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Five Technologies for Understanding Outdoor Small Cell Backhaul Networks

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Currently, pilot small cell networks are being deployed, with the first mass rollouts just now being planned. A critical component to these networks that needs to be addressed is backhaul, which changes dramatically from traditional networks due to street level deployments and a prioritization on radio aesthetics, size and power. It's clear that, in contrast to traditional mobile backhaul networks, future small cell backhaul networks will be hybrid in nature and require a mix of technologies. This article looks at 5 of the most important technologies that need to be considered when planning an outdoor small cell backhaul network:

1. Fiber Backhaul - Fiber Backhaul is typically the first choice for outdoor small cell backhaul. However, it is limited by the business case and availability. Fiber brings benefits by eliminating line of sight concerns, so that connectivity can be provided even in urban canyons, behind buildings or under tree cover. Fiber also provides close to unlimited capacity for future scale. However, for small cell deployments, the issue with fiber is that it will often not be available at the urban furniture sites (such as lamp poles, traffic lights, and bus stops) where small cells are installed. While fiber may often be nearby, such as across the street or half a block away, trenching it the last few feet can be very costly and take a long time, as right of ways, permits, and even street closures will be required. The cost and time to extend fiber for many locations often rule it out as an option, but depends very much on the market and the operator. In some

cases, fiber may be available at up to 80% of the sites, but in other markets it may only be viable at 10% of the sites.

2. Wireless Non line of sight (NLOS) equipment - The next option for outdoor small cell backhaul is often non-line of sight wireless equipment. This is equipment that uses sub-6 Ghz bands. There are a few different options in this spectrum range. There are licensed options in the 2.5 and 3.5GHz bands. In most markets, an operator often already owns these area licenses. The issue with these bands is that there is limited spectrum, typically only 20 MHz, which severely limits backhaul capacity. What's more, this access spectrum is very expensive, so operators are reluctant to use it for backhaul. In 5.8 GHz, there is much more spectrum, roughly 180 MHz, with 40 MHz channels often available. This makes 5.8GHz the most commonly used sub-6 GHz band, but there are still many challenges with this band. Because it is an unlicensed band, there is often interference from consumer devices, making a system unreliable and often reducing throughput. And, in order to combat interference and enable line of sight, TDD systems are typically used, which can cause system latencies of 1-3 ms, so that only a single link can be used for LTE advanced. In addition, even with 40 MHz, the capacity is limited to about 150 Mbps full duplex, and can be further reduced if there is line of sight blockage or interference. There are, however, a number of factors that make this spectrum very attractive. The global availability of this spectrum makes it a broadly useable band. This spectrum is also very suitable for near and no line of sight connectivity. This is often very valuable for outdoor small cells, where there may be building blockage, trees, or other street level clutter impacting a path. In addition to these factors, 5.8 GHz equipment can reuse very high volume components to enable very low cost backhaul systems, which can be critical for the small cell business case.

3. Microwave Backhaul Equipment - Where line of sight is not available, or higher capacities are required or secured licensed spectrum is needed, licensed microwave backhaul is a good option for small cells. In order to be viable for small cell backhaul, small antennas (<8") are required, and this is typically only permitted in 24-42 GHz bands. However, the permitted use of these bands varies widely by country, although in many countries some spectrum is available in these bands as area licenses (24, 26, 28, 31, 38, 42 GHz). The use of area licenses permits a wide scale deployment without the need for individual link licensing. The 24-42 GHz wireless systems are desirable, as they can provide much higher capacities, typically 500Mbps to 1 Gbps full duplex. In addition, line of sight and licensed spectrum allows links to be engineered with confidence, delivering high link reliability. The licensed microwave spectrum is FDD spectrum, which allows very low latencies to be delivered, typically below .2ms. This can be critical when there is a daisy chain of links, and delay sensitive services such as Advanced LTE.

4. E-Band Backhaul Equipment – The 70/80 GHz or E-Band spectrum is newer spectrum that is quite suitable for small cell backhaul. While this spectrum is not yet released in all countries, it is generally available in most parts of the world. A major benefit of this spectrum is that it is usually available to any user, and the spectrum license cost is quite low compared to

microwave spectrum. There is also a vast amount of E-Band Spectrum (>10GHz), so operators can get very large channels (250MHz-1GHz), and as a result can transport high capacities from 1-10 Gbps. In most countries outside of the United States (where there are current efforts to loosen regulations), small antennas are permitted in the E-Band spectrum, making the band suitable for small cell deployments. FDD or TDD is permitted in E-Band, and when combined with the very wide channels and high capacities, low delays below .2 ms can be achieved in the band. The common knock with the E-Band spectrum has been its limited reach due to a high amount of rain attenuation. However, distances with small antennas of .5 to 1Km are quite achievable and very suitable for small cell applications. The E-Band equipment does require Line of sight for connectivity, and has a fairly narrow beamwidth. This makes alignment a bit more complex, as well as perhaps limiting the type of structures suitable for E-Band equipment, as there will need to be limited sway to ensure stable links.

