ALLION USA
INTERNET SERVICE PROVIDER WIRELESS GATEWAY COMPETITIVE ANALYSIS

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Introduction

Internet Service Providers (ISP) have a number of factors to consider when deploying wireless gateways with their service, and those decisions on gateway selection can have a major impact on the end user experience – especially as homes become more wirelessly connected (i.e. TVs, gaming consoles, media servers, computing devices, etc.). Both performance and coverage delivered throughout the home should be key considerations when ISPs evaluate the capabilities of the gateways they offer. As the widely deployed 2.4GHz band becomes increasingly congested, the ability to leverage the 5GHz band becomes an important consideration. The newly developed 5GHz 802.11ac mode which can theoretically deliver up to 1.7Gbps (4x4), is also an important factor when planning for the future when more client devices develop this capability.

Allion's competitive analysis evaluated both the performance and coverage of the gateways currently available from major ISP's (including Comcast, AT&T, Frontier and Google). It highlights how ISPs decisions on including the following Wi-Fi technologies impact performance:

- SISO vs. MIMO
- Dual-band capability (2.4GHz vs. 5GHz)
- 802.11ac vs. 802.11n vs. Legacy (802.11bg) protocols

The performance analysis was accomplished by conducting lab measurements of each gateway's throughput rate over the connection range of the test station / gateway connection. This was done by performing a Rate vs. Range test.

Wireless Gateway's Tested

The *"Allion Internet Service Provider Wireless Gateway Competitive Analysis*" summarizes a study conducted by Allion USA, LLC of the potential strengths and weaknesses of the following residential gateways available from major Internet service providers:

Non-Gigabit Internet Service Providers:

- Verizon / Frontier FiOS Greenwave G1100 (3x3 802.11a/b/g/n/ac)
- Verizon / Frontier FiOS Actiontec MI424WR (2x2 802.11b/g/n)
- Frontier / U-Verse Pace 3801HGV (1x1 802.11b/g)
- RCN Linksys EA2700 (2x2 802.11a/b/g/n)
- WoW Arris MG5225G (2x2 802.11b/g/n)
- Comcast Cisco DPC3941T (3x3 802.11a/b/g/n/ac)
- AT&T DSL Pace 4111N (2x2 802.11b/g/n)
- CenturyLink Technicolor C2100T (3x3 802.11a/b/g/n/ac)
- AT&T Pace 5268AC (3x3 802.11a/b/g/n/ac)

Gigabit Internet Service Providers:

- Burlington Telecom TP-Link Archer C7 (3x3 802.11a/b/g/n/ac)
- Google Fiber GFRG210 (3x3 802.11a/b/g/n/ac)
- Metronet Linksys EA6900 (3x3 802.11a/b/g/n/ac)
- EPB Fiber Optics NETGEAR R6300v2 (3x3 802.11a/b/g/n/ac)*
- Fairpoint Comm-Fiber & DSL Zyxel VMG4380 (2x2 802.11b/g/n)
- Comcast NETGEAR R8000 (3x3 802.11a/b/g/n/ac)*
- AT&T Gigapower Arris NVG599 (3x3 802.11a/b/g/n/ac)

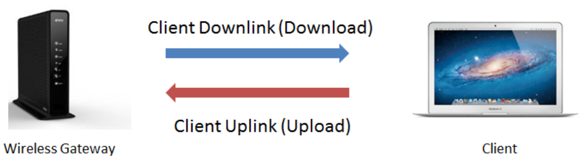
Note: The NETGEAR R6300v2 and R8000 were retail devices

The following reference station was used to collect measurements:

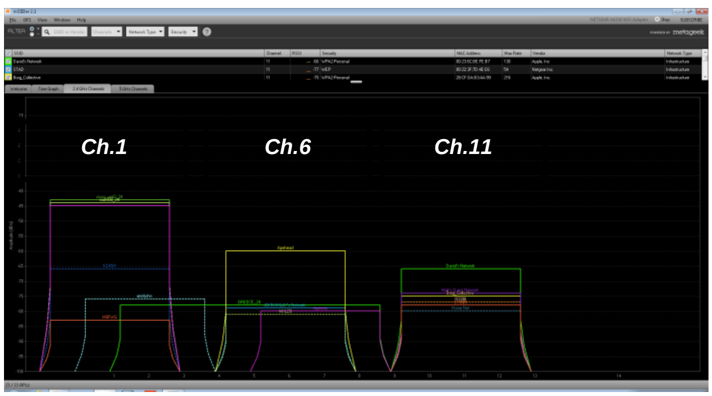
- 2015 MacBook Pro 802.11a/b/g/n/ac (Mac OS X Yosemite 10.10.5) with Broadcom BCM4360 chipset

