White Paper

The Advantages of E-Band Wireless Systems in Mobile Backhaul Applications

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Executive Summary

To meet growing subscriber demand, mobile operators are constantly seeking additional network capacity to enable the delivery of bandwidth-intensive data services. Nowhere are these challenges felt more acutely than in the backhaul network. Understanding the advantages, operators are migrating to all-Ethernet/IP backhaul networks. However, “traditional” packet-based backhaul transport suffers from a number of inherent limitations. In places where there is fiber coverage, fiber can provide the required capacity and more. However, fiber reach is often limited, and deploying new fiber links is often prohibitively expensive. Copper has limited capacity and reach, and “traditional” microwave links suffer from spectrum congestion and limited channel size.

Today, as the demand for bandwidth increases daily, operators who rely on wireless backhaul are turning to new frequency spectrums to lower their wireless backhaul costs. Wireless systems operating in the newly-allocated E-Band spectrum (71-76 GHz, 81-86 GHz and 92-95 GHz) - also referred to as millimeter-wave wireless systems - have clear technological and economic advantages. As such, the E-Band spectrum is expected to become the *“Next Generation Wireless Backhaul Spectrum”* playing an important role in easing the backhaul pain of mobile operators.

The Mobile Backhaul Challenge

The introduction of broadband cellular technologies such as HSPA, LTE and WiMAX - which provide users with DSL-like and higher data speeds at flat-rate pricing models - is changing consumer mobile phone usage habits, making mobile web browsing and emailing routine. This changing user behavior generates huge amounts of data, leading to an explosion in bandwidth demands as data traffic doubles and even triples. This data explosion places an ever-increasing strain on operators' mobile backhaul networks.

The mobile backhaul network is commonly referred to as the transport links, which connect cell sites (Base Stations, Node B, eNodeB) with the core switching and management elements (as can be seen in Figure 1). Traffic, both voice and data, is transported to and from the cell sites via the backhaul network, delivering the required services with high reliability and availability.

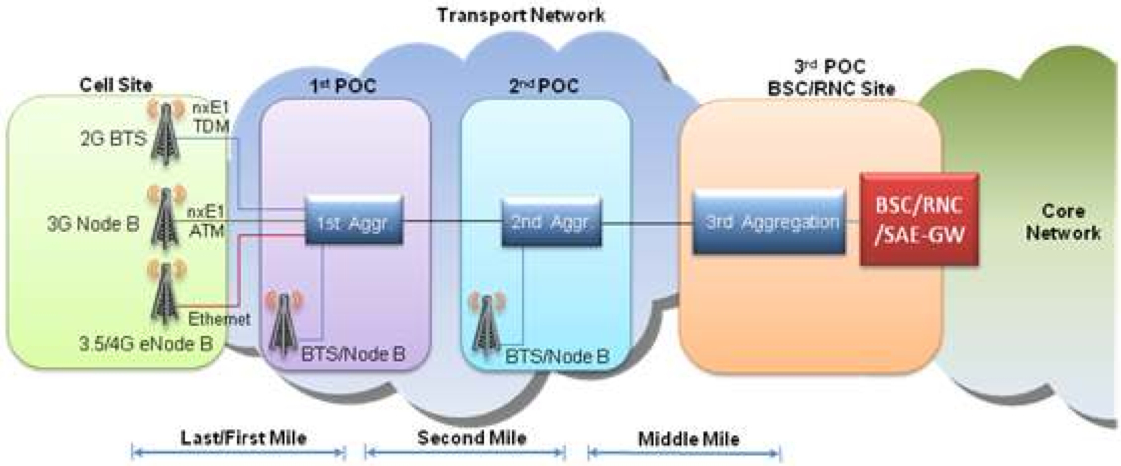

Figure 1 – a snapshot of the mobile backhaul network

In today's cellular networks, the backhaul network is mostly comprised of copper-based E1/T1 circuits, and "traditional" TDM-based 6-38 GHz microwave links. Deterministic transport technologies, such as PDH and SDH, do not scale efficiently and thus do not provide a cost-efficient solution for the dramatic increase in backhaul capacity demands. If mobile operators continue using "traditional" TDM-based backhaul technologies, service quality for both voice and data applications will at some point suffer - as the incremental addition of more TDM-based bandwidth is economically unjustifiable.

