

White Paper

Flex Your Backhaul Network with Adaptive Coding & Modulation

FOR PRICING CONTACT:
MapleNet
WIRELESS
877-MAPLE-01
sales@maplenetworkwireless.com
www.maplenetworkwireless.com
 CERAGON
"Best Value Added Reseller"
2007 & 2008 Award Winner

Authors:

Aviv Ronai - Chief Marketing Officer

Ron Nadiv - Director of Technology

Tsachi Rosenhouse - Chief Engineer

Ceragon Networks®, CeraView®, FibeAir® and the FibeAir® design mark are registered trademarks of Ceragon Networks Ltd., and Ceragon™, PolyView™, ConfigAir™, CeraMon™, EtherAir™, QuickAir™, QuickAir Partner Program™, QuickAir Partner Certification Program™, QuickAir Partner Zone™, EncryptAir™ and Microwave Fiber™ are trademarks of Ceragon Networks Ltd. All rights reserved.

Flex Your Backhaul Network with Adaptive Coding & Modulation

Adaptive Coding and Modulation (ACM) was designed to help operators maximize spectrum usage and increase the capacity of their backhaul links over any given channel bandwidth, under any weather condition, at any link budget. This paper provides an introduction to ACM and offers a number of examples that show how the technology simplifies mobile network planning and helps operators achieve better results both in the field as well as on their balance sheets.

Wireless point-to-point (PtP) microwave solutions, used in over 50% of all mobile backhaul deployments worldwide (and nearly 70% outside the U.S.A.), offer operators a simple, cost efficient path for upgrading and expanding their networks. These solutions support higher data rates than copper T1/E1 lines, and easily overcome the high cost and limited availability associated with fiber. Yet wireless backhaul has its constraints. Network planners often caught between the need to increase the capacity and availability of the network, and the need keep cost at check. Now, a new and unique technology called Adaptive Coding & Modulation, or ACM, makes high-capacity PtP microwave even more attractive.

ACM refers to the automatic adjustment that a wireless system can make in order to optimize over-the-air transmission and prevent weather-related fading from causing communication on the link to be disrupted (the technology is discussed in detail in the last section of this paper). In April 2008, Ceragon Networks introduced its FibeAir® IP-10 solution which features full-range dynamic ACM. This advanced platform was designed to meet the unique requirements of mobile operators and to help network planners to successfully deal with some of the more common constraints of today mobile networks. These constraints include: capacity and availability limitation, scarce frequency resources, covering the distance between cell towers and reducing overall rent, licensing and equipment costs.

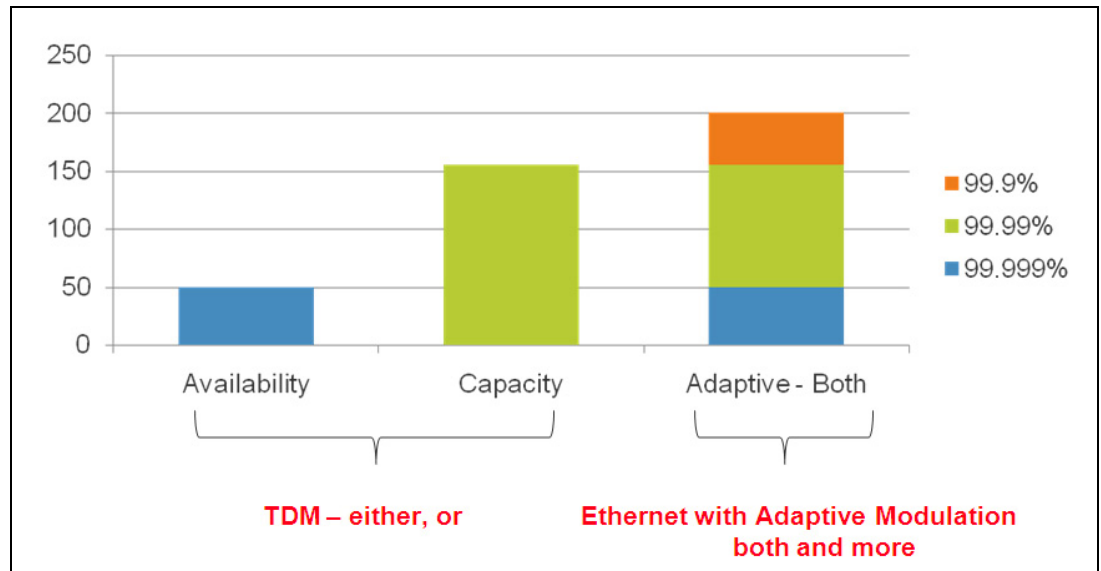
It's all about handling data...