Tools used:

- Iperf (traffic generator): This tool was used for collecting throughput measurements during the test. Commands used during the test are shown below:
    - Sender: iperf –c <IP> -w 256K –l 1460 –P4 –fm –i1 –t <DURATION>
    - Receiver: iperf –s –w 256K

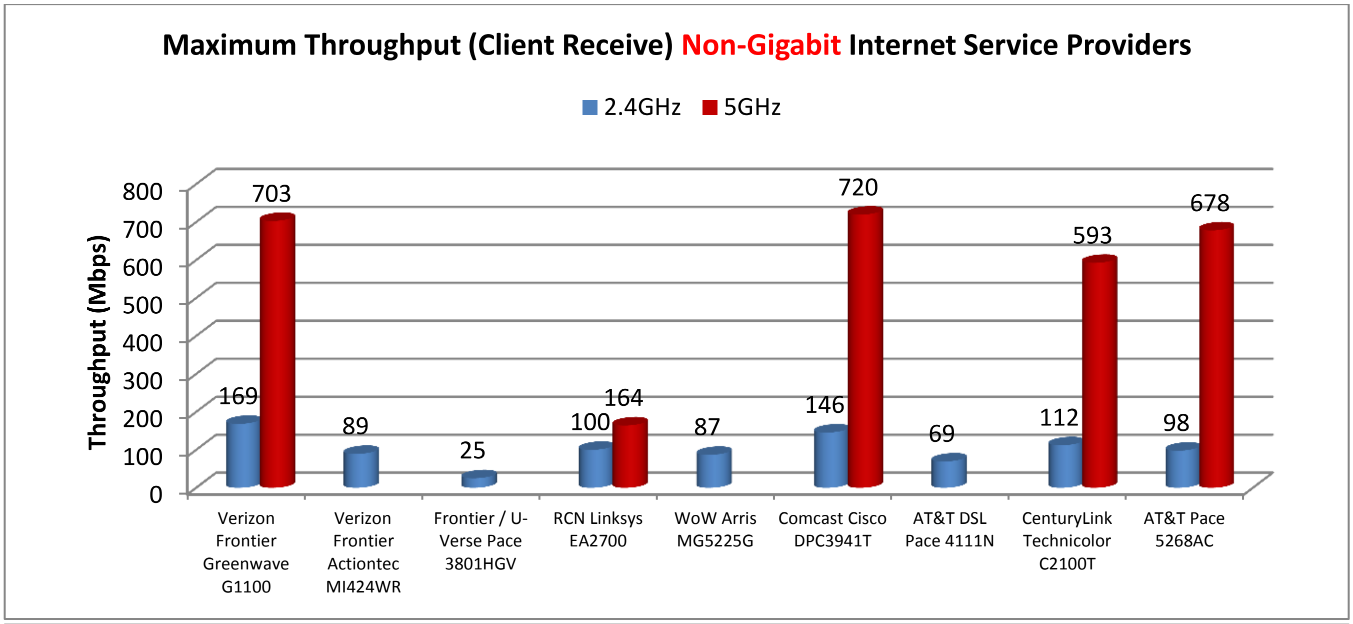


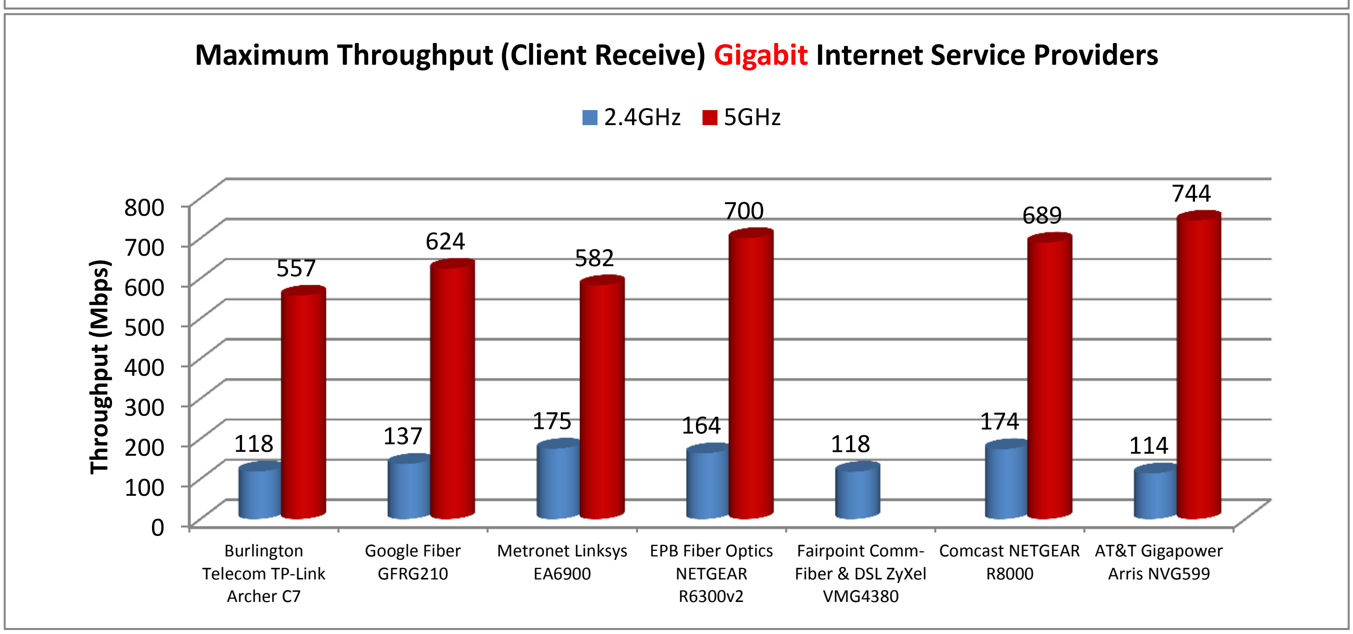
- InSSIDer by Metageek: This SW tool detects the operating channel and the signal strength of all Wi-Fi signals (both bands) in nearby areas



Conclusion

The devices were separated into two separate groups for analysis purposes – gateways deployed by Gigabit service providers vs. Non-Gigabit providers. Below were the results for peak throughput observed during the test for both 2.4GHz and 5GHz:





Note: See benefits of 5GHz operation on p.10

Based on the tests performed, the following devices exhibited the fastest throughput:

- Non-Gigabit Internet Service Providers
  - 2.4GHz – Verizon / Frontier Greenwave G1100 at 169Mbps
  - 5GHz – Comcast Cisco DPC3941T at 720Mbps
- Gigabit Internet Service Providers
  - 2.4GHz – Metronet Linksys EA6900 at 175Mbps
  - 5GHz – AT&T Gigapower Arris NVG599 at 744Mbps

Several key features contributed to the significant delta across some of the gateways:

1. 3x3 antennas (MIMO)
   a. Several gateways were equipped with more antennas (up to 3) while some gateways only had 1 or 2 antennas. Each antenna can theoretically add up to 150Mbps in 802.11n mode (40MHz) and 433Mbps in 802.11ac mode (80MHz).
2. Dual band capability
   a. Some gateways were only capable of operating on the 2.4GHz band. The ability to leverage both the 2.4GHz and 5GHz has big advantages for several reasons. 5GHz 802.11n/ac has the option to widen the channel width to 40/80MHz in order to theoretically double or quadruple the throughput.
   b. The 2.4GHz spectrum is limited in the number of available channels while the 5GHz band offers many more. Due to this, the 2.4GHz experiences noticeable interference from neighboring Wi-Fi signals.
3. 802.11ac vs. 802.11n vs. 802.11b/g
   a. 802.11ac is a relatively new feature that operates on the 5GHz band only. 802.11ac mode supports channel widths of 80MHz and 160MHz; theoretically doubling or quadrupling the throughput compared to 802.11n 40MHz mode. With a 3x3 antenna system, the theoretical max throughput can reach up to 1.3Gbps (many of the new client devices today are dual band 11n/ac capable).

