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# How will 5G compare to fiber, cable or DSL?

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With 5G now officially on the drawing boards, an obvious question is how will new wireless broadband networks perform compared to wireline alternatives such as fiber, coax or DSL? An even better question is what will these networks need to look like to provide sufficient broadband capability for a majority of customers, one that lets them cut the cord to their wired broadband connection if they so desire?

A good place to start is reviewing the various broadband offerings and their capabilities. Fiber-optic cable is the gold standard. Companies have demonstrated over 100,000 billion bps throughput over a single strand of fiber.

By comparison, even with an enormous 10 GHz wide radio channel and 10 bps/Hz of ultra-high spectral efficiency, spectrum-based networks could only reach 100 Gbps of theoretical throughput, 1,000 times lower than the fiber value. Plus, fiber cables consist of multiple fiber strands--if you run out of capacity on one strand, another one is right there. Coax cable, used for cable broadband, also only carries a small fraction of the capacity of a fiber optic cable.

Since it is not practical to extend fiber to every building, broadband architectures are pushing fiber as far out as is affordable, then completing the connection--whether the last mile or last one hundred yards--with technologies such as DSL, coax cable and wireless. Advances in wireless technology will make wireless increasingly competitive with coax and other wired approaches.

Realistically, most American customers don't need hundreds of gigabits per second of throughput for their broadband applications. Usage studies show that many people are satisfied with the 10 Mbps and higher that they get with their current LTE connections. And this throughput will continue to improve, even if not up to par with fiber. Given roughly a ten times throughput increase in network speeds every decade, 100 Mbps might be a reasonable target for 2020. Even 4K super HD only requires some 15 Mbps.

A more important factor when considering wireless as an alternative to wired broadband is capacity. Today, just a few, simultaneous 10 Mbps LTE connections can consume sector capacity in a 10 MHz LTE downlink radio channel--this is one reason that typical service plans for mobile broadband range from 1 to 10 Gigabytes each month. At a continuous throughput of 10 Mbps, a user can consume a Gbyte of data in 15 minutes. This is why mobile broadband network operators are so focused on increasing their network capacity, and various organizations (e.g., 4G Americas, are calling for a 1000X capacity increase.)

To increase capacity per user, the wireless network needs to both increase the capacity of the radio connection and reduce the number of users on that channel--in mathematical terms, combine a higher numerator, the capacity, with a low denominator, the number of people.

The numerator is easy. Operators need more spectrum and will need to continue deploying spectrally efficient radio technologies. The big question is where will more spectrum come from?  The biggest swathes of contiguous spectrum suited for expanding capacity reside in the multi-GHz range, which is available in higher bands, beginning above 10 GHz and especially in mmWave frequencies (30 GHz to 300 GHz).

But there is a challenge deploying super-high frequency spectrum: High frequencies have shorter ranges and don't penetrate walls and other obstructions well. Advanced beamforming will help resolve both issues, but the mmWave frequencies under consideration for 5G will be best suited for small cells.

Not only do the high frequencies augment capacity in the numerator, but the small cells mean fewer people in each coverage area. The higher capacity value in the numerator combined with the lower number of people in the denominator results in much higher capacity per person.

A side benefit of mmWave technology development is that the technology will also be applicable to backhaul connectivity, currently a major small-cell challenge.

To understand what capacity and capability a hypothetical next-generation network might have, consider being able to use 5 GHz of spectrum (compared to 500 MHz of licensed mobile spectrum today) and obtaining 4 bps/Hz of spectral efficiency from advanced smart antennas (twice that of LTE-Advanced). These values multiply to an impressive 20 Gbps of capacity. This much capacity in a small-cell coverage area would support 200 simultaneous users at 100 Mbps, and would be competitive with wireline alternatives.

The industry is already focused on exploiting more spectrum, enhancing smart antennas, and deploying small cells. What differs in the network of the future, likely available beginning five years from now, is the extreme application of these items.

Wireless can be a competitive form of broadband for many people. Maybe someday in the distant future fiber will extend to every house or building, but until then, it only needs to come close enough for wireless to do the rest.

*See this infographic for a visual representation of the network of the future.*

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