White Paper

Optimizing Millimeter-Wave System Design to Boost Network Performance While Reducing Costs

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Abstract

To meet growing subscriber demand, mobile operators are forced to add network capacity to enable the delivery of bandwidth-intensive data services. Nowhere are these challenges felt more acutely than in the backhaul network. As operators migrate to all-Ethernet/IP backhaul networks, fiber backhaul can provide the required capacity and beyond, wherever it is deployed; however, the 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 sizes. Therefore, current packet-based transport networks fall short in meeting the ever increasing backhaul demands.

Operators who rely on wireless backhaul are turning to new frequency bands to provide this capacity while reducing costs. The newly-allocated E-Band spectrum (71-76 GHz, 81-86 GHz and 92-95 GHz) – has many clear technological and economic advantages.

The Mobile Broadband Explosion

While the HSPA air-interface and the core network allow true mobile broadband user experience, the backhaul network is not designed to cope with the increased traffic demand. The capacity bottleneck in mobile networks has shifted from the access, (air-interface), to the backhaul network. The current design of backhaul networks limits the data speeds that mobile users can experience on their HSPA-enabled handhelds, which in turn impair their user experience of mobile broadband services.

While subscriber demand for capacity-intensive services exponentially increases, the cost of keeping these backhaul networks up-to-pars, is resulting in a decrease in the operators revenues. Already, backhaul accounts for approximately one-third of the total cost of ownership (TCO). Operators need a new backhaul solution designed for cost efficiency that will allow them to upgrade their backhaul network to support the growing demand while keeping TCO at a level that will enable them to generate revenues.

Equipment Cost and Operating Cost

The use of microwave wireless links for mobile backhaul is well established. Wireless technology serves more than 70% of the backhaul links in Europe. When utilized in dense urban environments, millimeter-wave (mm-wave) technology shares many of the qualities that made microwave technology a success and provides additional advantages due to unique hardware characteristics.

Antenna – The short wavelength used in mm-wave frequencies leads to a small sized antenna with high antenna gains and high directionality. Several important cost and technological advantages result from this fact:

1. Reduced antenna cost – While comparing an antenna with the same performance parameters, a smaller antenna has a lower manufacturing cost as it requires less material and needs less overall accuracy
2. Reduced installation and operating costs – a smaller antenna is easier to install and the smaller footprint results in lower leasing costs on the tower
3. Reduced level of interference – a more directional antenna emits less radiation in unwanted directions and enables higher link density and better reuse of the spectrum. This effect is squared due to the fact that it occurs on both the transmit and receive sides.
4. Increased link budget – when wavelength decreases and the antenna size is kept constant, the output power concentrated at the TX antenna main lobe is maintained. But since there is also a RX antenna whose gain (for a fixed size) increases with the decreasing wavelength, the overall link budget is increased when the wavelength is decreased.

Modem – The cost and scarcity of the 8-38 GHz spectrum drives microwave backhaul equipment manufacturers to improve its spectral efficiency. This is achieved by utilizing higher order modulations, lower coding rates, and utilizing polarization diversity. The improvement in efficiency does not come without a price. Doing this reduces the link sensitivity, drives up the cost of the equipment and is ultimately limited by the signal to noise ratio that is practically realizable in the radio. As mm-wave channels are significantly wider than microwave channels, up to 5 GHz in the E-band compared to up to 56 MHz in lower frequencies, modem design becomes simpler. As spectrum limitations are nowhere near those of “traditional” frequency bands, there is no need to implement costly high order modulation schemes or XPIC.

Radio – The mm-wave radio design becomes less complicated as it does not have to support high order modulations which require high linearity, high dynamic range and low phase noise. This can be clearly exemplified if we compare QPSK modulation and 256QAM modulation. Since we assume that both modulations are transmitted at the same power level, and since we assume that every constellation point is transmitted with equal probability, we can calculate the average transmitted power.