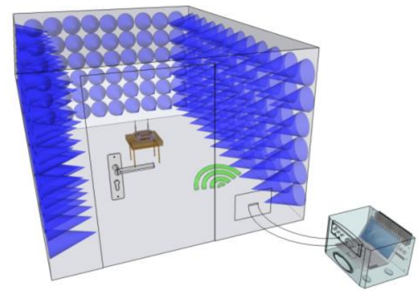
This study showed that Comcast's Cisco DPC3941T exhibited the fastest throughput in the Non-Gigabit provider category at 720Mbps.

In the Gigabit provider category, although the AT&T NVG599 device was the fastest at 744Mbps, AT&T's Gigabit services are not widely available and limited to less than 5% of AT&T's footprint, or approximately 1.6 million locations[1]. Comcast's NETGEAR R8000 device is available widely across its footprint to 18 million locations[2].

1 https://apps.fcc.gov/edocs_public/attachmatch/FCC-15-94A1.pdf

2 http://corporate.comcast.com/comcast-voices/imagine-where-2-gigabit-speeds-will-take-you

Rate vs. Range



This test simulated the effect of moving a wireless gateway from within very close proximity of the connected station to outside of the connectivity range of the gateway / station – effectively measuring the ability of the gateway to negotiate an optimal modulation with a client under a given signal condition.

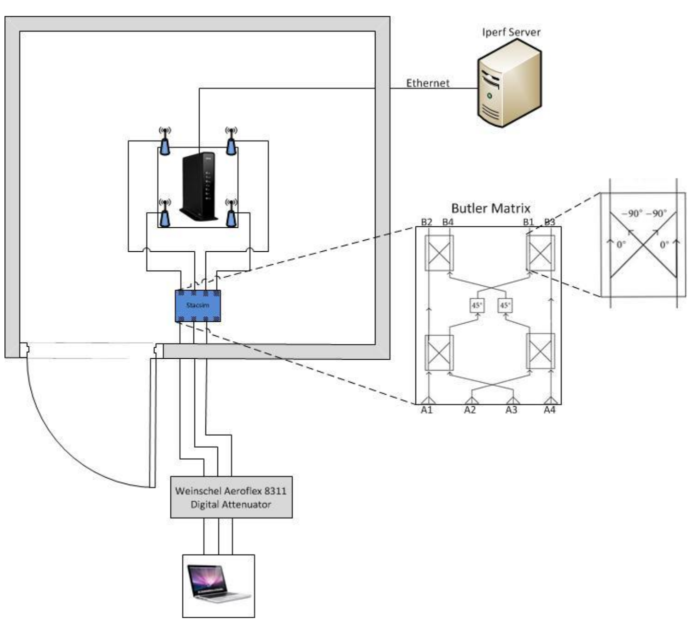
Throughput performance is base-lined by collecting throughput measurements based on the changing RF conditions (channel fading) by performing a throughput speed test at each attenuation level – incrementally increasing the attenuation between the station and wireless gateway.

The goal of this test was twofold:

1. To determine the baseline ***peak throughput performance*** of a connected station as the signal is gradually faded out.
2. To understand the ***connection range*** of the tested wireless gateway device.

Typically, rate vs. range tests are run in a completely conductive (cabled-only) environment where the gateway's antenna sub-system is by-passed via a cabled solution. This methodology is inadequate when system integrators (ISPs) want to make these same types of measurements in an end-to-end environment with an integrated product that has a specific antenna sub-system.