5. V-Band Backhaul Equipment – The 60 GHz, or V-Band, spectrum is also newer spectrum that is very suitable for small cell backhaul. This spectrum is especially attractive, as it's nearly globally available and unlicensed in most countries. Additionally, small antennas (<6") are permitted in this band. This makes for quick deployments and ensures that operators have a broadly deployable spectrum option. Although V-Band is unlicensed, currently there is not much interference concerns in the band, because the V-Band spectrum is also very wide, with about 10GHz of spectrum available. And, V-Band beamwidth is narrow, and when coupled with high attenuation in this band, it results in the signal not traveling far beyond the desired receiver. Due to the high oxygen absorption in this spectrum, link lengths are typically limited to .5Km with small antennas, although this is still quite suitable for the small cell backhaul application space. TDD and FDD are permitted in this band, enabling a number of technology options, including low delay alternatives. With the large amount of spectrum available, 250 and 500 MHz channels can be used to enable links with multi-gigabit capacities. One important V-Band consideration that adds value, but also has negative consequences, is that it is being opened for usage by consumer devices with the WiGig standard. With a risk that many more devices will be using the spectrum, the potential for interference is higher. However, the risk is mitigated by the wide spectrum and WiGig being targeted for in home, ground level usage,

and, directional antennas being used for backhaul should provide good isolation from potential interferers. The benefit to small cell backhaul of the WIGig standard is that it will result in very high volume components and technologies being built in this spectrum that can be reused for backhaul. This will help improve the cost points for 60GHz backhaul equipment in the future and enable new features – the development of electronically steerable antennas as an example. This technology could be extremely valuable for small cells, as it could drastically reduce installation times and enable single person installs while also allowing networks to easily reconfigure during failures, or path blockage.

Comparing the Technologies

Unfortunately, for outdoor small cell backhaul networks, there is not a single technology that can be used at 100% of small cell sites. Although fiber would be desirable at all sites, it is impractical and uneconomical to have it at every lamp pole and traffic light. That said, when fiber is available it will likely be used. When fiber isn't an option, operators can draw upon the 4 other aforementioned technologies, knowing that no one choice will be suitable for all wireless sites. There will be a mix of technologies used depending on the site requirements. For example, at an end point, with low capacity and no line tree blockage in the path, a wireless NLOS system is suitable, but for a link carrying multiple sites, an E-Band or V-Band link will be required due to capacity. A summary of the key characteristics of these technologies is shown in the table below.

	Fiber Backhaul	Wireless NLOS equipment	Microwave Backhaul Equipment	E-Band Backhaul Equipment	V-Band Backhaul Equipment
Capacity	Terabits	~150 Mbps	500Mbps-1Gbps	1-10 Gbps	1-10 Gbps
Time to Deploy	~1 Year	Days	Month	Days	Days
Install+Equipment Cost	High	Low	Low-Medium	Low-Medium	Low-Medium
Potential for Interference	N/A	High	Low	Low	Medium

	Fiber Backhaul	Wireless NLOS equipment	Microwave Backhaul Equipment	E-Band Backhaul Equipment	V-Band Backhaul Equipment
Range	N/A	>1Km	>1 Km	500M-1Km	300-500M
Non-Line of Sight Capability	N/A	Some	No	No	No
Spectrum Type	N/A	Unlicensed, or narrow access spectrum	Area Licensed	Light, low cost license	Unlicensed
One-Way Delay	<.1ms	2-5ms	.1ms	.1-1ms	.1-1ms

Clearly, the small cell challenge is a formidable one, where operators are tasked with deploying huge volumes of sites in a short period of time, and needing to do so at the lowest possible cost per site in order to achieve a viable business case. The avenue to success will not require the selection of a single, all-encompassing technology, but rather the adoption of flexible processes that allow for a mix of technologies. That approach, coupled with an enhanced understanding of the deployment environment, which will be much more dynamic and unpredictable at street level than what's previously been addressed at the tower, will see a dynamic changing of network architecture to meet growing capacity demands today and for the future.

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