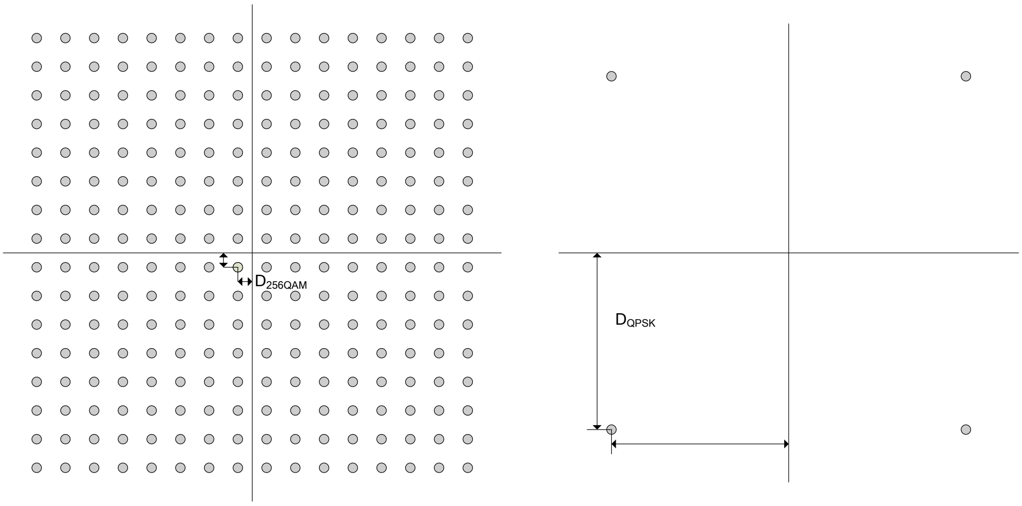

Figure 1. QPSK and 256QAM constellations

$$P_{TX} = \sum \mathbf{(}\text{Probaility that constelation point C is transmitted}\mathbf{)} \cdot \mathbf{(}\text{Power of constelation point C}\mathbf{)}$$

Applying this calculation to the shown constellations above and equating their transmit power would yield:

$$\sqrt{170} \cdot D_{256QAM} = \sqrt{2} \cdot D_{QPSK}$$

This means that the power ratio between the 256QAM constellation distance and the QPSK constellation point distance is almost 20dB. These 20dB need to be accounted for in the radio linearity, dynamic range and phase noise if the 256QAM is to be successfully resolved by the receiver.

The availability of very wide frequency channels at mm-wave frequencies enable providing very high link throughput even while using low order modulations. As a consequence it becomes possible to have an integrated silicon radio design, rather than costly modules. In addition, the radio emission may be kept to relatively low levels. All in all, this results in higher system reliability and overall low system power consumption which in-turn results in major reduction in the maintenance and operations and energy bills.

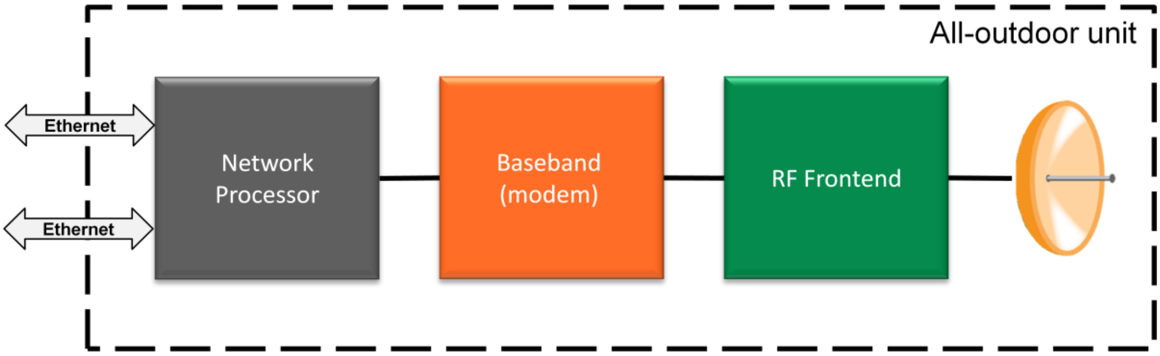

Figure 2. The main building blocks of a millimeter-wave solution

Environmental friendly – Owing to the highly integrated radio and the small size of the components, the entire mm-wave system may be small and tightly integrated. The small footprint and low power consumption contributes to lowering operation costs, as electricity cost and tower space leasing cost are greatly reduced. The small footprint allows mm-wave solutions to gently and naturally blend in the urban environment without distorting the natural landscape, an advantage for urban locations. mm-Wave solutions are also designed as all-outdoor backhaul solutions completely eliminating the need for an indoor unit.

