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A Paradigm Shift in Benchmarking Wi−Fi™ Performance

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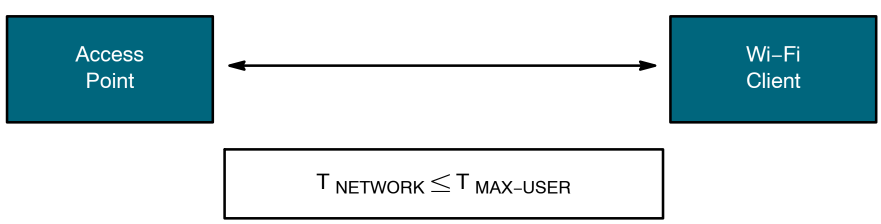
Abstract

Networks are not all created equal. It is essential for network operators and end users to be able to properly evaluate the performance of networks. However, as the networks evolve in their capabilities and usage models, testing and qualification methods must also evolve to accommodate this. This evolution has already taken place in mobile networks, and the same evolution is happening for Wi−Fi networks, while the benchmarking task for Wi−Fi networks is more challenging as these networks are ad−hoc and uncoordinated.

Earlier Wi−Fi Network Speed Testing

Not long ago, Wi−Fi networks were mostly single−band (at 2.4 GHz), utilizing single user protocols, meaning at each given time only one user occupied the airtime. Therefore, testing of network performance was straightforward: take a single Wi−Fi client device (typically a smartphone or a laptop) and measure the throughput between the Wi−Fi access point and that device. This would provide a good indication for the network throughput as measured at that location and at that instant. Normally a simple speed test would suffice. By using a state−of−the−art client and access point and measuring the throughput across many locations in the house as well as at different times, and averaging, it is possible to compute the "average network throughput" of this legacy network.



In these legacy Wi−Fi networks, consider two scenarios for doing speed test. In the first scenario, multiple devices are connected and are all simultaneously trying to do the speed test and in the second scenario, only a single device, the one with maximum throughput is connected and performing the speed test. The total aggregated throughput in first scenario will be definitely lower than the second one.

This is due to two reasons:

- Inefficiency of Wi−Fi MAC layer, and having to share airtime between multiple devices
- Devices may not be collocated and hence signal quality at the receivers would be different resulting in different data rates to the users

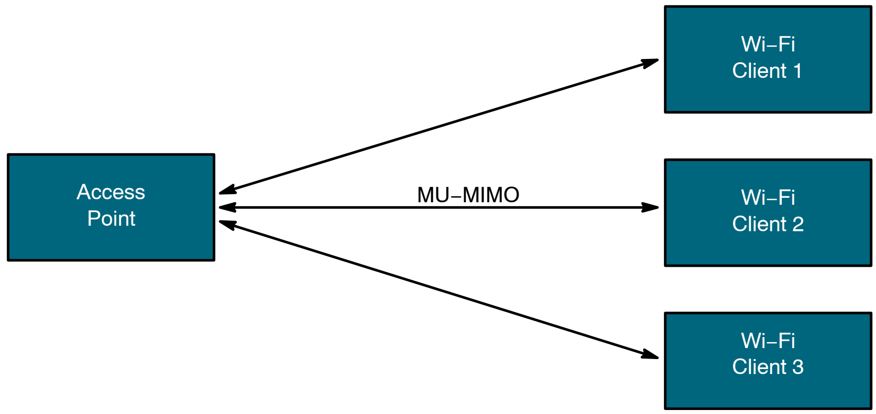
In other words, it could be easily concluded that *the maximum possible multi−user throughput* as measured by the sum of the throughput for multiple simultaneous users *will always be lower than the maximum possible throughput measured for a single user.*

A New Paradigm in Network Benchmarking

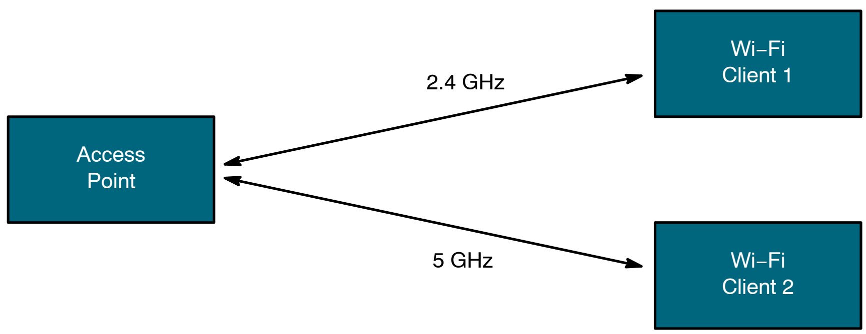
With the latest evolution of Wi−Fi networks, the paradigm has shifted, and the maximum network throughput will be greater than each individual throughput.

The introduction of multiple bands (2.4 GHz, 5 GHz, and in the future 6 GHz), then the introduction of advanced techniques such as MU−MIMO (Multi−User Multi−Input Multi−Output), Orthogonal Frequency division multiple access (OFDMA) and improved spatial reuse, has opened up the possibility for simultaneous transmissions from the access point to several devices. Sophisticated algorithms such as band steering are designed not only to manage the best performance for a single client but also to manage the overall network capacity. In that case, *the maximum possible network capacity* as measured by the sum of the throughput for multiple simultaneous users *will always be higher than the maximum possible throughput measured for a single user.*

The total network throughput ($T_{NETWORK}$) can now aggregate the throughput to the various devices, as illustrated below, first for the MU−MIMO case, then for multi−band.



$$T_{NETWORK} = T_{USER1} + T_{USER2} + T_{USER3}$$



$$T_{NETWORK} = T_{2.4G} + T_{5G}$$

As we can see, with these network evolutions, total network capacity will be higher than the highest individual throughput.