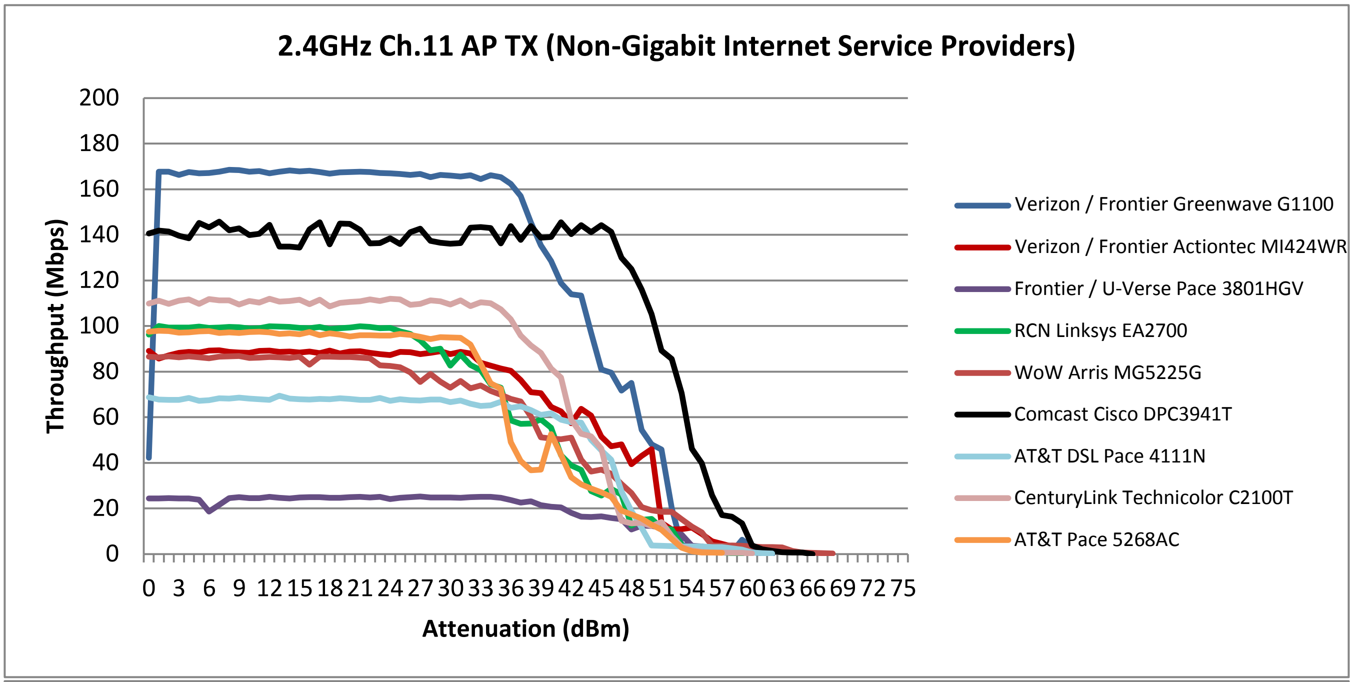
Allion leverages a unique solution that combines a large anechoic chamber (3m x 3m x 3.5m) coupled with inline programmable attenuation and butler matrix used to simulate the multi-path that is usually seen in an over-the-air environment.

