most likely even lower rates depending on environmental noise and size of total network and signal levels involved) when scaling a network -- especially using narrower channels and/or lower signal levels.

At the same time, SR9/Mtik is possible of higher performance links using the auto-rate or higher data rate settings, but sufficient signal strength must be maintained and conditions must be ideal (please consult Point to Point study).

2.) SR9/Mtik solution generally robust with lower signal links: With the correct settings, the overall network throughput and robustness does decline with lower signal links, but not too significantly -- suggesting that networks should scale successfully beyond a few clients in real world applications if recommendations from this study are followed.

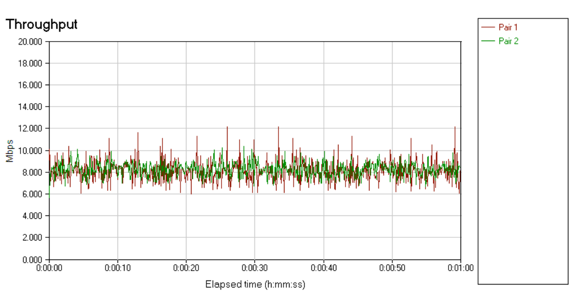
Test	Settings	Throughput (Mbps)	LoopTime(sec)	Robustness Factor
Mid Links x3				
11	10MHz, 36Mbps max limited	7.425	0.653	0.398
12	10MHz, 24Mbps max limited	6.153	0.784	0.481
Mid Links x2, Weak Links x1				
21	10MHz, 36Mbps max limited	6.952	0.798	0.370
22	10MHz, 24Mbps max limited	6.415	0.751	0.503
Mid Links x1, Weak Links x2				
31	10MHz, 36Mbps max limited	6.910	0.744	0.369
32	10MHz, 24Mbps max limited	6.245	0.774	0.489



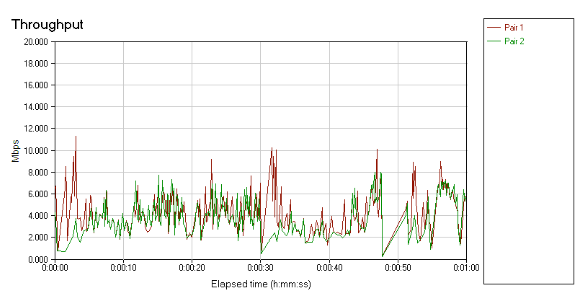
Comparing the Effect of Client Signal Levels on network with 10MHz/36Mbps and 10Mhz/24Mbps settings

The above table and graph refer to the 10MHz channel case when limiting data rates at 36Mbps and 24Mbps. The network throughput do drop as weaker signal clients are added, but not significantly. It is important to note that when scaling the networks, other considerations (such as hidden node) must be taken into consideration. But, based on results above, SR9 should scale comparatively to 2.4GHz Atheros based networks when deployed in a somewhat noise controlled environment and with suggested controlled data rates and antenna considerations.

3.) Antenna Matching is Critical: IThis is a conclusion from the point to point sutdy which must be reiterated as it is even more crucial for scaling a multipoint network. If the antenna and/or RF cable causes RF output mismatch in the frequency of operation, the link can become unstable and even useless. In order to ensure a good RF output match, make sure the VSWR of the antenna/cable combination being used is at least 1.5:1 or better.



Link with Good Antenna Match

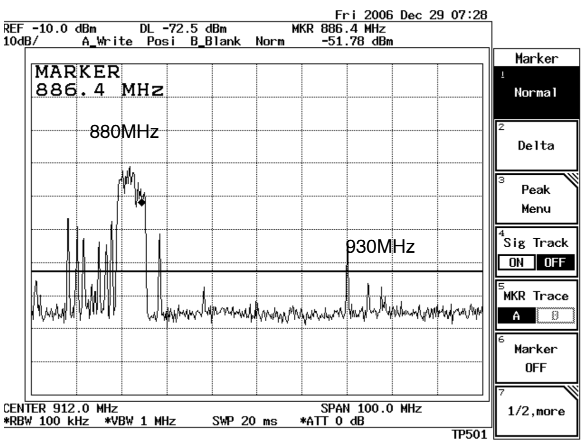


Same link with bad antenna match on one end

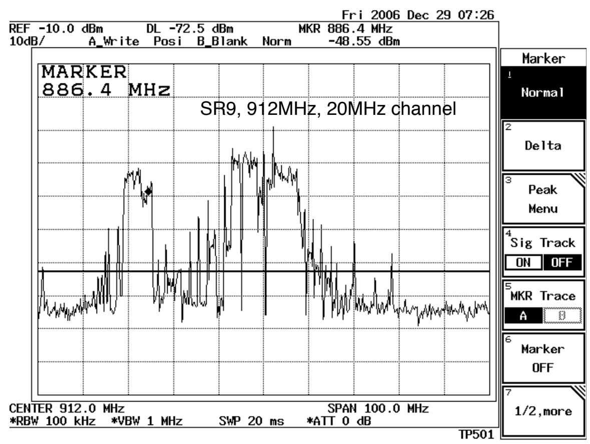
In this report, all testing was performed using the PacWireless Rootenna R2T9-12-XX

http://www.wisp-router.com/items.asp?Cc=Client900

3.) Environmental noise: Quanitifying the affect of noise on a SR9 link is difficult. For the most part, the SR9 has excellent out of band rejection and is able to maintain a stable link with mid strength level out of band interferers. The description below provides some insight into problems associated with noise and suggestions on how to overcome them.



Ambient noise in Ubiquiti Labs, San Jose CA

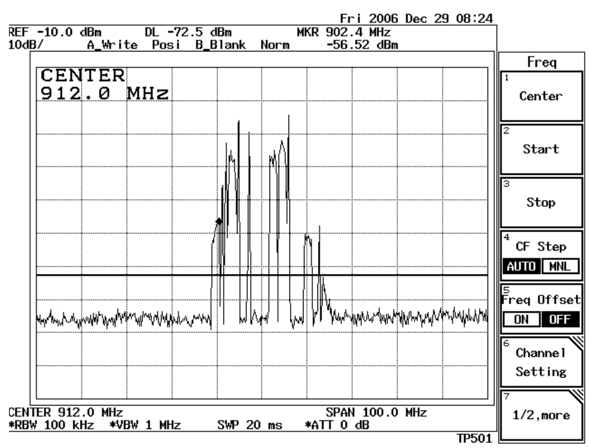


Noise relative to SR9: (10ft. spacing from transmitting SR9) Note: level is further attenuated by 50dB+ in selected tests

A.) Proximity of the Interferer to the Link Operating Frequency

The closer the interference is to the frequency of operation, the more it will degrade the stability of the link. SR9 links can sustain very high 880MHz interferers without any affect on link performance. However, low-mid level noise at the ISM band edges (902 and 928 MHz) can make a link unstable quickly. In these cases, the SR9 cavity filter can be of benefit.