Those familiar with cellular networks know that this is how cellular networks are measured. While peak throughput to a given smartphone is important, but the total capacity provided by a cellular node is the most important metric for a carrier, considering the different bands/channels it operates, and the multiplexing factors provided by MU–MIMO or spatial reuse.

As Wi–Fi networks adopt some of the same technologies as cellular networks, it is needed for network testing to evolve and look at total capacity as well.

Why Network Capacity is a Key Metric

In a typical household, multiple devices run simultaneously with demanding applications (video streaming, online gaming, server uploads, etc.). To avoid bottleneck, the network must be properly dimensioned to support all of these. What really matters is having a high enough network capacity to run all of these at the same time.

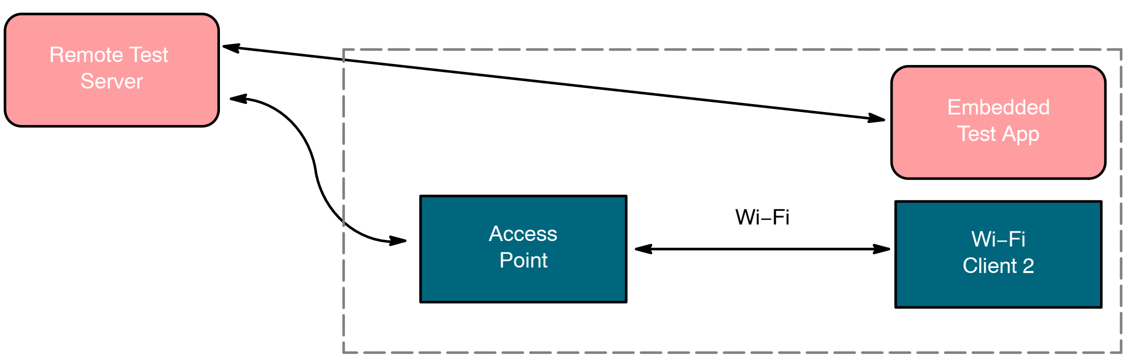
While peak individual throughput to a single client is important and must be high enough to allow each of these demanding applications to operate, network capacity, as defined by the total aggregated throughput to all devices, is the key metric for home internet quality, because it measures the capacity of the network to serve all applications running in the home at one given time.

The Bottleneck is not Always Wi−Fi

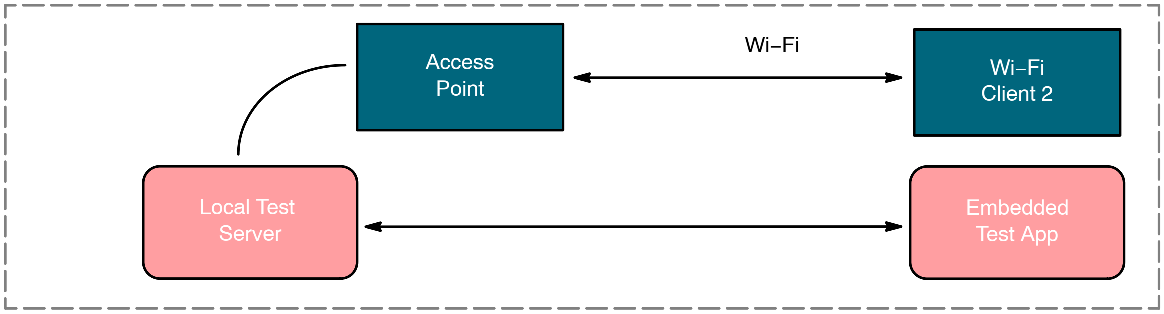
Furthermore, something else to consider in testing the performance of Wi−Fi networks is the impact of the broadband access speed. For prior generations of Wi−Fi (e.g. 11b/g/n), it was common that the broadband speed be greater than the speed of the Wi−Fi (especially with fiber access). Now that Wi−Fi has moved to 11ac (Wi−Fi 5), and 11ax (Wi−Fi 6), that provide multiple gigabits per second of peak throughput, it is nearly always the case that Wi−Fi speeds are higher than the broadband access.

Meanwhile, it must be noted that having a good Wi−Fi speed, higher than broadband, is becoming essential to allow for practical in−home networking, as well as to ensure the whole home coverage under interference.

In that case, testing Wi−Fi speeds using simple test apps (such as the popular speed test) will not be relevant, because the measured speed will be reflecting primarily the broadband speed and not the Wi−Fi speed, as illustrated in the figure below.



To properly isolate the Wi−Fi performance from the broadband speed, it is necessary to use a local test server attached to the access point, as illustrated below. Using traffic generation tools such as iPerf or Chariot to allow for accurate testing of Wi−Fi only traffic.



Conclusion

In legacy networks, the maximum network capacity was equal to the peak individual throughput of a given user, and therefore measuring that individual throughput was all that mattered.

The paradigm is now shifting thanks to the latest evolutions of Wi−Fi networks, and network capacity can be greater than the peak individual throughput. To properly evaluate the real performance of a Wi−Fi network it is important to look at total network throughput. Simple end user testing (using for instance the popular speed test app) will not be able to accurately reflect that total network capacity, and it is needed to adopt more sophisticated testing that provides true Wi−Fi testing and takes into account the full network utilization.

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