White Paper

The Business Case for Microwave Backhaul Spectral Efficiency

DragonWave

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Importance of Microwave Spectral Efficiency to Minimize Total Cost of Ownership

Data growth continues to drive Backhaul capacity

With the broad deployment and acceptance of LTE, operators are seeing growing demand for higher capacities to enhance the user experience. While all this new access capacity is a major step forward, everything grinds to a halt if the backhaul network does not scale accordingly. For this reason, many operators are evaluating next generation packet microwave solutions for their performance, scalability, reliability, and low total cost of ownership.

When selecting a microwave solution, many factors such as deployment flexibility, reach, capacity, and of course cost, come under review. An equally, if not more important, but often overlooked consideration is the spectral efficiency that can be achieved by the microwave backhaul solution. The reason why this is so important is an issue of future availability and cost; just as we have seen spectrum availability issues in the Radio Access Network (RAN), microwave spectrum is facing similar congestion challenges in many parts of the world. This is leading to reduced availability of larger channels and increased pricing for popular frequency bands.

Spectrum is increasing as percentage of total network cost

With capacity requirements increasing and spectrum availability decreasing and becoming more expensive as a portion of the total network cost, operators will need to extract the maximum value from their spectrum investment. In the coming years, spectrum licensing costs will have the potential to make or break the backhaul business case and become a significant barrier for operators.

This paper will examine the trends in microwave spectrum as well as the impact of spectrum cost to the backhaul network business case, followed by an overview of the techniques used by next generation packet microwave systems to squeeze more capacity out of the same spectrum allocation.

Spectrum Licensing Trends

Even though much of the business and regulatory attention tends to be on the highly valued lower frequency spectrum allocations used in the radio access network (RAN), there is now an increased focus on microwave spectrum due to concerns of congestion and future availability; this is particularly true in areas where the high cost of deploying fiber has led to a greater concentration of microwave backhaul solutions.

In response to these concerns, many of the world's telecommunications regulators have implemented new measures to more carefully manage the available microwave spectrum. Several European countries including France and Russia have essentially eliminated larger channel bandwidths (56 MHz and above) in order to encourage greater efficiency in smaller channels.

The Office of Communications (Ofcom), the independent regulator in the UK, is addressing spectrum congestion with a pricing strategy that favors higher frequencies and smaller channel sizes. As shown below, spectrum costs can vary widely by region and frequency band. In the commonly used, and longer reach 6-23 GHz bands, a 28 MHz channel ranges from $1000 to greater than $3000 per year outside of the US.

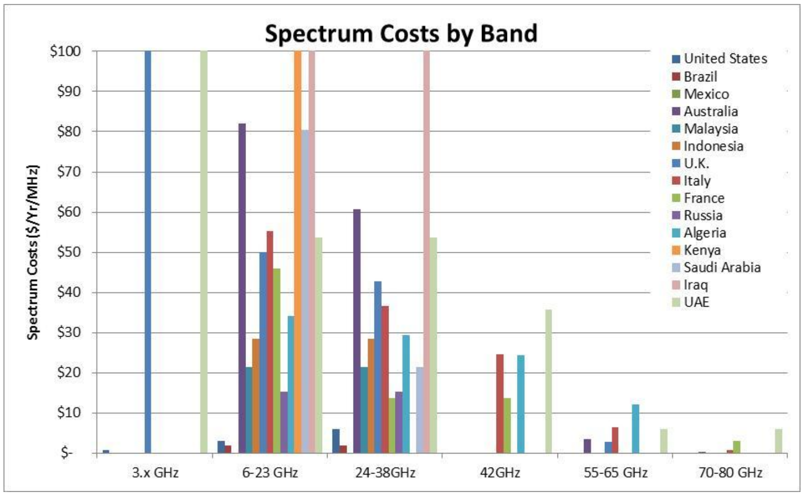

Figure 1: Spectrum Costs by Band

Spectrum Costs vary widely by Country and Band

As mobile networks have scaled with increasing capacity, so too have the supporting microwave backhaul networks, which serve 70-80 per cent of all mobile sites. Backhaul links have scaled through advancements in technology, higher capacity configuration, such as 2+0, and increased spectrum. The most commonly used and available channel size is 28MHz in most countries and this 28MHz channel is limited to about 200Mbps with most traditional microwave systems. Already today, costly annual spectrum lease charges for a 28 MHz channel represent between 50-75% of the 7-year total cost of ownership. If a second or wide channel is required, it can increase the total cost of ownership by 30-50%. Compounding this problem is the fact that, in many countries, backhaul spectrum is so congested even acquiring a channel can often be difficult.