Increasing the capacity by adding more E1/T1 or TDM links is certainly technically feasible. However, it is extremely costly, inefficient and often too time-consuming to meet immediate bandwidth needs. Operators are seeking new and different solutions - based on a more scalable, flexible and economically suitable technology - to upgrade their backhaul network. The technology chosen must be able to deliver a substantial change in the economics of scale, as backhaul capacity demand will grow to hundreds of Megabits-per-second, and even Gigabits-per-second.

It is commonly accepted by the worldwide mobile operator community that Carrier Ethernet technology holds the technological answers to reducing mobile backhaul network Total Cost of Ownership (TCO), while still providing the necessary bandwidth to meet current and future demands. By introducing lower-cost Ethernet links into the backhaul network, operators are enjoying lower OpEx and CapEx.

The Solution: Ethernet/IP-Based Backhaul

The key to coping with the bandwidth explosion in the mobile backhaul network is adoption of a more scalable, flexible and cost-efficient backhaul technology. Ethernet/IP has emerged as the leading technology for metro networks in general, and wholesale services in particular. In the backhaul, Ethernet allows operators to quickly scale bandwidth on a pay-as-you-use basis, reaching Gigabit-per-second capacities without major infrastructure changes.

Understanding this, mobile operators worldwide have started to migrate to all-packet-based networks - starting by implementing Ethernet/IP/MPLS technologies in their core networks. However, to get the most out of packet technology, mobile operators must also introduce this technology in the backhaul segment.

Mobile operators have three main strategic options to evolve backhaul networks to an all packet-based infrastructure, as depicted in Figure 2:

1. ***"Traditional"*** - Continue using "traditional", E1/T1 and TDM-based backhaul infrastructure, make efforts to optimize the network and introduce packet-based infrastructure in the future, when they feel confident with the technology.
2. ***"Hybrid"*** - Adopt a hybrid backhaul infrastructure that utilizes "traditional", TDM-based backhaul for voice traffic, while offloading data traffic to a separate packet backhaul network, which will eventually carry all combined traffic.
3. ***"All-Packet"*** – Implement and utilize an all packet backhaul infrastructure directly, enjoying the capacity and cost advantages that Ethernet technology has to offer immediately.

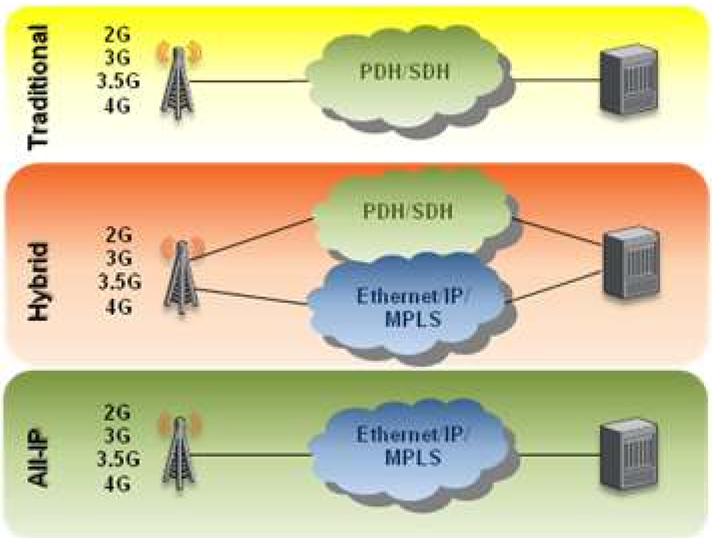

Figure 2 – evolving to an all-Ethernet/IP network

Evolving to an all Ethernet/IP backhaul network also has its challenges:

1. ***Carrier grade capabilities*** – as the leading technology in carrier networks, Ethernet needs to provide mobile operators with carrier grade capabilities that meet the rigorous support and management demands of multiple service types, Quality of Service (QoS), service prioritization, reliability, and advanced Operation, Administration & Operation (OAM) and management capabilities.