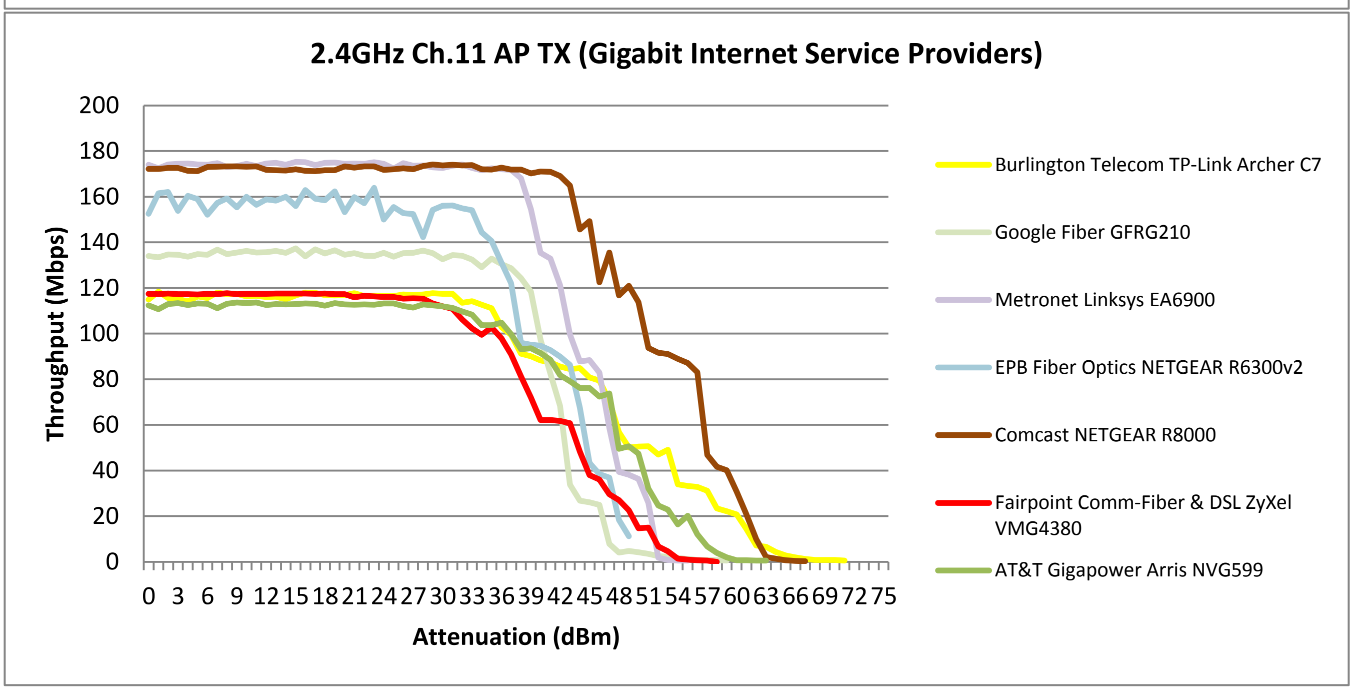


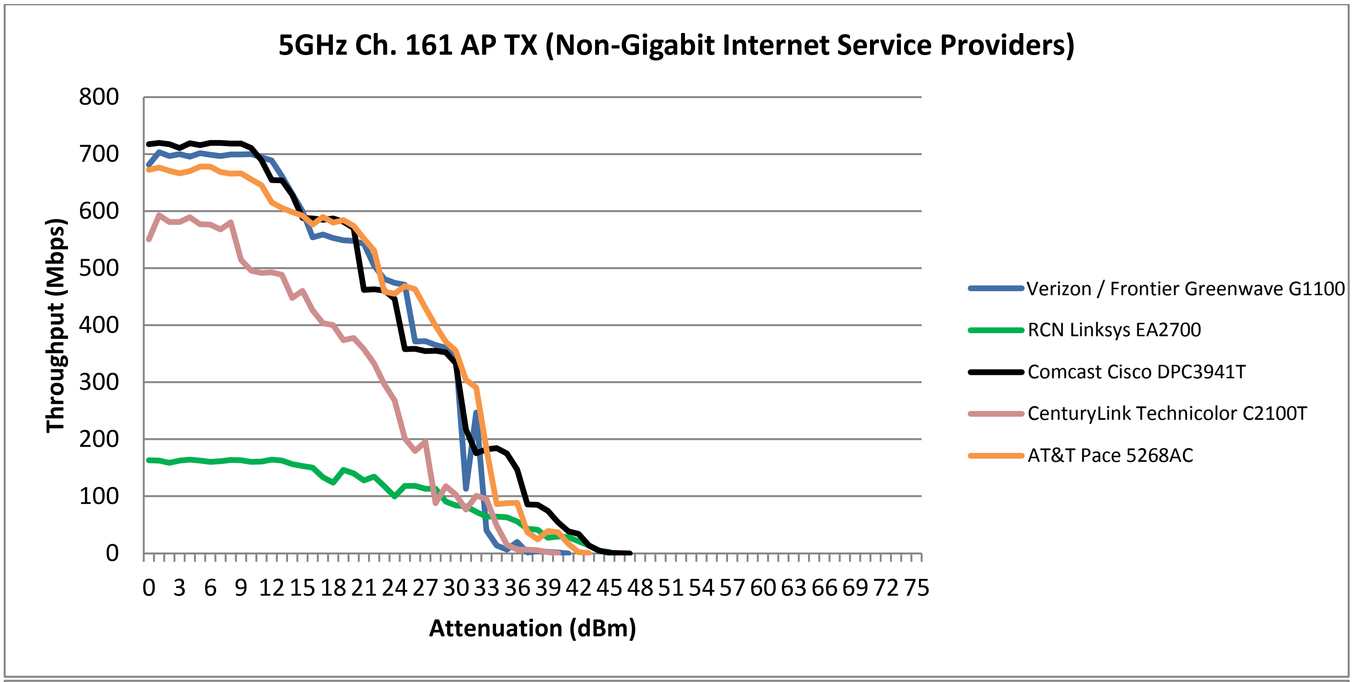
This environment provides the ability to test the performance of a wireless device in an ideal environment with consistent repeatable results, while at the same time keeping the Wireless Gateway intact as a final integrated solution.