SR9_912_CF Hi-Selecitivty Cavity filter http://ubnt.com/cf.php4



Ambient noise after adding Cavity Filter on Out of Band Ambient Noise

B.) In Band Noise vs. Out of Band Noise

Dealing with in band noise is a greater problem. Generally, if the in band noise is much stronger than the signal link, it will cause the link to fail, frequently disconnect, cause RSSI levels to widely vary, and exhibit very poor throughput. In our investigations, we found changing center frequencies and channel bandwidth modes can provide help in overcoming in band noise. It is also beneficial to limit data rates to lower levels (especially in 5/10MHz modes) as they are more robust in the presence of in band noise.

C.) Types of in Band Noise

In addition to their signal strength level, there are other characteristics of interference signals in the 902-928MHz ISM band that can have significant affects on performance including varying duty cycles, spectral bandwidth, and shifting/hopping characteristics. In band noise can come from cordless phones, paging systems, security systems, wireless audio/video equipment, and even from shipping trucks and couriers moving around towns. We observed some periods where links would significantly be affected for several seconds to several minutes due to in band interferers (identified on the spectrum analyzer).

C.) Directional Antennas can Help

Using hi-gain directional panel, yagi, and dish antennas can provide some defense against noise as their gain non-uniformity can be taken advantage of by pointing them away from noise sources. In effect, this will reject both out of band and in band noise (where filtering maybe cannot). It is always recommended to operate a network with directional antennas as a way to isolate problems due to noise and minimize the affect of overall network performance in the presence of noise.

APPENDIX

Test	Settings	Throughput (Mbps)	LoopTime(sec)	Robustness Factor
MID SIGNAL LINK (-70dBm) X2				
Test	Settings	Throughput (Mbps)	LoopTime(sec)	Robustness Factor
1	20MHz, Auto DataRate	11.032	0.298	0.203
2	20MHz, 36Mbps max limited	12.700	0.251	0.350
3	20MHz, 24Mbps max limited	12.600	0.253	0.520
MID SIGNAL LINK (-70Bm) X3				
Test	Settings	Throughput (Mbps)	LoopTime(sec)	Robustness Factor
4	20MHz, b mode	5.369	0.896	0.451
5	20MHz, Auto	11.339	0.459	0.208
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MID SIGNAL LINK (-70Bm) X2, WEAK SIGNAL LINK (-85dBm) X1				
Test	Settings	Throughput (Mbps)	LoopTime(sec)	Robustness Factor
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Test	Settings	Throughput (Mbps)	LoopTime(sec)	Robustness Factor
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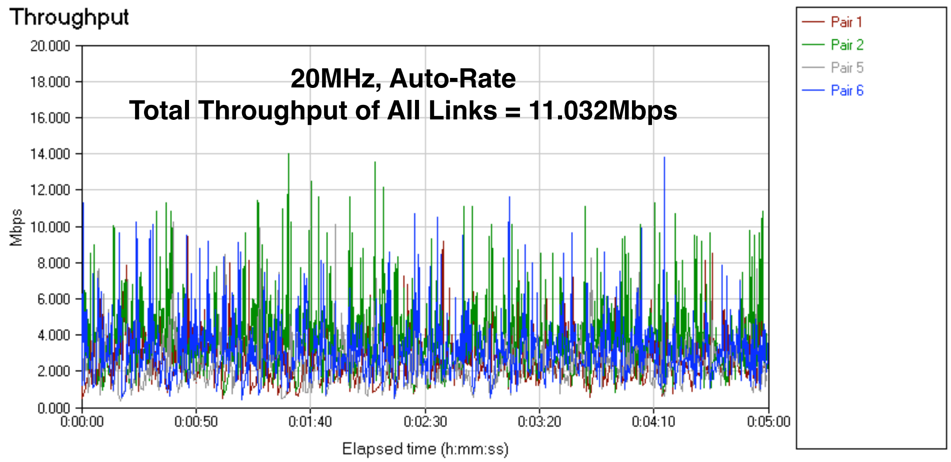
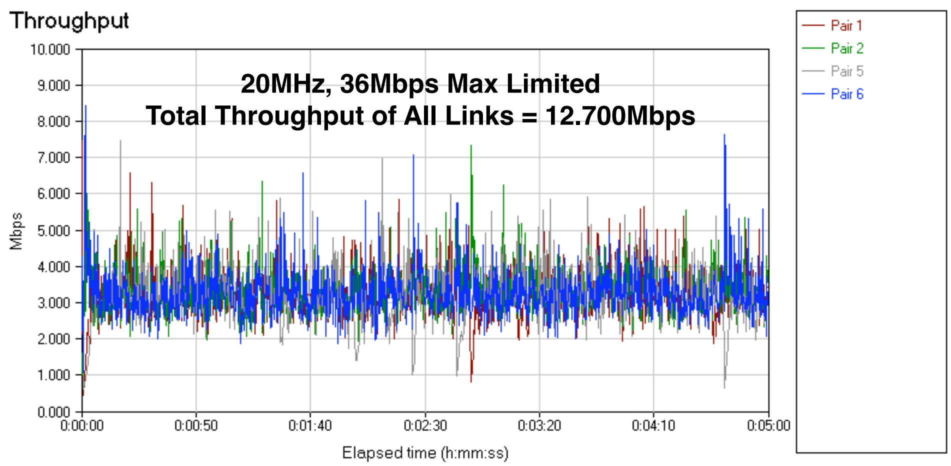
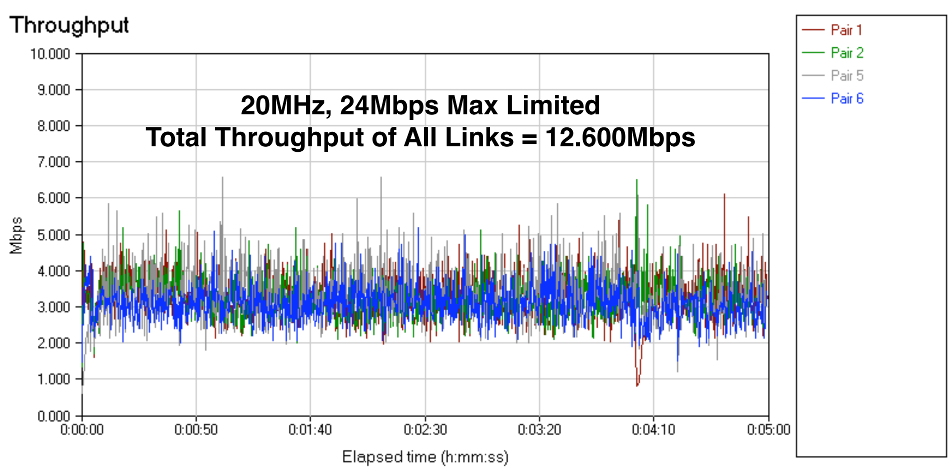
34	5MHz, 36Mbps max limited	2.779	1.949	0.254
35	5MHz, 24Mbps max limited	2.944	1.677	0.383