2. ***Supporting existing legacy services*** - TDM services and packet services are expected to continue coexisting in the same network for quite some time. Using Pseudowire Emulation Edge to Edge (PWE3) and other encapsulating technologies, TDM-based legacy voice services can be reliably transported using the Ethernet/IP backhaul network.
3. ***Providing synchronization over the packet-based network*** - Mobile networks are highly dependent on clock and timing information transfer to synchronize. With the introduction of packet-based backhaul, new synchronization technologies such as IEEE 1588v2 and Synchronous Ethernet have come into play, providing clock and timing information.

Mobile Backhaul Alternatives

Not long ago, when mobile services involved mostly voice, backhaul bandwidth required for cell sites was just a few Mbps. Copper-based E1/T1 and PDH/SDH microwave backhaul links were sufficient for transporting these services. However, with the introduction of 3G mobile networks, and as mobile broadband data services became more popular, these links are no longer able to scale up and provide the necessary bandwidth at reasonable costs. Operators are thus migrating to Ethernet-based transport solutions - whether xDSL over copper, Ethernet and Hybrid microwave or fiber optic.

As backhaul capacity requirements are expected to continue growing, particularly with the introduction of 4G mobile networks, mobile operators are left with few relevant options for the backhaul network (as depicted in Figure 3):

1. Copper – VDSL/VDSL2 may be able to provide the necessary bandwidth. However, it offers limited reach (tens of meters) and therefore may not be relevant.
2. Fiber optic – fiber can provide all the necessary backhaul bandwidth both today and in the future. However, fiber is not always readily available, and new fiber links are often prohibitively expensive to deploy - costing from $2,500 to $10,000 per meter, due to the high costs of excavation, trenching and rights of way.

3. Ethernet/IP Wireless systems – can provide backhaul links to cell sites that are either out of reach of fiber deployments, and in cases where new fiber deployments are not cost effective.