The world of wireless telecommunication is changing. Voice is no longer the main generator of mobile traffic. Today, data generates significantly more traffic than voice, albeit with only marginal added revenue. But there's a bright spot too. Unlike real-time services, such as voice or video, most data applications do not require stringent 99.999% availability, also known as "five-nines". For instance, while a 50 millisecond delay is unacceptable during a voice conversation, a web page or email message taking several seconds to download is tolerable.

Flex Your Backhaul Network with Adaptive Coding & Modulation

Now planners can flex their networks, guaranteeing sufficient bandwidth for voice and delay critical services with 99.999% availability and allowing for a range of data services at slightly lower availabilities (99.99% or 99.9%).

The example in figure 1 compares a legacy TDM solution with a native Ethernet solution using ACM. In this particular case, a DS3 service is delivered over a 50 Mbps link at 99.999% availability. Alternatively, the same system can provide a single service carrying 155 Mbps at 99.99% availability delivering an STM-1/OC-3 service. When introducing ACM in the equation, the Ethernet link, using the same frequency spectrum and radio equipment, can offer the following: carrier-grade 50 Mbps at 99.999% availability, a second service providing 105 Mbps at 99.99% availability, and a third service delivering an additional 45 Mbps at 99.9% availability. This constitutes a total of 200 Mbps using the same link budget.



**Figure 1: Ethernet Microwave with Adaptive Modulation:
Gain in overall capacity while increasing availability**

FOR PRICING CONTACT:
MapleNet
WIRELESS
877-MAPLE-01
sales@maplenetwireless.com
www.maplenetwireless.com

 CERAGON
"Best Value Added Reseller"
2007 & 2008 Award Winner

Flex Your Backhaul Network with Adaptive Coding & Modulation

Network planners' peace of mind

Now that we know that ACM can increase the capacity and availability of wireless backhaul links without the need to invest in additional spectrum or revise network planning schemes, let's take a glance at a number of additional benefits the technology offers:

- **Overcomes the issue of limited frequency resources** - In areas where frequency resources are scarce, ACM allows operators to extract more from their licensed frequencies. Meeting the demand for more bandwidth without increasing the link budget allows operators to maintain their service, business and customer-base growth even in areas in which no additional spectrum is available. Figure 2 shows the capacity range operators can expect at each frequency channel using Ceragon's FibeAir IP-10 with ACM.

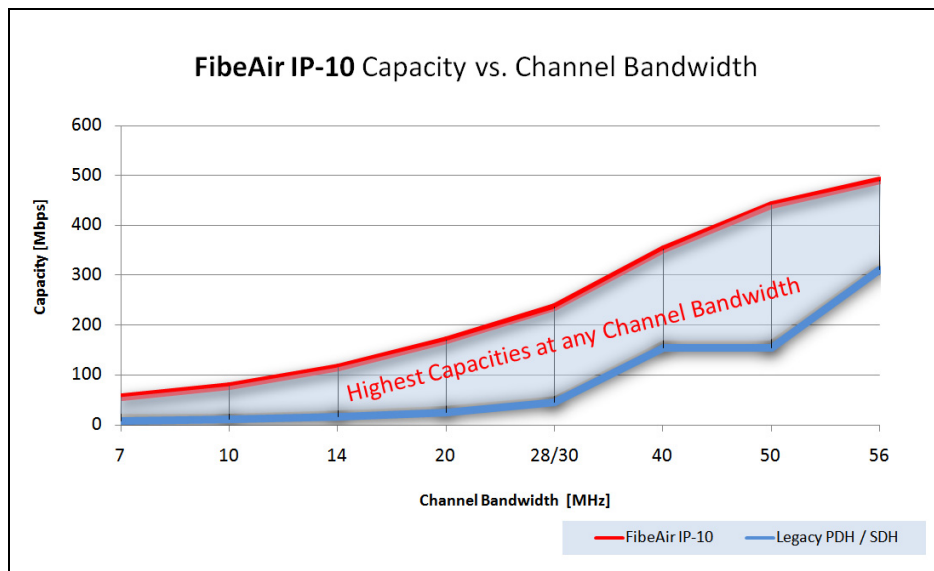


Figure 2: Enhanced spectrum utilization using Ceragon's FibeAir IP-10 with ACM

- **Cap license fees.** – By allowing operators to maximize their licensed bandwidth, ACM-enabled radios can transmit more data rates over the operator's existing spectrum. Saving the need to license additional frequency channels, and pay additional licensing fees, can significantly reduce OPEX.
- **Fewer Hops** – reducing the number of relays, or hops, has a significant and positive influence on the operator's CAPEX and OPEX. Each "hop" equals costs of equipment, licenses, real-estate fees, and sometimes even erecting an entirely new tower. ACM enables

