Rethinking 5G Microcell Backhaul to Deliver Superior Customer Experiences

Kumu Networks – White Paper

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Data traffic on mobile networks is growing by leaps and bounds. The continued success of mobile phone networks depends on the industry's ability to deliver the capacity to meet tomorrow's demand. Backhaul links from new 5G microcells to the network backbone are a critical component because they must carry the aggregate traffic for multiple high-speed users. This white paper describes how to ensure affordable, high-performance backhaul links for every 5G microcell.

Not all backhaul solutions are up to the challenge. Fiber optic cable is in one way an ideal solution. A single fiber strand has 1,000 times the bandwidth of the entire usable radio spectrum. Unfortunately, the use of fiber is often not practical due to prohibitive installation costs and the time required to obtain permits and complete construction. Wireless backhaul using millimeter wave spectrum has sufficient capacity, is potentially less expensive, and can be deployed quickly. This is why Integrated Access and Backhaul (IAB), the use of new millimeter wave spectrum for both 5G access and backhaul, is being incorporated in the 5G standards. However, not all IAB solutions are equal: some entail significant performance or cost trade-offs.

Kumu Networks' Self-Interference Cancellation (SIC) technology is the only solution that completely and simultaneously reuses the access spectrum for backhaul, enabling true "self-backhaul" and increasing network capacity. Unlike other IAB schemes, Kumu Networks' solution does not compromise performance by dividing the 5G microcell's wireless capacity between access and backhaul, and avoids using twice the spectrum resources at twice the price.

Background: Backhaul is a Wireless Network's Achilles' Heel

Backhaul has become a challenge for mobile phone networks. In early generation cellular networks, backhaul links handling the aggregate traffic for dozens of mobile users could be provided using digital phone lines, microwave radio links, or fiber optic links when they happened to be available. However, with today's high-speed 4G and 5G mobile networks, digital phone lines and microwave radio links are no longer adequate. Much higher performance backhaul links are needed.

Since the introduction of the iPhone in 2007, wireless network traffic has been growing at breakneck speed. To meet future demand, the Federal Communications Commission (FCC) is allocating vast swathes of spectrum in the millimeter wave region for 5G, and operators are densifying their networks by adding thousands of microcells.

Small cells are undoubtably the wave of the future. They are less obtrusive, less expensive, and easier to deploy than traditional tower-based macrocells. Small cells not only improve coverage (both indoors and outdoors), they multiply capacity in busy urban and suburban locations.

The increase in spectrum being made available for 5G is unprecedented. Up until mid-2016 a total of roughly 750 MHz of bandwidth was available for use by US mobile phone operators. In July of 2016, the FCC allocated an additional 3.85 GHz of spectrum in the 20 and 30 GHz bands for 5G. That single action increased the total spectrum available to US mobile operators by over 500%. Mobile phone operators are also eyeing spectrum in the 3.5 GHz band for rural densification, and some operators are looking at unlicensed spectrum in the 57-71 GHz range to supplement their licensed spectrum.

Use of millimeter wave frequencies is not without its challenges, however. At millimeter wave frequencies, signals travel shorter distances and are easily blocked by objects. Consequently, 5G microcells are expected to be spaced just 100-200 meters apart, with each cell requiring its own backhaul link. The Small Cell Forum predicts that by 2025, more than 12 million 5G small cells will be deployed worldwide.[1]

User devices supporting higher speeds will make applications such as 4K Ultra-High Definition and Virtual Reality possible. However, providing adequate backhaul capacity will be a challenge. According to CTIA, a trade group representing the US mobile phone industry, annual wireless data traffic increased from 0.4 terabytes in 2010 to 15.7 terabytes in 2017.[2] That's nearly a forty-fold increase. With wireless data traffic quadrupling every 2-3 years, operators need backhaul links that can keep pace with torrid growth.

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While fiber backhaul is clearly up to the task capacity-wise, wireless backhaul must take maximum advantage of the available bandwidth. Insufficient backhaul capacity means lower average throughput and greater latency. That, in turn, means poorer customer experiences.

An outdoor, underground fiber run typically costs about $25 - $50 per foot. However, that assumes a straight shot. Running fiber under streets or parking lots, or around buildings, adds considerable expense. The cost of a wireless backhaul link using 5G millimeter wave spectrum will generally be limited to the radios and antennas. Consequently, a fiber backhaul link can easily cost two, three or more times as much as a millimeter wave wireless backhaul link.

The majority of anticipated 5G microcell sites do not currently have access to fiber. While telco and cable operators are extending fiber deeper into their

[1] Figure 5-2 New deployments and upgrades of 5G or multimode 4G/5G small cells, indoor vs outdoor, 2019-25, https://scf.io/en/documents/050_-_Small_cells_market_status_report_February_2018.php

[2] https://www.ctia.org/the-wireless-industry/infographics-library

networks, many microcells will still not have fiber access for the foreseeable future. Plus, at millimeter wave frequencies equipment and antennas are smaller and less conspicuous, meaning that 5G microcells can be deployed in locations that are hard-to-reach with fiber, such as parking lot lighting poles.