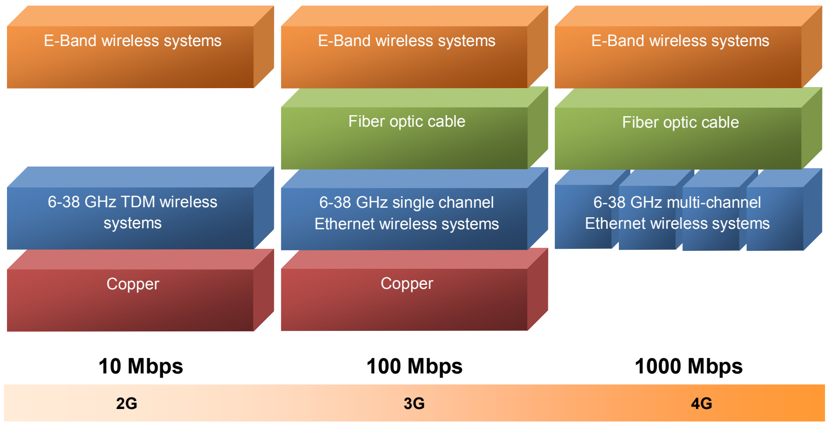

Figure 3 – transport options to provide cell site backhaul capacity

Today's wireless backhaul is comprised of PDH/SDH links operating in the "traditional" 6-38 GHz frequency spectrum. Understanding the advantages of Ethernet/IP transport technologies, mobile operators are introducing Ethernet/IP-based wireless links which also operate in the "traditional" 6-38 GHz frequency spectrum. Due to this extremely high demand, the 6-38 GHz frequency spectrum is becoming increasingly congested, particularly in dense urban areas where the increased backhaul capacity is particularly important. Furthermore, the maximum allocated channel bandwidth in this frequency spectrum does not exceed 56 MHz, and even with high-order modulation schemes such as 256 QAM, the maximum link capacity of such systems does not exceed 350-500 Mbps. As operators require greater capacity, these systems will need to utilize multiple radios - leading to higher equipment costs, higher frequency licensing costs, and even more congestion of the spectrum.

Operators worldwide are looking for new wireless solutions that are scalable and flexible in providing necessary bandwidth, while also allowing them to reduce wireless backhaul expenditures. The newly allocated E-Band spectrum (71-76 GHz, 81-86 GHz and 92-95 GHz) has the potential to become the "next generation wireless backhaul spectrum," offering clear technological and economic advantages over the lower 6-38 GHz spectrum.

Using E-Band for Ethernet Wireless Systems

The newly-allocated E-Band spectrum (71-76 GHz, 81-86 GHz and 92-95 GHz) has been designated for ultra-high capacity point-to-point communications (fixed links). The US FCC was first to regulate and allocate the E-Band spectrum in 2003, followed in early 2007 by Ofcom in the UK. Regulators worldwide are soon to follow the FCC and Ofcom's lead, allocating this spectrum in a consistent manner worldwide. In Europe, CEPT has published a formal recommendation for the allocation of the E-Band spectrum, and ETSI is expected to approve its recommendation for wireless systems operating in this band by the end of 2009. In general, local and national regulators both within and outside of the European Community follow the recommendations and guidelines provided by CEPT and ETSI.

The new E-Band frequency spectrum has clear technological and economical advantages over the lower 6-38 GHz spectrum. Millimetric-wave wireless systems utilize a dramatically larger allocated spectrum divided into significantly larger channels to deliver multi-gigabit data rates. By comparison, the largest allocated channel in the 6-38 GHz spectrum is 56 MHz while the smallest typical channel size in the E-Band is 250 MHz - which can scale up to 5 GHz (as seen in Figure 4). By utilizing the large allocated spectrum and channels, E-Band wireless systems can be considerably more robust, while simultaneously easing modem and radio requirements. Thus, millimetric-wave wireless systems provide significant cost advantages over the lower "traditional" wireless systems, allowing scaling up to gigabit-per-second capacities, without additional radio equipment or licensing fees.

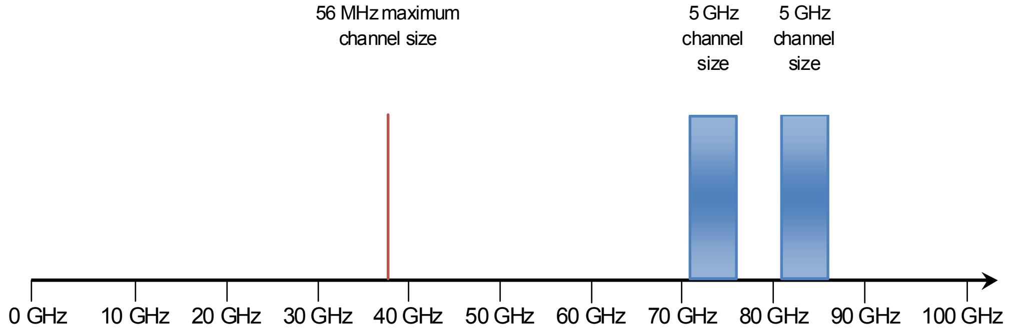

Figure 4 – channel size comparison between 38 GHz and E-Band

Despite being affected by rain attenuation, the robust system design and higher antenna gains allows E-Band wireless systems to provide the necessary high capacities with 99.999% carrier grade service availability at link distances of up to three kilometers. Considering that ultra-high backhaul capacities are generally required in urban scenarios where distances between the mobile base stations are relatively short (1.5 Km average for urban and 2.5 Km for suburban scenarios), E-Band wireless systems are ideal in these locations. Needless to say, these urban and sub-urban scenarios account for 80% - 90% of the network elements requiring a backhaul solution.