MID SIGNAL LINK (-70dBm) X2
Throughput Plots

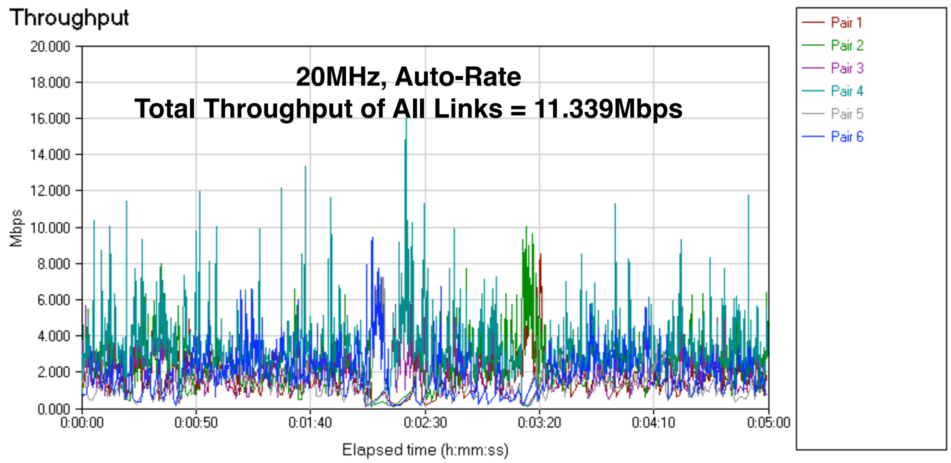


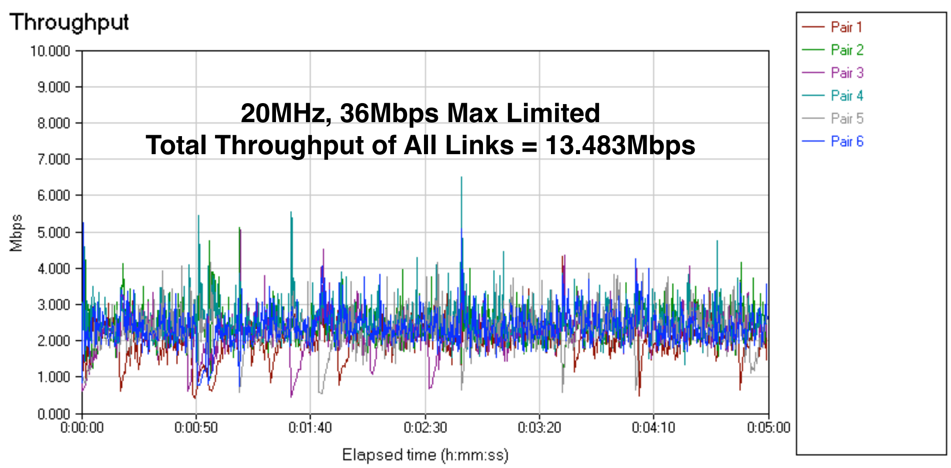


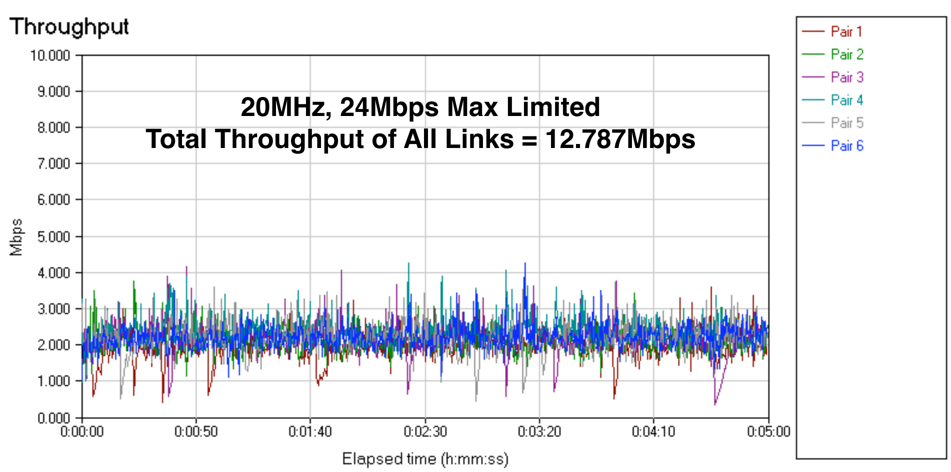


MID SIGNAL LINK (-70dBm) X3
Throughput Plots

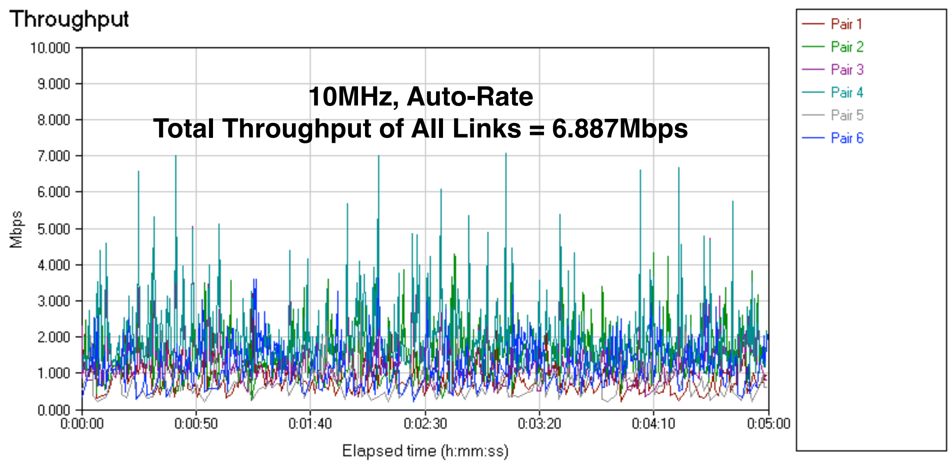
*Note: Additional client makes general throughput curve appear lower from 2 client case, but only because overall throughput is now divided further. (Overall throughput is comparable to 2 client case; please reference table at Appendix start).

