ACM is the key to next-generation backhaul

Ran Soffer of Provigent explains how adaptive code and modulation optimizes a backhaul link whatever the local conditions.

Cellular networks are evolving rapidly from traditional circuit-switched voice traffic to mixed voice and data traffic, which is increasingly reliant on packet-switched data transmission. At the same time, the high-capacity data and video services enabled by the 2.5G and 3G radio networks have dramatically increased demands on the cellular backhaul network.

Bandwidth use per subscriber is growing thanks to increased competition among operators to provide data services. However, the revenue generated on a per-bit, per-Hz basis is not increasing significantly so operators are seeking efficient network technologies that can lower the cost of delivering data services.

Emerging technology

Adaptive code and modulation (ACM) backhaul technology provides a way forward for operators. This emerging technology allows operators to achieve high-capacity data transmission over microwave links and improve the link utilization. This reduces both operational and capital expenditures for maintaining high-capacity links. Link modulation and forward error correction (FEC) can be changed on the fly (depending on the link conditions) without any loss of data. ACM can also maintain the highest link spectral efficiency possible at any given time in any link condition.

In traditional voice-dominated wireless backhaul transmission networks, service availability levels of 99.999% are the norm. However, newer services such as Internet browsing, video streaming and video conferencing can operate at more relaxed availability levels. ACM can separate various services into different class types and then allocate the required availability based on class. As a result, high-class services such as voice enjoy 99.999% availability, while lower-class services like video streaming are allocated lower levels of availability.

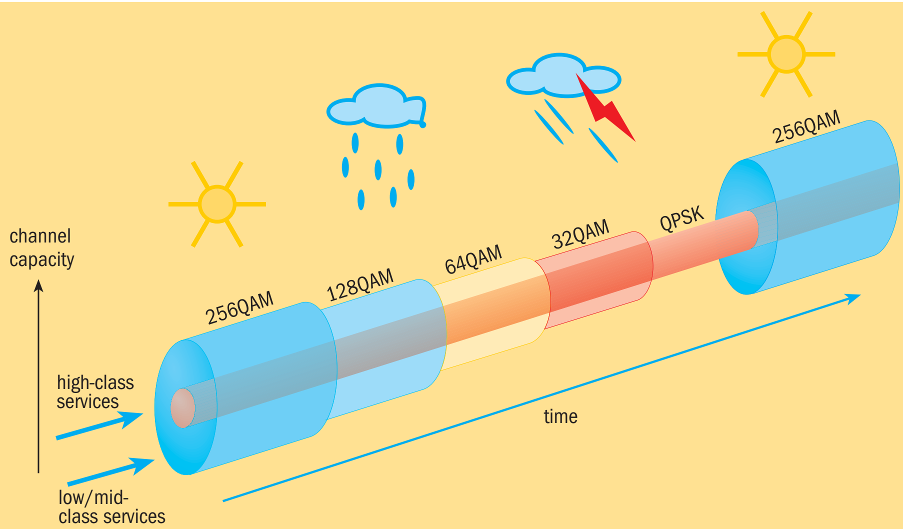
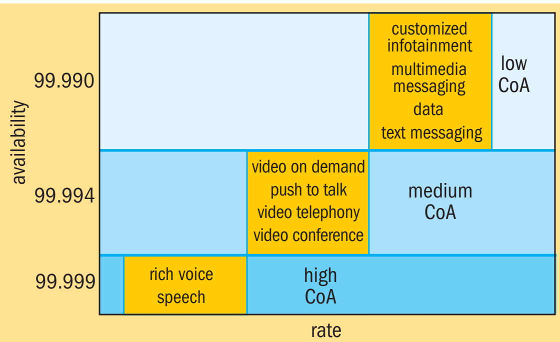


Fig. 1. Channel capacity is decreased in bad weather while maintaining high-class services with full bandwidth capacity. This is achieved by adapting the bandwidth capacity of low- and mid-class services.

Fig. 2. Different classes of service (CoS) are mapped into different classes of availability.



ACM uses the class of service to define which services should be transmitted under any link condition and which services should be adapted whenever the link condition is degraded and the link payload is decreased. For example, when bad weather has decreased the channel capacity of a link, ACM maintains high-class services – such as E1 channels – with full bandwidth capacity while adapting the bandwidth capacity of low- and mid-class services such as Internet browsing (see figure 1).

Traffic can be mapped into different classes of service (CoS), which define the level of service for each application. Figure 2 illustrates how different CoS – such as rich voice and video – are mapped into different classes of availability (CoA) such as 99.999% or 99.99%.