Throughput, Spectrum Availability and Cost

Microwave wireless backhaul equipment operates on a wide range of channels that extend from about 8GHz and up to 38GHz. In Europe, these frequency bands are typically used with channels whose bandwidth is $2^n \times 1.75$MHz up to a maximum of 56MHz. The lower the operating frequency, the less spectral bandwidth is available at that frequency. Additionally, due to the assignment of the spectrum at these frequencies to additional applications rather than backhaul, only a small part of the spectral bandwidth is available for mobile operations. In many countries, particularly in Europe the spectrum in the 8-38 GHz range is becoming increasingly congested especially in urban areas where the increased backhaul capacity is predominantly important.

The cost of spectrum is typically proportional to the bandwidth of the channel used, which in turn is proportional to the backhaul throughput that can be carried by that channel.

One factor driving down the spectrum cost is the "light licensing" frequency registration scheme that is adopted by regulators worldwide. As the frequency of operation increases, the propagation of a radio wave transmitted from a given size antenna becomes more directional. In addition, the mm-waves, E-band spectrum was standardized to have directional “pencil beams”. In a dense urban environment where multiple links are operating in close proximity, this translates to better spatial isolation between links, and consequently less interference. Recognizing the greatly reduced risk of interference when operating in mm-wave frequencies, regulators worldwide adopted a new, “light licensing” approach. Under this “light licensing” approach, link licensing is based on registration in an on-line database and simple interference calculations that guarantee the coexistence of collocated links. The frequency licenses cost a fraction of the “traditional” licenses and can be obtained within minutes. For operators with hundreds or even thousands of links in their networks the lower frequency licenses means dramatic annual savings.

mm-Wave Radio Range

The mm-wave technology sweet-spot is at short-range high capacity backhaul links. This is dictated by the propagation characteristics of the spectrum, particularly the rain attenuation. As the size of rain drops are of the same order of magnitude as the wavelength of the mm-wave signal, rain would tend to attenuate the mm-wave signal more than in lower frequencies. The level of attenuation is proportional to the rain rate and to the distance traversed in the rain cell. Since rain rate is statistically characterized as a probability to exceed a certain rain rate, the rain effect may be expressed as a probability that the link attenuation exceeds certain thresholds. This probability depends on the rain zone, and translates to a maximum link range according to a certain given performance. In order to overcome the variation link, attenuation mm-wave wireless solutions apply modulation and rate adaptation algorithms, which modify the over-the-air-interface in order to increase transmission robustness at the cost of transmission throughput.

This robust system design, together with the 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 (up to1.5 km for urban and up to 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 70% - 80% of the deployed network elements.

To Sum Up

Today, as operators need to provide more and more bandwidth, they are turning to new frequency bands, and looking for alternatives to reduce the 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 8-38 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, particularly in urban deployments where the backhaul capacity is becoming increasingly critical.

About Siklu

Siklu redefines wireless backhaul by optimizing every aspect of mm-wave system design to enable service providers to boost network capacity and performance, while dramatically reducing costs by 80%. By re-engineering mm-wave system components, and leveraging silicon-based technologies, Siklu provides gigabit-per-second wireless connectivity at the lowest price point in the industry. Siklu’s solutions are easily scalable enabling service providers to evolve their networks from 2G/3G to HSPA and 4G and incorporate capabilities to support future topologies. In addition, Siklu’s environmentally friendly design results in easier and quicker deployment and adoption.

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