Yet another economic advantage of the E-Band frequencies over the “traditional” frequencies is the dramatic reduction of the licensing fee. The nature of propagation in the E-Band and the possibility of employing directional “pencil beam” signal characteristics mean that applications can be implemented with minimal interference concerns - allowing potentially highly efficient spectrum re-use, reducing coordination requirements, and allowing regulators to adopt a “light licensing” scheme.

In the UK, for example, the licensing fees for E-Band frequency licenses are negligible - costing £50 for an annual license per link. While in the USA the frequency license is even lower, with a 10-year license costing $75 per link. The licenses are obtained using an online registration process, lowering license acquisition time to just a few hours. In contrast, a frequency license in the 6-38 GHz spectrum can cost up to several thousands of dollars annually, and can take over a month to acquire. For operators with hundreds or even thousands of links in their networks, these frequency licensing costs are a real concern.

	6-38 GHz wireless systems	E-Band wireless systems
Available spectrum	Limited, highly congested (in urban areas)	**Dramatically large** **Widely available**
Channels	Up to 56 MHz	**250 MHz up to 5 GHz**
Capacities	Sub-gigabit	**Gigabit and up**
Frequency licensing	High-cost, time consuming	**“Light Licensing”** **Low-cost and immediate**

Table 1 – the advantages of E-band vs. 6-38 GHz wireless systems

Propagation Characteristics of the E-Band Spectrum

Despite being just recently allocated, the propagation characteristics, such as the weather behavior characteristics, of the E-band spectrum are well-known and understood. Like any wireless system, millimeter-wave wireless system performance is also affected by environmental conditions, including atmospheric attenuation and rain attenuation. The total transmission loss for a wireless link is given by:

$$\boldsymbol{Attenuation(dB) = 92.45 + 20 * log_{10}(f_{GHz}) + 20 * log_{10}(D_{km}) + Att_{atmosphere} + Att_{rain} + Att_{fog/mist}}$$

Equation 1 – the total transmission loss of a wireless link

1. ***Atmospheric attenuation:*** Between 70 GHz and 100 GHz there is a relatively low atmospheric attenuation window, making these frequencies attractive for high-capacity wireless transmission. At the 71-76 GHz and 81-86 GHz spectrum the atmospheric attenuation is negligible - approximately 0.5 dB/km. At around 60 GHz, there is major increase in the atmospheric attenuation caused by the oxygen absorption, limiting radio transmission distances for 60 GHz wireless systems.