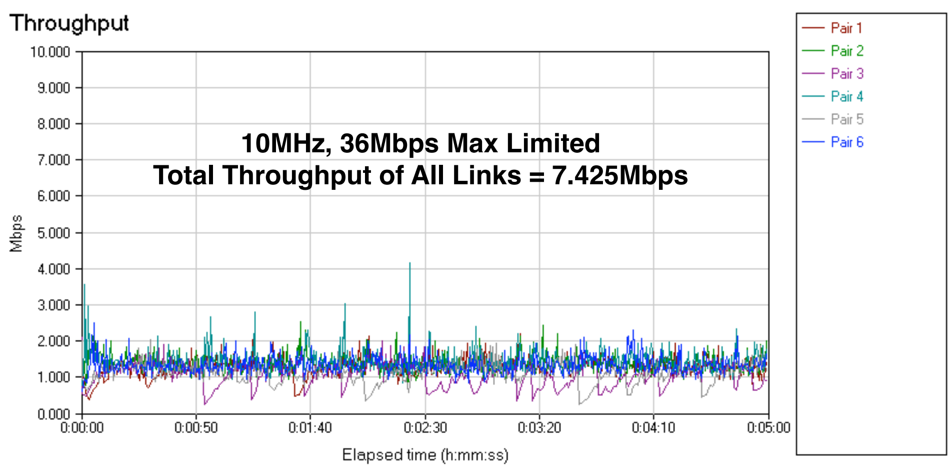




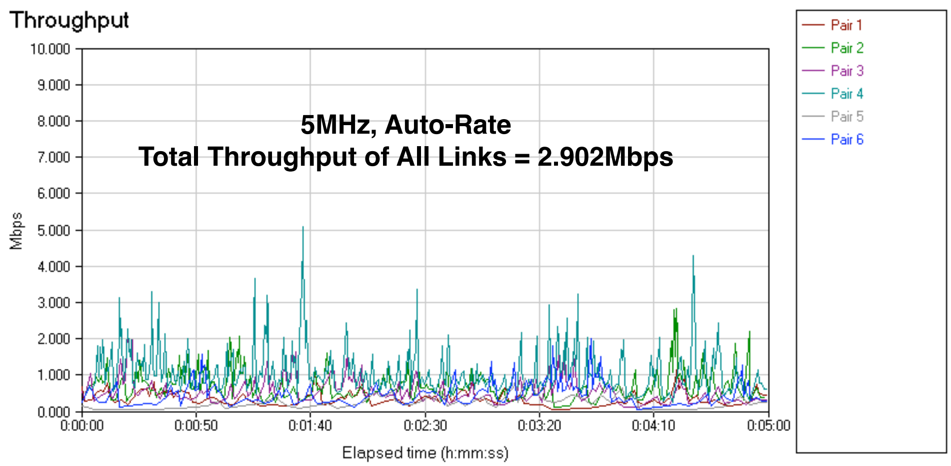


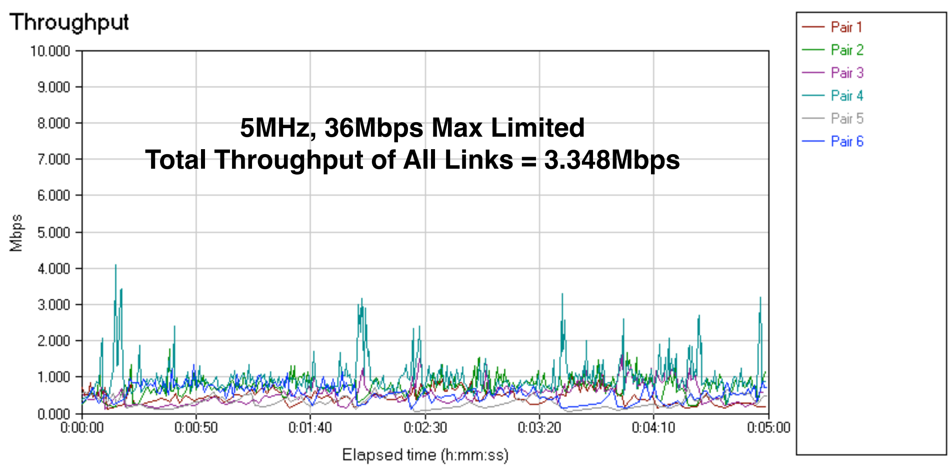
MID SIGNAL LINK (-70dBm) X3
Throughput Plots

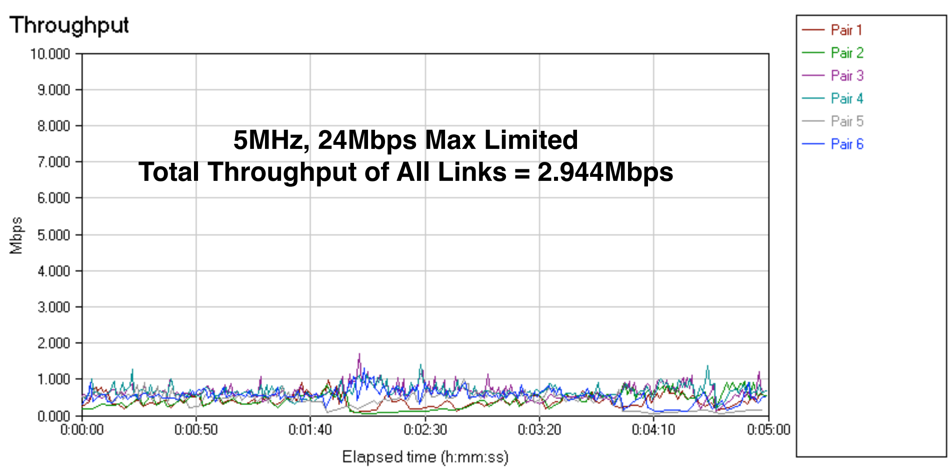




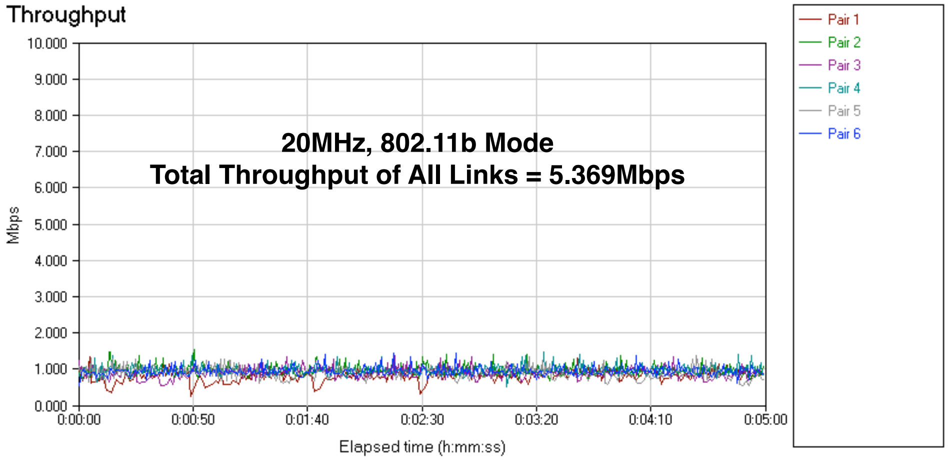
MID SIGNAL LINK (-70dBm) X3
Throughput Plots