Flex Your Backhaul Network with Adaptive Coding & Modulation

operators to increase the range of their high-capacity radio links, thus requiring fewer hops between tail and fiber sites, as shown in the following illustration (figure 3).

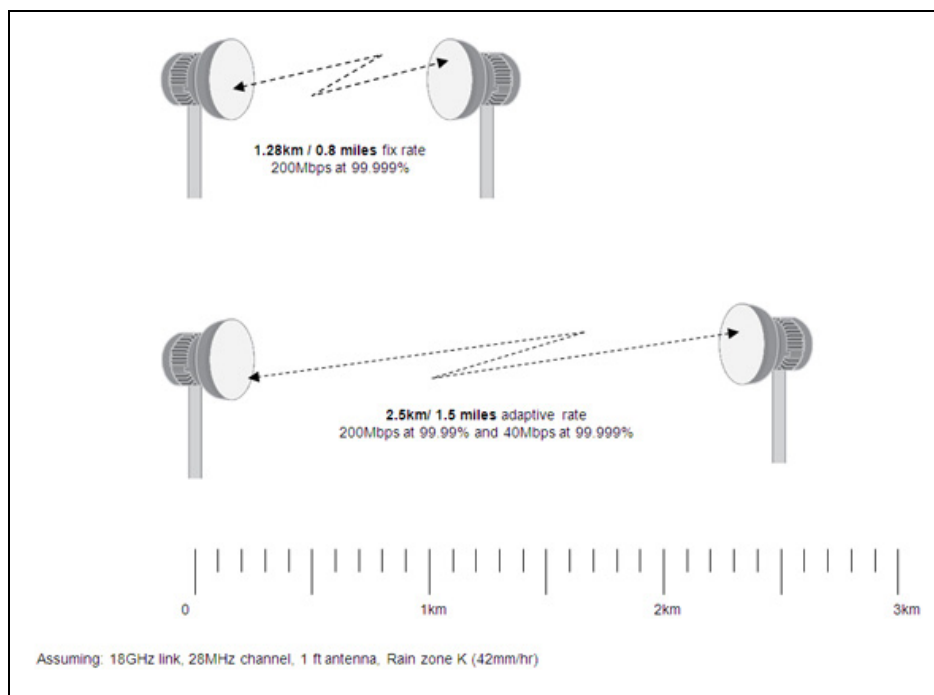


Figure 3: Increasing link span using ACM

- **Decreased tower loads** – cellular towers have limited space or real-estate and can sustain only a limited amount of radios. ACM helps network planners' deal with tower loads and other real-estate constraints by allowing microwave radios to increase capacity without having to replace outdoor equipment. In fact, as shown in figure 4 below, ACM can actually help to decrease antenna size, thus allowing operators to either reduce tower loads or serve more sites without having to set up additional towers.
- **Lower rent fees and equipment costs** - Smaller antennas have an additional advantage. Roof and tower space lease in the US for example is \$100 per foot per month, on average. A simple calculation shows that an operator would have to pay \$4,800 a year for a 4 ft antenna, compared with only \$1,200 for a 1 ft antenna. That's \$3,600 saved every year per antenna, or \$7,200 per link. Needless to say, smaller antennas cost less, both to purchase and to deploy.