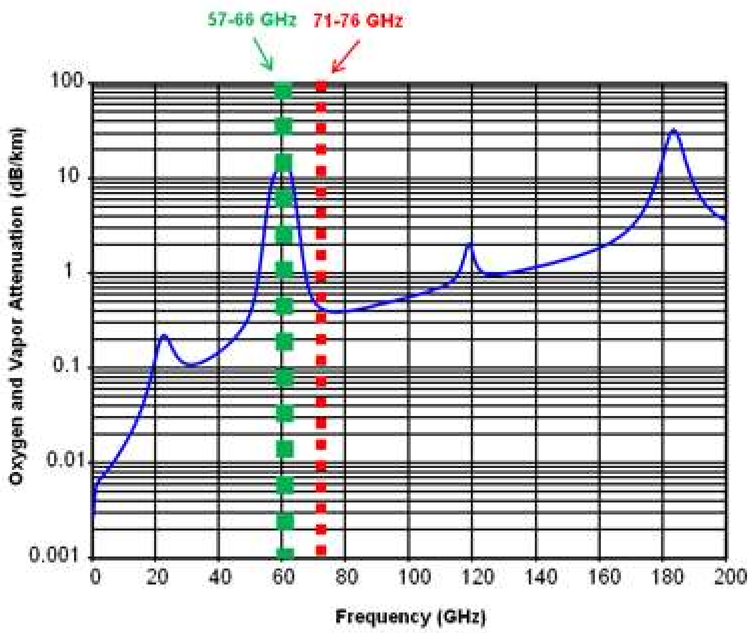

Figure 5 – atmospheric attenuation influencing the E-Band spectrum

2. ***Rain attenuation:*** Rain affects microwave and millimetric-wave wireless systems. Rain attenuation has a significant influence on determining the practical limits on wireless transmission distances, including systems operating in E-Band frequencies. For example, tropical rain falling at a rate of 100 mm/hour can cause attenuations of 30 dB/km to wireless systems operating in the E-Band spectrum. However, since severe weather events usually move quickly across the link, rain effects tend to be short-lived, especially over short links.

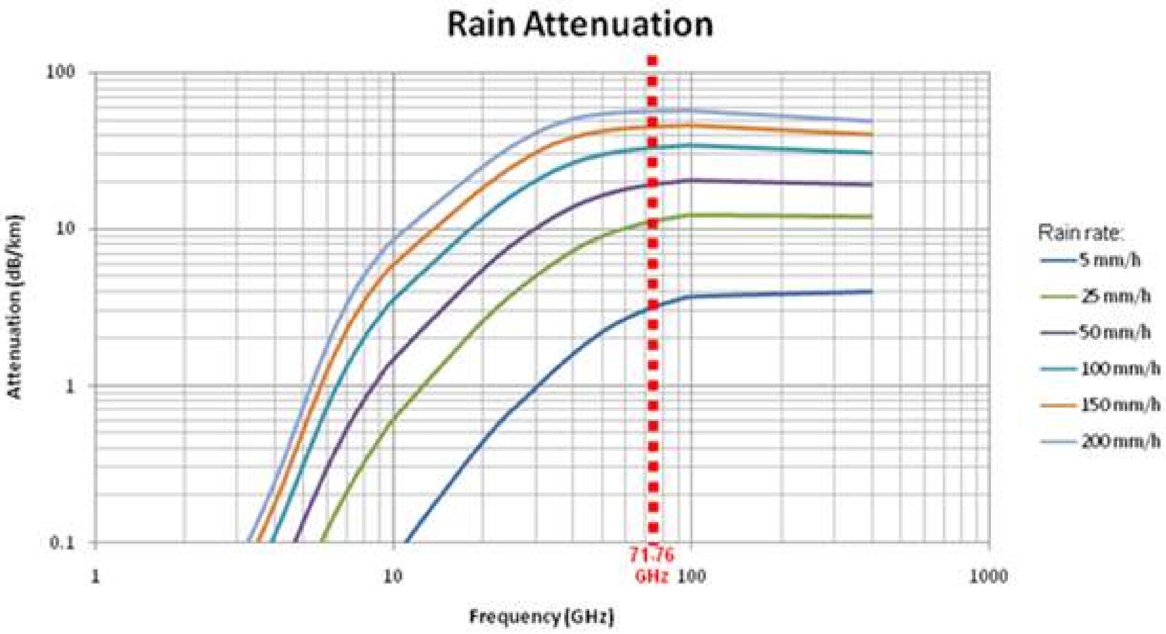

Figure 6 – rain attenuation influencing the E-Band spectrum

3. ***Fog/mist attenuation:*** Fog attenuation is relatively low in the E-Band frequencies and does not require consideration.

As a native Ethernet systems, E-Band wireless systems can implement adaptive modulation and coding (also known as adaptive rate) to significantly improve availability and performance. Adaptive rate technology automatically makes the necessary modulation and coding adjustments to the wireless system, optimizing over-the-air transmission and preventing weather-related losses from causing traffic link disruption.