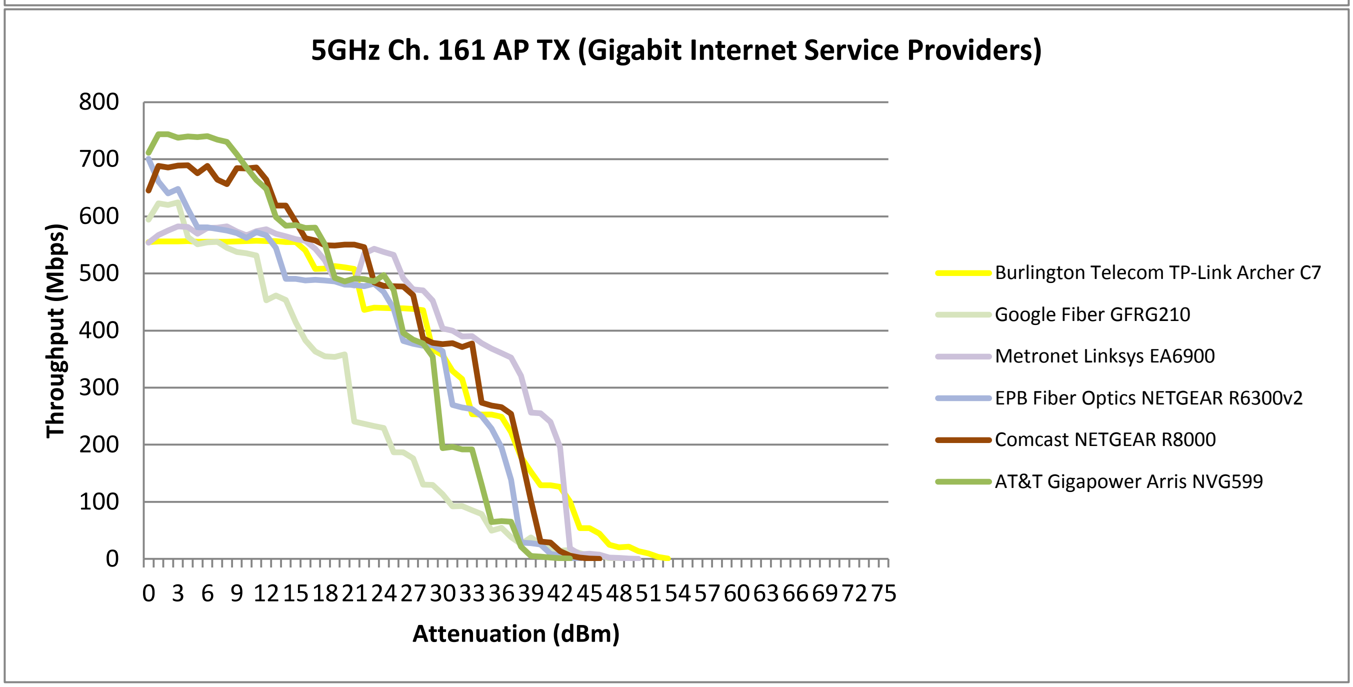
The throughput measurements taken at each attenuation step are based on TCP (Transmission Control Protocol) results using a 30 second throughput test using Iperf. Traffic direction is based on "client receive" throughput values at each attenuation point.

Below were the results from this study.