Given the spectrum challenges with a current 200Mbps link, scaling with traditional technology to 400Mbps or higher is extremely problematic. If more spectrum is available, the options are to use a wider 56 MHz channel or deploy a 2+0 system that consumes 2X28MHz channels. Yes, both of these options double the already very expensive spectrum lease charges.

Advances in Microwave technologies are rapidly improving system spectral efficiency.

To enable greater scalability, operators are exploring any advances in spectral efficiency of microwave backhaul systems. In the past, the most common technological improvement for spectral efficiency has been modulation. Most systems today offer 256QAM, which can deliver up to 200Mbps in the 28 MHz channel. Newer systems on the market are now offering 2048QAM, which provide about a 35% improvement over 256QAM. While there is some link budget reduction, it can typically be managed through the use of adaptive modulation, which will switch back down to 256QAM or lower during a link fade event. Other advancements in microwave backhaul spectral efficiency are also being made.

Recently, some microwave systems are offering compression techniques to further improve spectral efficiency. Many systems offer header optimization, which removes common fields from headers and provides a 10-20% throughput improvement. More significantly, advanced systems are beginning to offer bulk payload compression. Bulk payload compression analyzes the traffic, looks for bit patterns, and replaces them with shorter symbols. This technology has been found to offer 50-150% throughput improvement. Each of these technologies can be used together to provide overall improved throughput. The Bandwidth Accelerator which employs bulk compression, delivers significant throughput improvement, which will range dependent on the traffic pattern of the operator and customer base. Below are test result excerpts from a Mobile operator customer. Although gains of 200%+ were achieved in the testing, the cost studies in this paper assume more modest gains of 70-80%.

Major Carrier Test Results of Bandwidth Accelerator

Bulk Compression can improve spectral efficiency by 1.5-3X.

Test Pattern	Packet Size	Throughput observed w/o Compression	Throughput observed w/ Compression
PRBS 9	68	305 Mbps	840 Mbps
PRBS 11	68	305 Mbps	780 Mbps
PRBS 15	68	305 Mbps	580 Mbps
PRBS 9	1518	242 Mbps	840 Gbps
PRBS 11	1518	242 Mbps	780 Mbps
PRBS 15	1518	242 Mbps	520 Mbps

Packet Size	Latency w/o BAC	Latency w BAC	Improvement
1518 bytes	256 µs	257.2 µs	- 1.2 µs
9600 bytes	618 µs	486 µs	132 µs

By combining these features, speeds greater than 500Mbps are achievable in a single 28 MHz channel. In comparison, traditional microwave systems would require 3X28 MHz channel and 3 separate microwave systems that would require 2 antennas, which would, in turn, incur 3 times the annual spectrum costs, double the tower lease costs, and 2-3 times the CAPEX costs.

The above spectral efficiency techniques can also improve total cost of ownership on existing and lower capacity links. For example, 200-250Mbps can be delivered in a single 14 MHz channel with these new features versus a 28-56MHz channel that would currently be used. This can provide a 50-75% decrease in the recurring annual spectrum costs. The two figures below show the total cost of ownership benefits of the 250 Mbps scenario and 500 Mbps scenario, assuming a spectrum cost of $1000/year. As shown, the 250Mbps case provides a 50% total cost benefit for improved spectral efficiency and, in the 500 Mbps case, there is close to a 55% total cost benefit through increased spectral efficiency.

Total Network Cost can be reduced by 50% through spectrum savings.

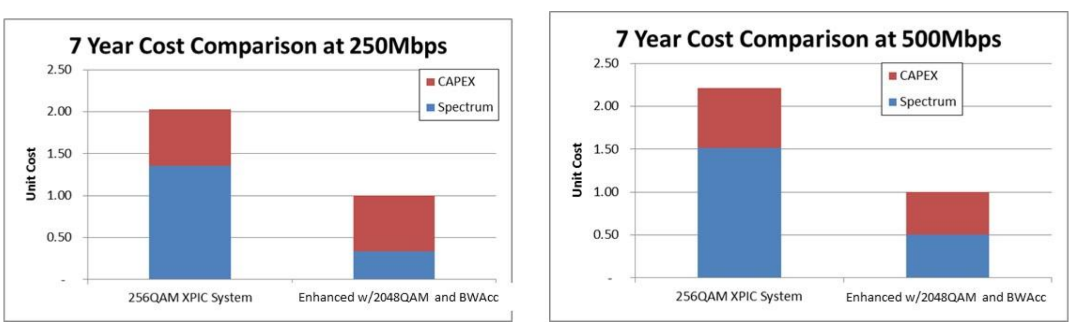

Figure 2: Total Cost of Ownership Benefits

The total cost savings in the network will be dependent on the region and spectrum costs in that country. However, in almost all cases, the benefit of the bandwidth accelerator and 2048 QAM results in 40% total savings, as shown in the graph below.