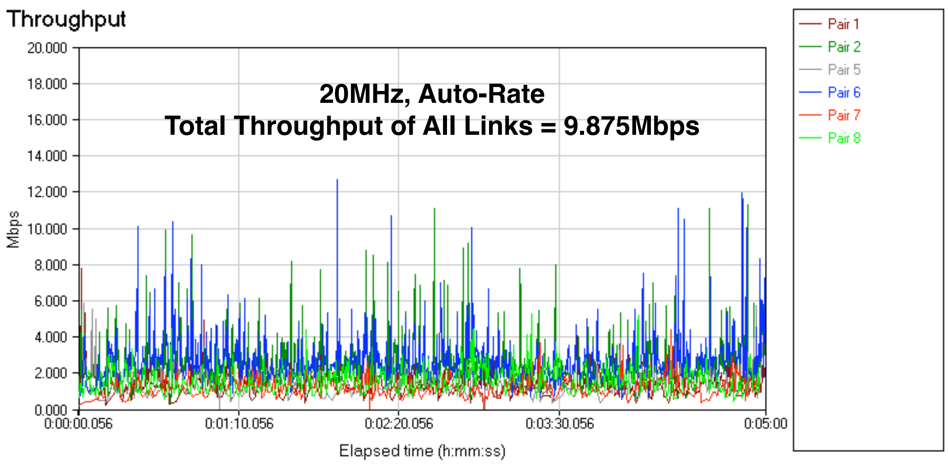


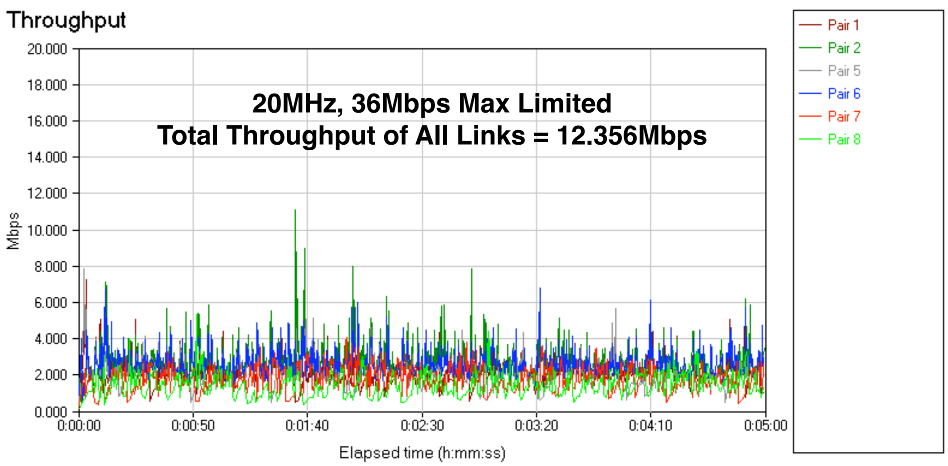


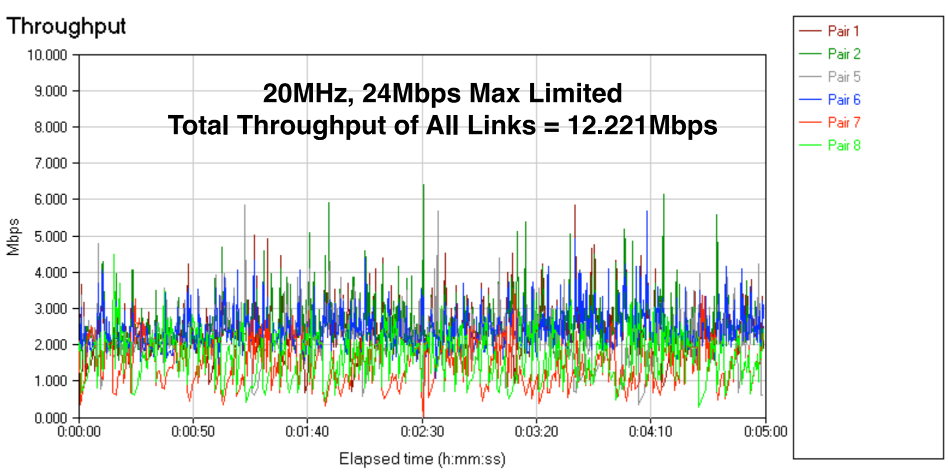
MID SIGNAL LINK (-70dBm) X3
Throughput Plots



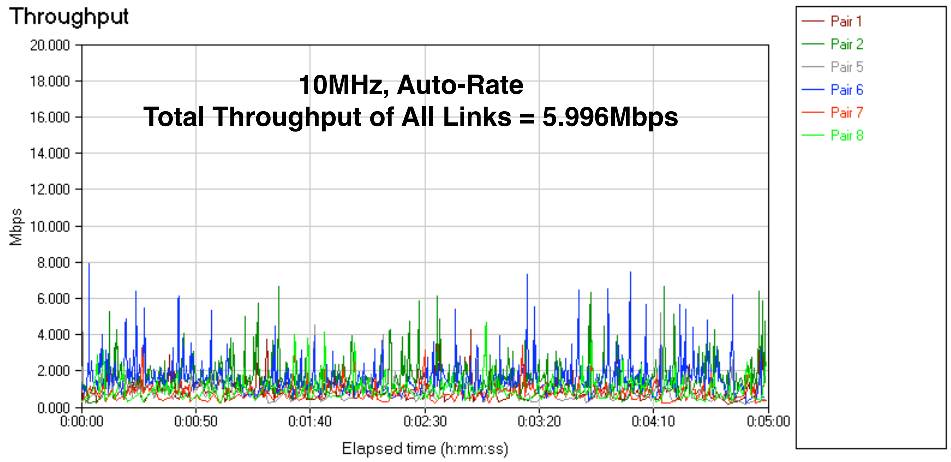
MID SIGNAL LINK (-70dBm) X2, WEAK SIGNAL LINK (-85dBm) X1
Throughput Plots