Flex Your Backhaul Network with Adaptive Coding & Modulation

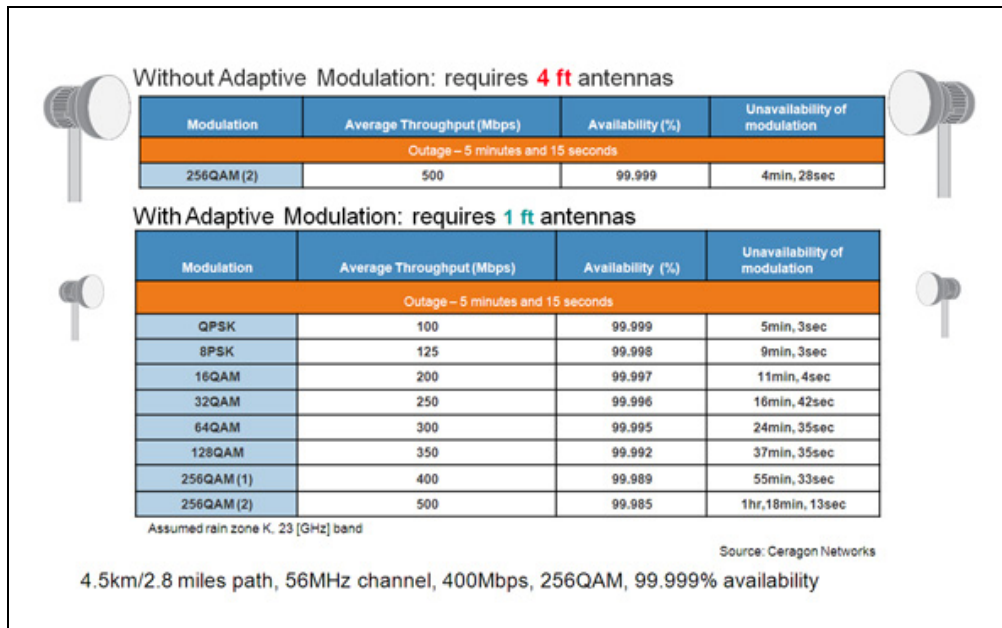


Figure 4: ACM enables similar performance using smaller antennas, yielding a lower cost structure

What is Adaptive Coding and Modulation?

Adaptive Coding and Modulation refers to the automatic adjustment that a wireless system can make in order to optimize over-the-air transmission and prevent weather-related fading from causing communication on the link to be disrupted. When extreme weather conditions, such as a storm, affect the transmission and receipt of data and voice over the wireless network, an ACM-enabled radio system automatically changes modulation and/or coding allowing real-time applications to continue to run uninterrupted. Varying the modulation and/or coding will also vary the amount of bits that are transferred per signal, thereby enabling higher throughputs and better spectral efficiencies. For example, a 256 QAM modulation can deliver approximately four times the throughput of 4 QAM (QPSK).

Ceragon Networks employs full-range dynamic ACM in its new line of high-capacity wireless backhaul product - FibeAir IP-10. In order to ensure high transmission quality, Ceragon solutions implement hitless/errorless¹ ACM that copes with 90dB per second fading. A quality of service awareness mechanism ensures that high priority voice and data packets are never “dropped”, thus maintaining even the most stringent service level agreements (SLAs).

¹ Hitless/Errorless” means that the change in modulation occurs with no errors and no loss of synchronization, thereby introducing no delay to the remaining traffic.

Flex Your Backhaul Network with Adaptive Coding & Modulation

The hitless/errorless functionality of Ceragon's ACM has another major advantage in that it ensures that TCP/IP sessions do not time-out. Lab simulations have shown that when short fades occur (for example if a system has to terminate the signal for a short time to switch between modulations) they may lead to timeout of the TCP/IP sessions – even when the interruption is only 50 milliseconds. TCP/IP timeouts are followed by a drastic throughput decrease over the time it takes for the TCP sessions to recover. This may take as long as several seconds. With a hitless/errorless ACM implementation this problem can be avoided.

So how does it really work? Let's assume a system configured for 256 QAM with 500 Mbps capacity over a 56 MHz channel. When the receive signal Bit Error Ratio (BER) level arrives at a predetermined threshold, the system will preemptively switch to 128 QAM and the throughput will be stepped down to 400 Mbps. This is an errorless, virtually instantaneous switch. The system will then run at 128 QAM until the fading condition either intensifies, or disappears. If the fade intensifies, another switch will take the system down to 64 QAM. If on the other hand the weather condition improves, the modulation will be switched back to the next higher step (e.g. 128QAM) and so on, step by step. The switching will continue automatically and as quickly as needed, and can reach during extreme conditions all the way down to QPSK.

As shown in Figure 5, Ceragon's FibeAir IP-10 ACM implementation offers eight modulation and coding steps. This unmatched level of flexibility is achieved by using both adaptive modulation as well as adaptive coding functionalities. Adaptive coding allows the FibeAir IP-10 to use a lighter forward-error-correction (FEC) code when weather conditions permit it, thus gaining more bits for payload. If the system senses an increase in errors over the link, it automatically implements stronger FEC coding. The following paragraphs provide further explanation about the advantages of adaptive coding.