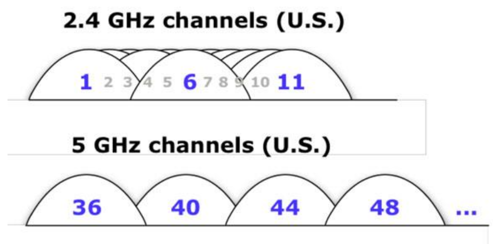






Range does NOT include the system path-loss of the test-bed

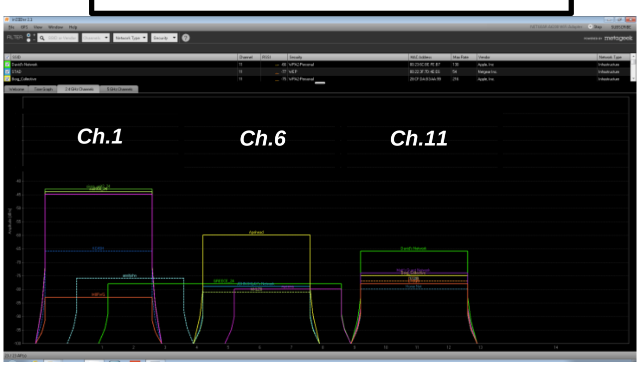
Dual-band Capability & 802.11ac



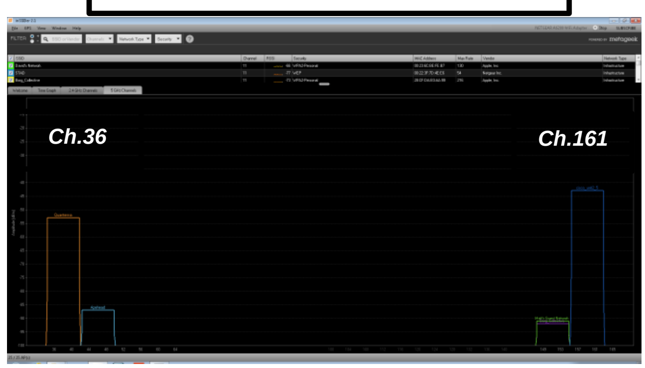
Wi-Fi can be deployed in 2 separate RF bands consisting of spectrum located in 2.4GHz and 5GHz spectrums. Many gateways operate solely on 2.4GHz because of the legacy Wi-Fi support of 802.11b and 802.11g, as well as the additional cost and complexity to design involved. Vendors have long avoided adding support for 5GHz. This line of reasoning is fast becoming an out of date strategy for ISP's providing gateways as a part of their deployment. In addition, the industry has recently expanded the 5GHz band with a new mode 802.11ac. This mode can support up to 160MHz of channel width - theoretically quadrupling the throughput compared to 40MHz 802.11n mode. Below is the outline of the major benefits of 5GHz operation:

1. Availability of 5GHz bands – more recent clients available in the market (i.e. iPhone 5/6, iPad Air, Kindle Fire HDX, various ultra-books, etc…) support 5GHz, and if a gateway could leverage this capability – it would allow the ability to off-load clients to an operating band that experiences significantly less interference with neighboring Wi-Fi networks. Below are Wi-Fi network examples of a typical home environment on both bands:

2.4GHz Home Environment



5GHz Home Environment



The image above shows that the 2.4GHz band not only has several APs across the entire spectrum, but a noticeable amount of RF noise generated due to the limited channels. On the other hand, the 5GHz band shows plenty of non-overlapping channels. The extra channels helps prevent RF interference, which results in a better end-user experience.

2. 20MHz vs. 40MHz channel width – with the introduction of 802.11n, the potential to widen the bandwidth of a certain connection was created by doubling the amount of channel width used for a single connection on a given Wi-Fi channel. Typical Wi-Fi channels operate on a 20MHz channel width, 802.11n allows the ability to double this channel width to 40MHz. However, this obvious advantage in bandwidth must also take into account overall available spectrum (2.4 GHz only has ~60 MHz of channel spectrum while 5GHz has over 600MHz available to utilize depending on the connection).
3. 802.11ac – the recently developed 802.11ac mode operates on the 5GHz spectrum which supports channel widths of 80MHz and 160MHz; theoretically doubling or quadrupling the throughput compared to 802.11n 40MHz mode. As many devices already support this mode and newer devices entering the market is expected to feature this option, 802.11ac may soon become the new norm in the near future.

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