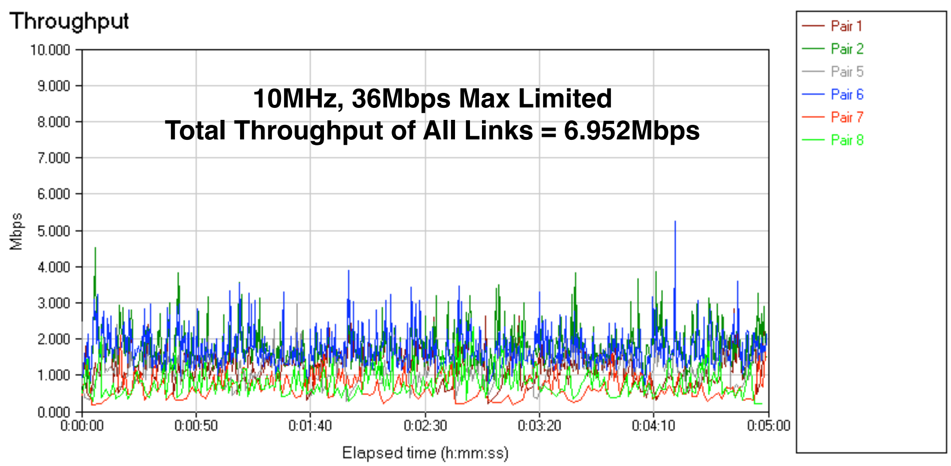


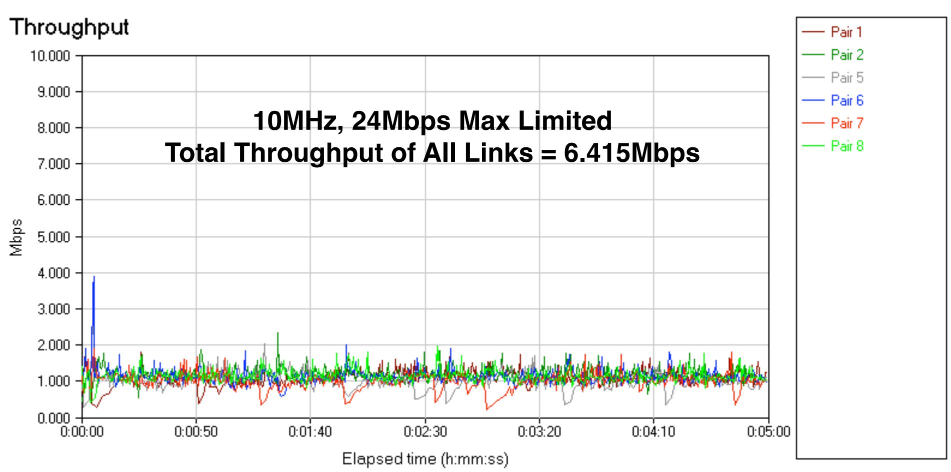




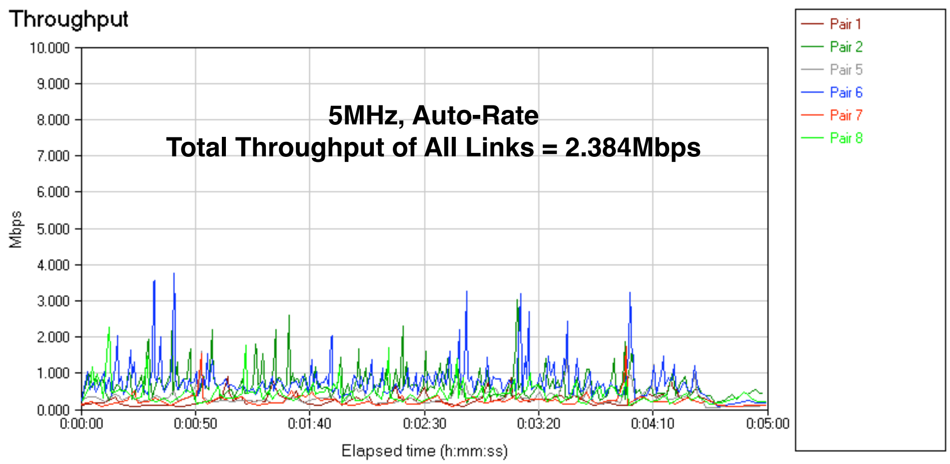
MID SIGNAL LINK (-70dBm) X2, WEAK SIGNAL LINK (-85dBm) X1
Throughput Plots

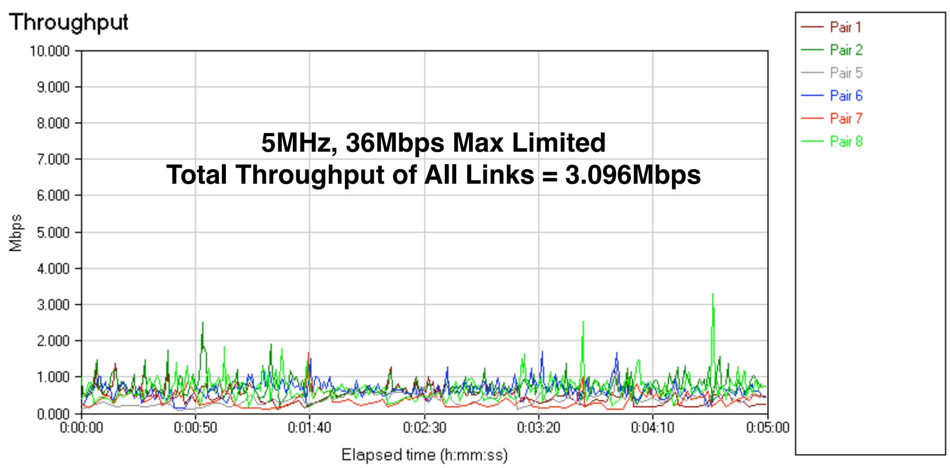


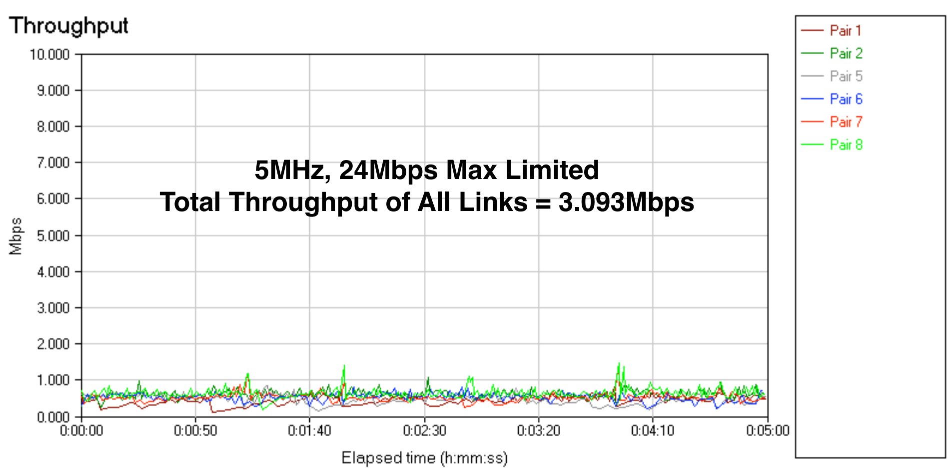




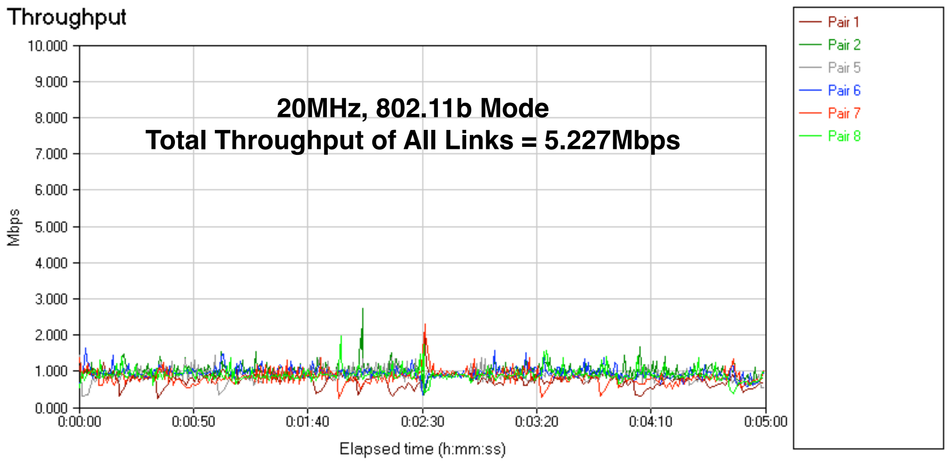
MID SIGNAL LINK (-70dBm) X2, WEAK SIGNAL LINK (-85dBm) X1
Throughput Plots