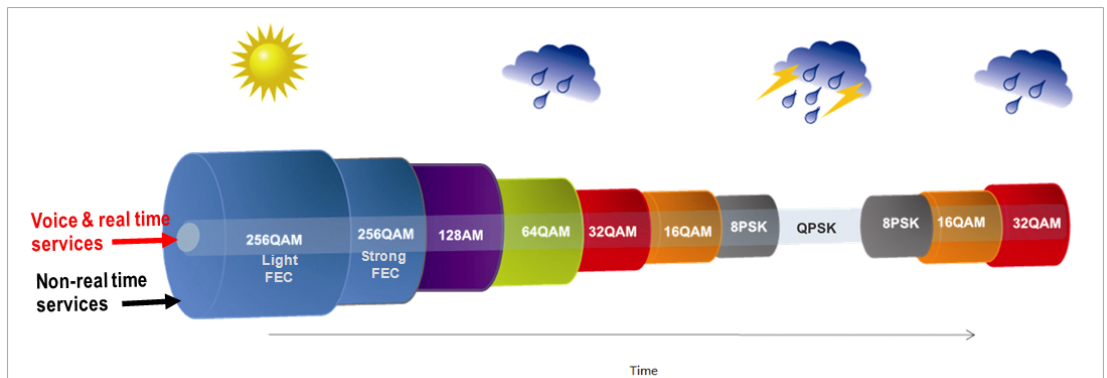


Figure 5: Ceragon's unique Adaptive Coding & Modulation

Improving Capacity with Adaptive Coding

By implementing full dynamic ACM, Ceragon's FibeAir IP-10 significantly improves user bit rate. User bit rate is calculated as follows: Symbol rate * modulation bits/symbol * coding rate. The actual user bit rate – or "net" bit rate for user traffic - over a given channel with a given symbol rate is determined by two main factors; One is the modulation scheme efficiency (modulation bits/symbol), the other is the coding rate.

Modulation Scheme Efficiency is actually the amount of bits that are carried by each transmitted symbol. For example: QPSK carries 2 bits/symbol, while 256QAM carries 8 bits/symbol. The Coding Rate determines the percentage of payload bits from the total amount of transmitted bits (in contrast to redundancy bits which are used for coding). For example: a coding rate of 0.9 means that we add one redundancy bit for every nine bits of payload. In this particular case, the code consumes 10% of the bandwidth. When the system needs to use a stronger code (to make up for bit-errors for instance), the coding rate is changed to 0.8. This would ensure better quality of transmission on the one hand, but reduce the percentage of payload bits as more bandwidth is consumed by coding.

Modulation Scheme Efficiency and Coding Rate influence the radio system's signal-to-noise ratio (SNR) - or system gain. As the modulation bits/symbol goes up there is a need for higher SNR which results in lower system gain. As the coding rate goes down, by introducing a stronger code, SNR is lower, resulting in better system gain. So, by dynamically adjusting both the modulation efficiency and the coding rate using ACM, a FibeAir IP-10 solution ensures the highest available bit rate. This automatic changing of channel coding and modulation gives operators more flexibility and a finer resolution on the curve of system gain verses delivered bandwidth.

Conclusion

High capacity wireless backhaul solutions provide a superior alternative to wired backhaul solutions in terms of available bandwidth (copper), cost (fiber) and ease of installation (both). Adaptive Coding and Modulation (ACM) which was designed to maximize spectrum usage and

Flex Your Backhaul Network with Adaptive Coding & Modulation

increase the capacity of wireless backhaul links at any link budget, now makes wireless solutions even more attractive. With ACM, network planners can better utilize their existing resources to increase the capacity and availability of their backhaul network.

Ceragon's FibeAir IP-10 which employs full-range dynamic ACM was introduced to the market on April 2008. This advanced solution sets new benchmarks in terms of capacity per-channel over any link budget, and enables carriers to significantly reduce the costs of equipment, frequency licensing, real-estate and more.

To learn more about Ceragon and its broad portfolio of Ethernet and TDM high-capacity wireless backhaul solutions please visit our website at: www.ceragon.com

FOR PRICING CONTACT:

MapleNet
WIRELESS

877-MAPLE-01
sales@maplenetwireless.com
www.maplenetwireless.com

 CERAGON

"Best Value Added Reseller"
2007 & 2008 Award Winner