The Integrated Access and Backhaul (IAB) Vision

IAB was conceived to exploit the millimeter wave spectrum's relatively abundant bandwidth to provide both access and high-capacity backhaul. Ideally, the same spectrum is used for both purposes, enabling self-backhaul for 5G microcells, ensuring that backhaul capacity is closely matched to access capacity, and increasing total network capacity.

The 3rd Generation Partnership Project (3GPP), the organization setting 5G standards, is incorporating IAB in Release 16 of its specifications, targeted for completion by mid-2020.

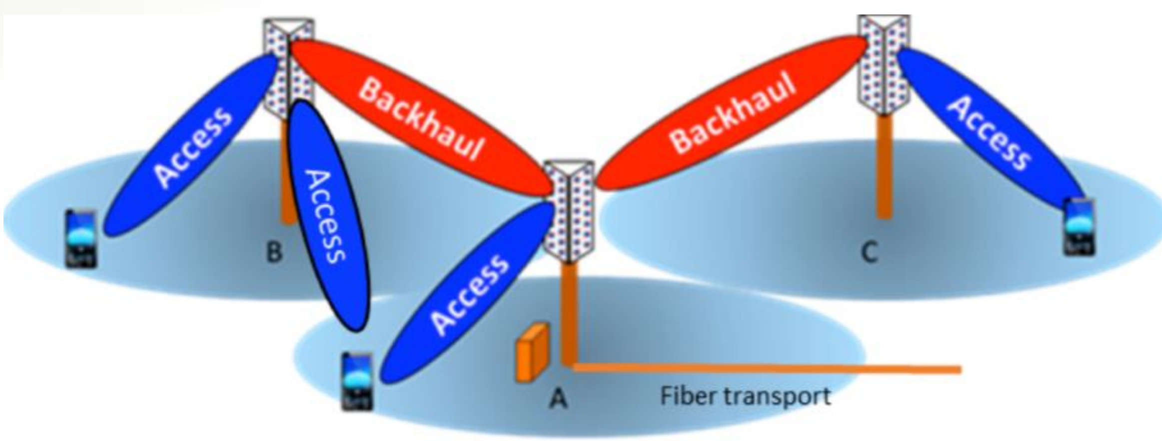

Figure 1, Integrated Access and Backhaul (IAB) uses new millimeter wave spectrum for both 5G access and high-performance backhaul.

IAB has additional advantages. While a fiber run typically requires time for obtaining permits and completing construction, IAB can usually be deployed much faster. Therefore, IAB is perfect for temporary uses such as disaster recovery, special events, and providing immediate relief to locations awaiting the construction of additional permanent capacity.

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However, the first IAB solutions proposed involve significant performance and cost tradeoffs. One approach is to time-share a single wideband channel. Access and backhaul each get about 50% of the channel capacity--minus some extra protocol overhead to manage sharing. The need to switch back-and-forth between access and backhaul also increases latency. Applications that require low latency, such as gaming and virtual reality, may no longer enjoy the responsiveness promised by 5G.

A second approach is to use separate frequency bands for access and backhaul. This solution really isn't "integrated" because it doesn't use the spectrum assigned to the microcell for both access and backhaul. Using separate channels may ensure high capacity and low latency, but it requires allocating twice as much valuable spectrum to each microcell. Given the high cost of spectrum--particularly spectrum acquired in auctions--consuming two licensed channels per microcell is likely to change the return on investment analysis, making it harder for operators to achieve profitability.

Kumu Networks' Self-Interference Cancellation Technology

The fundamental challenge for IAB is that self-interference prevents the backhaul and access links from using the exact same channel at the exact same time. Kumu Networks' Self-Interference Cancellation technology solves this problem, enabling 5G microcells to provide self-backhaul with a truly integrated approach to access and backhaul.

Self-interference cancellation technology was originally developed at Stanford University to enable "in-band full duplex" radios capable of transmitting and receiving on the exact same frequency at the exact same time. If radios could operate full-duplex on individual channels, it would effectively double the capacity of the radio spectrum. At first, it seemed like the development of such radios would be straightforward, because the transmitter knows in advance what it is going to transmit. However, it was soon discovered that the transmit signal appearing at a nearby receiver is the product of unpredictable noise and distortion (caused by the transmitter's circuitry) and reflections (caused by the local environment). Kumu Networks invented algorithms to track and compensate for the noise, distortion, and reflections, cancelling strong local signals down to or even below the noise floor, creating the first practical and effective self-interference cancellation solution.