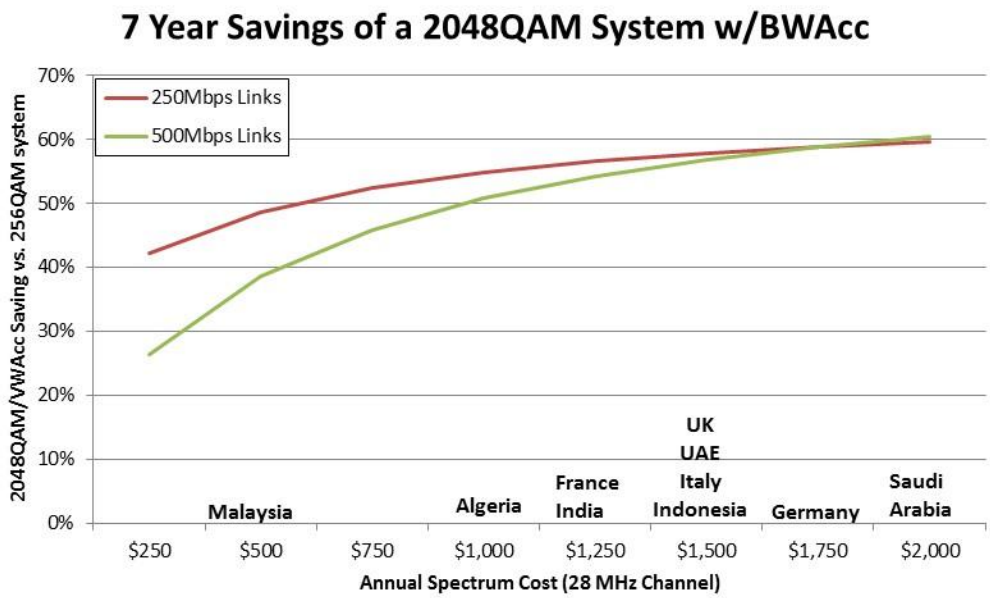

Figure 3: 7 Year Savings of a 2048QAM System w/ BWAcc

Another emerging spectral efficiency technique for microwave is Multiple Input, Multiple Output (MIMO). MIMO can deliver double the capacity in a single channel through spatial separation and by transmitting the two signals over separate antennas. MIMO can be used in combination with 2048QAM and acceleration to provide further spectral efficiency improvement.

The challenge with MIMO is that the separation of the antennas is very dependent on the link details, including frequency band link length. The antenna separation for many links often needs to be 5-10 meters. This provides a very difficult challenge for operators, as it requires them to fin two exact mounting locations on what is typically rented tower space. Each mounting location will incur monthly lease charges. Equipment cost and installation costs are also doubled versus a 1:0, because MIMO requires twice the radios and antennas. This combination of factors and deployment challenges make it very unlikely that MIMO will be deployed on a network wide scale. However, it may be used in combination with 2048QAM and compression on unique problem links to provide very high capacity, such as 1Gbps in a 28MHz deployment or in locations where only a 14 MHz channel is available to deliver up greater than 500Mbps.

A fourth spectral efficiency technique that is often discussed is XPIC. XPIC allows the microwave system to use both the vertical and horizontal polarization of the same channel on the same link. However, once the polarizations are used on a link they cannot be used on adjacent links where they would normally be deployed, so that the adjacent links would require different channels. As a result, XPIC does not provide any network wide spectral efficiency benefits. In addition, each polarization of a frequency channel is typically billed separately by the telecom regulator, so there is no spectrum cost savings. Where XPIC can be useful in a network is in select single link cases where only a single dual-polarized channel is available. These cases are fairly rare and deployment of XPIC has typically been limited to a small percentage of links in networks.

With spectrum costs representing a large portion of total backhaul network costs, it is clear more spectrally efficient technologies are crucial to scaling network cost effectively. The cases above all assume that for existing technologies more spectrum could be available to scale. In reality, many operators are restricted by the amount of spectrum available. So, without improved spectral efficiency, and with limited scalability, they may instead see negative impacts on service revenue. High order modulation and compression will be key technologies to delivering this spectral efficiency. Although MIMO and XPIC can also be useful on special network scenarios, they are much more difficult to be deployed on a network wide basis.