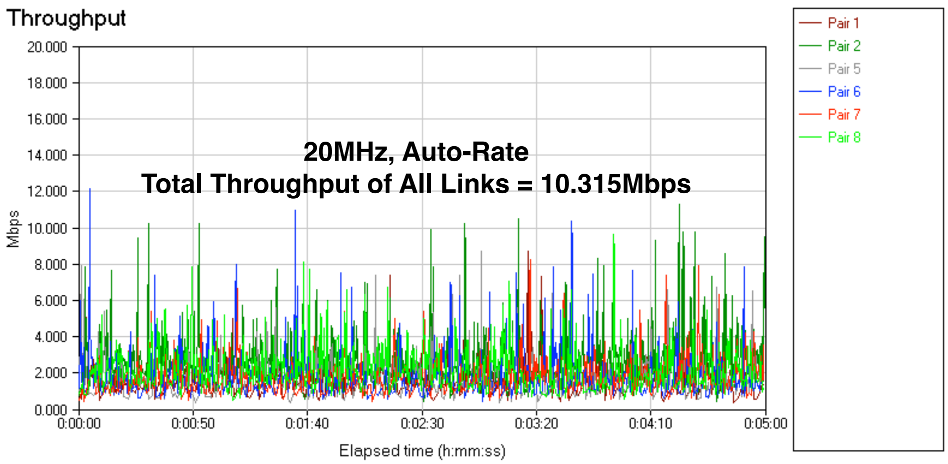


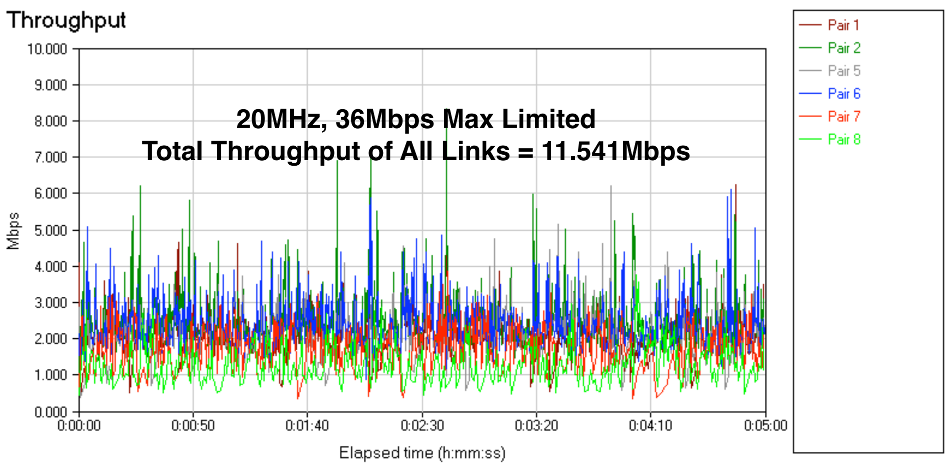


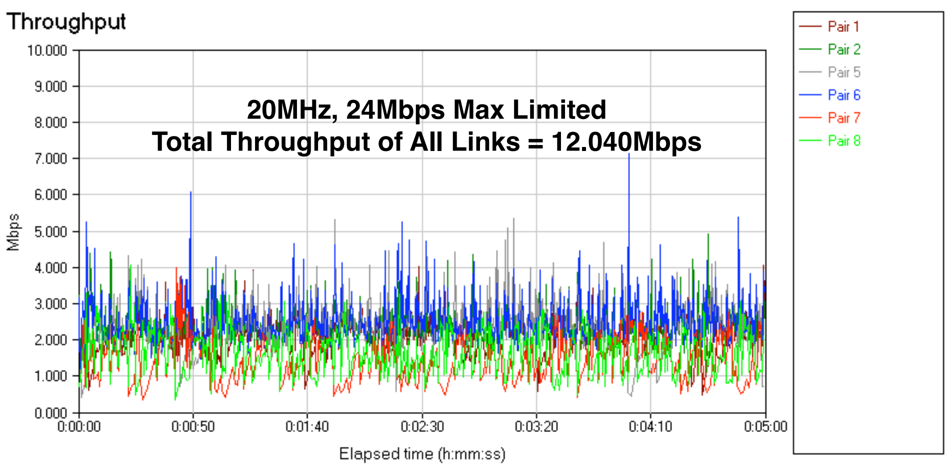
MID SIGNAL LINK (-70dBm) X2, WEAK SIGNAL LINK (-85dBm) X1
Throughput Plots



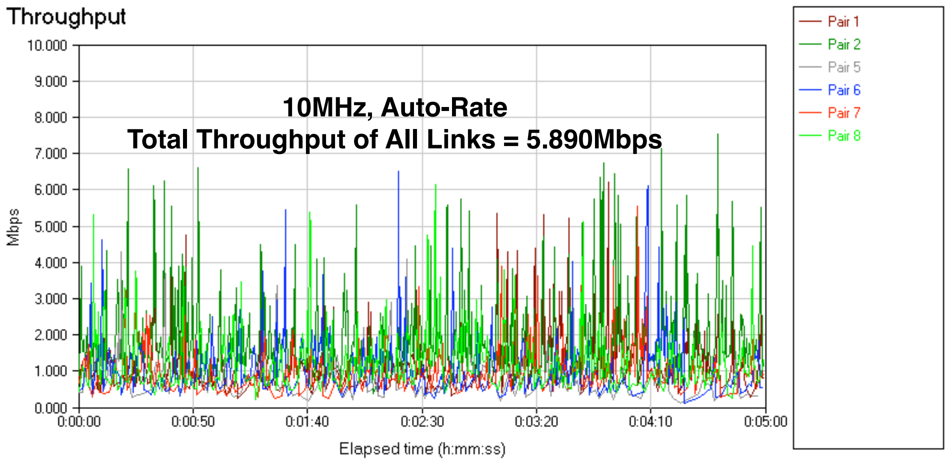
WEAK SIGNAL LINK (-85dBm) X2, MID SIGNAL LINK (-70dBm) X1
Throughput Plots