Kumu Networks' technology is a particularly powerful solution for IAB. Self-interference cancellation enables the access radio's transmit signal to be cancelled out at the backhaul radio's receiver, and enables the backhaul radio's transmit signal to be cancelled out at the access radio's receiver. Consequently, the local backhaul radio can receive signals from the remote backhaul radio even as the local access radio is talking to nearby users, and the microcell's access radio can receive signals from local users even as the microcell's backhaul radio is talking to its remote counterpart. The use of separate, directional antennas (for backhaul) and beamforming (for access) helps to ensure that self-interference is completely eliminated, and that the same channel used for access can be reused for backhaul with no degradation in performance. In practice, IAB based on Kumu's self-interference cancellation technology rivals the performance of a fiber link.

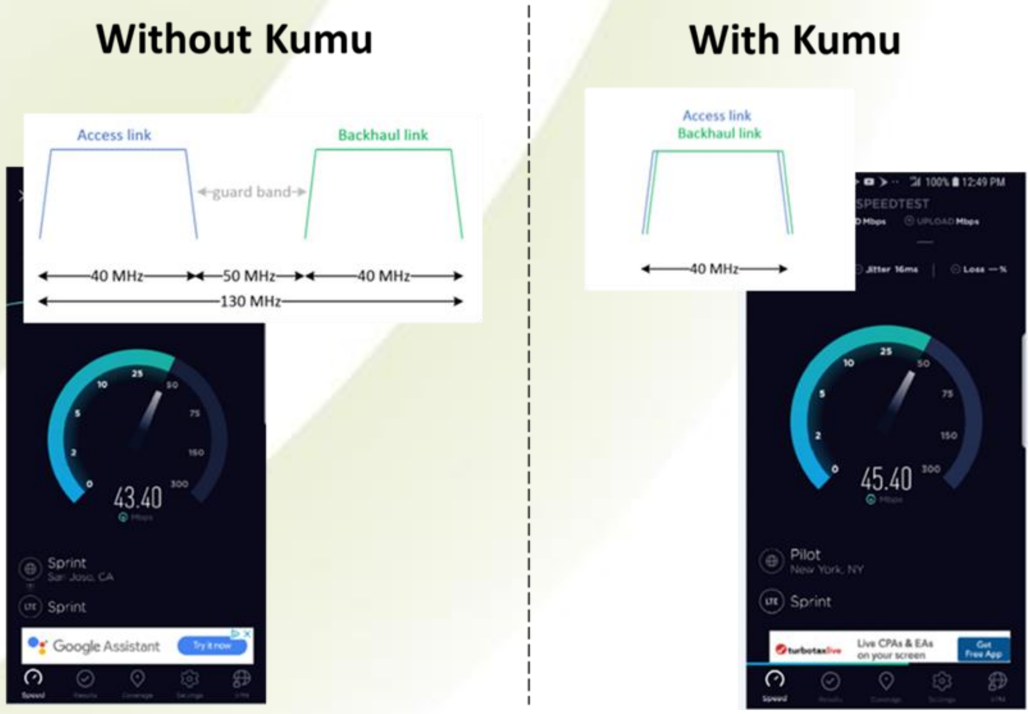

Figure 2, Kumu Networks' technology enables operators to use the exact same spectrum for access and backhaul without sacrificing performance.

In fact, an enhanced version of IAB with full duplex capability as described above is likely to be included in Rel. 17 of the 5G standard.

Kumu Networks' IAB solution is realized as an all-digital design that easily integrates with wireless infrastructure equipment. And only Kumu Networks' technology provides a high-performance IAB solution that is consistent with the capacity, throughput, latency, and user experience promised by 5G.

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While IAB is a new application, Kumu Network's SIC technology is not new. It is a field-proven, commercially-deployed solution for a closely related application: LTE Relay Node. Many LTE macrocells ("LTE" is the 4G standard) suffer from limited or inadequate coverage near the cell edges. The simplest way to solve the problem without generating additional, harmful noise is to deploy LTE Relay Nodes in areas with unsatisfactory coverage. A relay must be able to "repeat" the signals from mobile users in poor coverage to the macrocell, and from the macrocell back to the mobile users. As with IAB, the exact same spectrum is used both for local access and to relay the signals to and from the macrocell. Kumu Networks' SIC technology isolates each side of the relay node from the other, so that the access signals don't interfere with the backhaul signals--and vice-versa.

Figure 3, Kumu Networks' technology is commercially-deployed by Tier-1 operators in demanding LTE Relay Node applications.

By enabling 5G microcells to reuse their millimeter wave spectrum for access and backhaul, Kumu Network's Self-Interference Cancellation technology doubles the capacity of each microcell's millimeter wave spectrum, significantly increasing the total capacity of the operator's network.

Summary

Integrated Access and Backhaul is a great idea--provided that it doesn't take away with one hand what it gives with the other. The ideal IAB solution is truly integrated, enabling 5G microcells to provide self-backhaul using the same spectrum allocated for mobile and fixed user access.

Kumu Networks' patented Self-Interference-Cancellation technology provides a flexible, easy to deploy, low-cost way for operators to increase capacity and coverage with 5G microcells. It offers the only truly integrated solution that bundles microcell functionality with backhaul functionality. The solution is available in digital IP format for use by the operator's preferred system vendor.

For more information, please contact

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Thank You!