When extreme weather conditions affect traffic over a wireless system, adaptive rate technology automatically lowers the modulation and coding schemes to improve the system's link budget. By doing so, all-important real-time applications continue to pass through uninterrupted, at the expense of lower priority, non real-time services. When the link conditions improve, the system automatically recovers, returning to the original modulation and coding, higher throughputs, and better spectral efficiencies (as depicted in Figure 7).

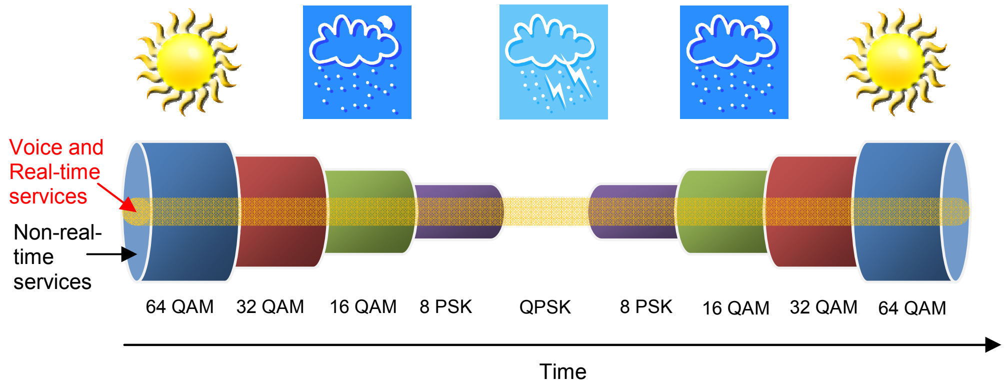

Figure 7 – improving link availability using adaptive rate technology

The large allocated spectrum and channel sizes, together with high antenna gains and adaptive rate technologies, enables effective compensation for atmospheric and rain attenuation. As such, E-Band millimetric-wave wireless systems can provide carrier grade, gigabit-per-second capacities at 99.999% availability over distances of up to three kilometers in most common rain zones worldwide.

Conclusion

As subscriber demand for bandwidth increases exponentially, and data services profit margins continue to shrink, the cost and complexity of increasing mobile backhaul capacity and the quest to lower cost per bit is leading providers to seek new backhaul alternatives. These concerns will grow even more serious as providers plan their transition to 4G - LTE and WiMAX technologies and their advanced, flat-IP network architectures.

Ethernet/IP backhaul solutions allow providers to scale bandwidth on a pay-as-you-go basis – reaching Gigabit-per-second capacity without massive infrastructure investments. However, “traditional” packet-based backhaul transport suffers from a number of inherent limitations - copper has limited capacity, new fiber links are often prohibitively expensive, and traditional microwave links suffer from spectrum congestion and limited channel size.

Today, as operators need to provide more and more bandwidth, they are turning to new frequency spectrums, and looking for alternatives to lower wireless backhaul costs. The newly allocated E-Band spectrum (71-76 GHz, 81-86 GHz and 92-95 GHz) has clear technological and economic advantages over the lower 6-38 GHz spectrum - enabling delivery of gigabit-per-second data rates, with considerably lower costs both in equipment and annual licensing. As such, the E-Band spectrum is expected to become the “next generation wireless backhaul spectrum,” playing an important role in easing mobile operators’ backhaul pain.

About Siklu

Paving the way for the mobile wireless backhaul revolution, Siklu delivers carrier-grade, millimetric-wave, Gigabit Ethernet radio solutions with paradigm-shifting price performance. Offering the industry’s lowest total cost of ownership (TCO), and incorporating on-board networking capabilities, solutions from Siklu are ideally suited for the both mobile backhaul and carrier Ethernet business services.

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