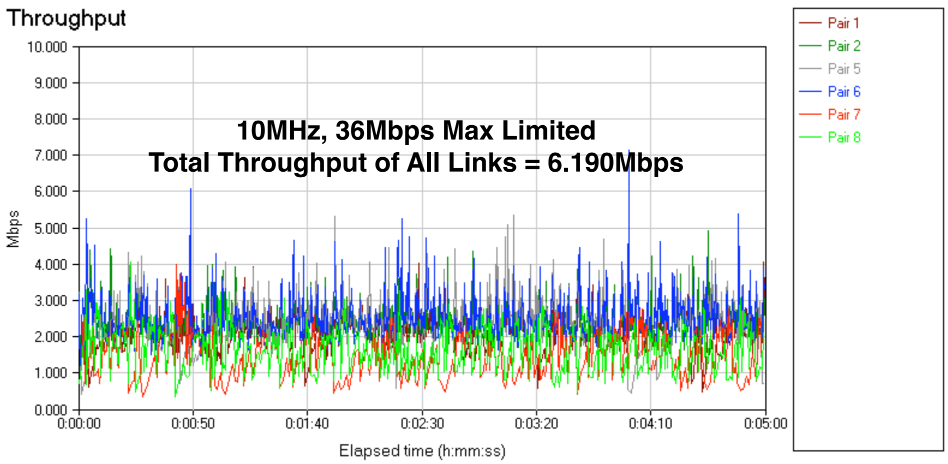


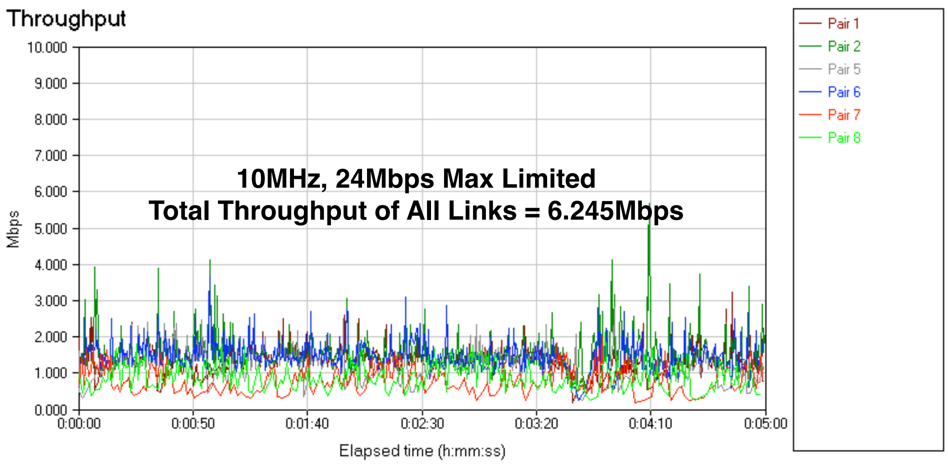




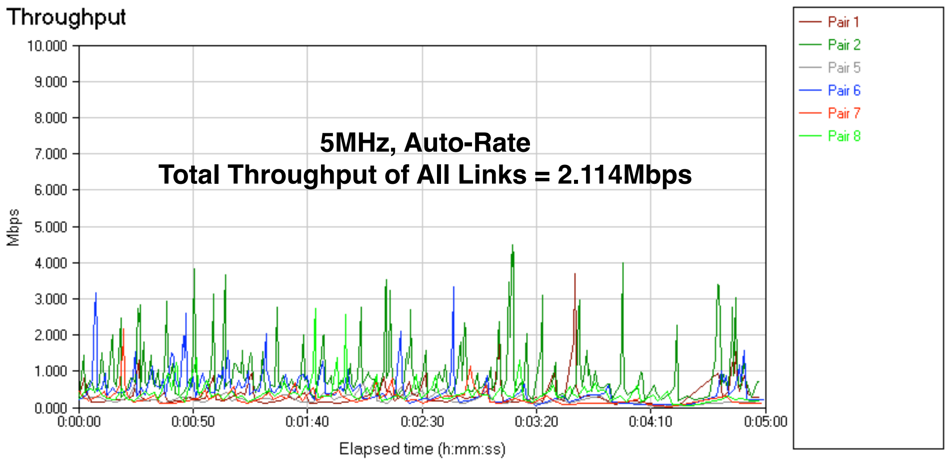
WEAK SIGNAL LINK (-85dBm) X2, MID SIGNAL LINK (-70dBm) X1
Throughput Plots

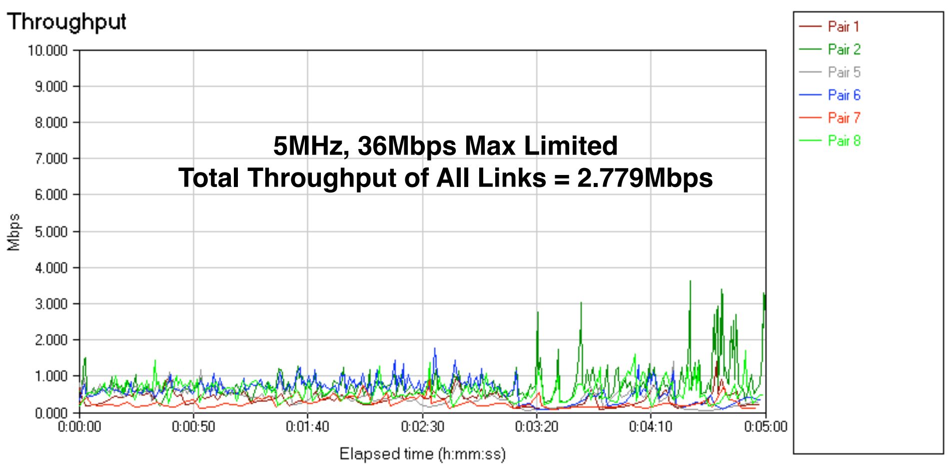


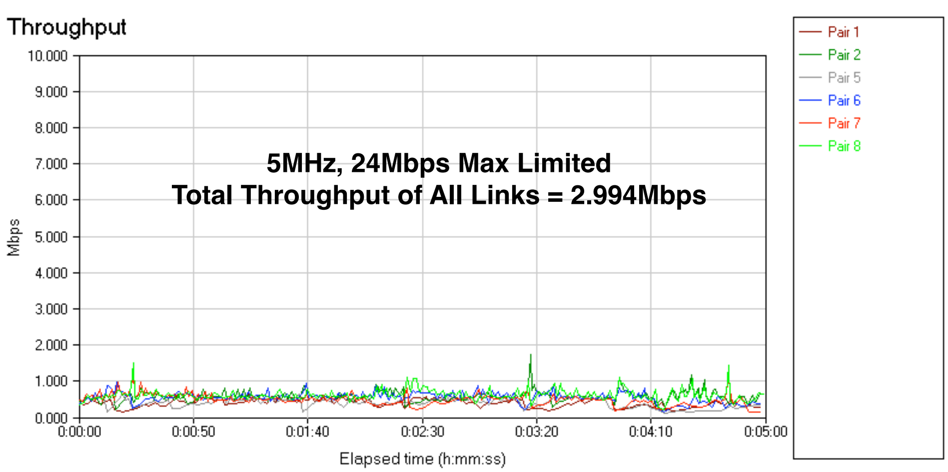




WEAK SIGNAL LINK (-85dBm) X2, MID SIGNAL LINK (-70dBm) X1
Throughput Plots







WEAK SIGNAL LINK (-85dBm) X2, MID SIGNAL LINK (-70dBm) X1
Throughput Plots