The implementation of multiple CoA increases the available capacity up to 10 times that of standard links. When conditions are

Fig. 3. Each adaptive code and modulation (ACM) profile has a different spectral efficiency, derived from its modulation and forward error correction (FEC).

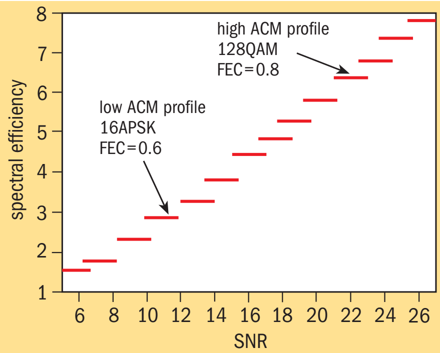
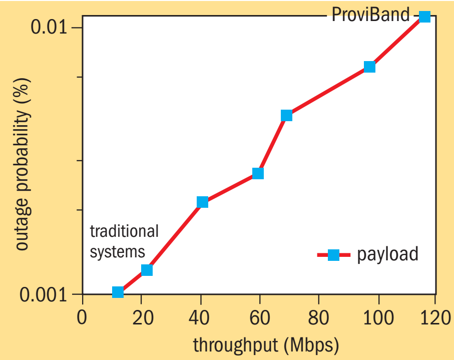


Fig. 4. In this case study, the system automatically monitored the link conditions and adaptively changed the capacity without interrupting the data.



clear, the wireless link operates at maximum capacity and provides all services with the full data rate. When link conditions are poor – during harsh rain, for example – predefined high-availability services such as voice are not affected. However, the capacity of lower-priority services is adapted dynamically to the changing link conditions. This is done by provisioning bandwidth according to the link conditions and traffic priority.

Increasing capacity

The US-based fabless semiconductor company Provigent is a pioneer in creating ACM implementations for the wireless backhaul. The company has developed a new technology called ProviBand, which increases the capacity of backhaul links by a factor of ten. By combining Provigent's PVG310 single-chip modem with ProviBand, equipment makers can design adaptive rate systems that can meet the requirements of mixed TDM and IP high-capacity traffic in next-generation backhaul networks.

ACM enables changes to the forward error correction (FEC) code rate and modulation on the fly according to the current condition of the link. ACM is implemented at both ends of the link – transmitter and receiver – which ensures that changes in the modulation and/or FEC occur synchronously throughout the link. The link condition is determined using several indicators, thus enabling swift adaptation of the spectral efficiency to maintain the link during fast-fading changes.

An ACM profile defines the link parameters (modulation and FEC) for a given range of the signal-to-noise ratio (SNR). The SNR range of each profile defines the threshold for switching from one ACM profile to another. Each ACM profile has a different spectral efficiency, derived from its modulation and FEC, as shown in figure 3. For example, the profile labelled "High ACM Profile" in figure 2 is suitable for an SNR range of 21–23 dB, and has a spectral efficiency of 6.8 bit/Hz. When link degradation causes the SNR to fall below 21 dB, a lower ACM profile is used. An example being the "Low ACM Profile" in figure 3, which is suitable for an SNR range of 9.9–11.9 dB and delivers a spectral efficiency of 3.8 bit/Hz.

The ACM profile also defines the data rate of each service, which ensures that high-class services will always be allocated the required constant bandwidth. Bandwidth is allocated to other services based on the link condition. The ACM profile also guarantees that the total data rate of all services equals the link data rate.

The receiver continuously monitors the link condition based on estimators like SNR, received signal level and bit-error rate. The trigger for switching ACM profiles varies from one algorithm to another. For example, it can occur when either an indicator threshold or an indicator gradient threshold is crossed. Some algorithms use several indicators to improve the ACM switching performance and reliability. ACM algorithms will usually include hysteresis to avoid undesired switching when there is jitter between two ACM profiles.

Once the estimators at the receiver side show that the link performance is not suitable for the current ACM profile, an ACM switching process will be initiated. In case of degradation in the link performance, the new ACM profile will include higher FEC and/or lower modulation, decreasing the link bit/Hz ratio. The ACM switching rate is measured in dB/s and is a key feature of ACM systems. In general, the higher the switching rate, the better the system's immunity to rapid SNR changes. When the switching is being executed, the payload rate is being modified to fit the aggregated data rate to the new available link data rate.

Case study

The following case study illustrates the benefits of ACM. Consider a backhaul microwave link operating at 23 GHz with 28 MHz channel spacing and 35 dB (30 cm) antenna gain. The link is operating in a rain region similar to Zurich, Switzerland.

The system operation was set to a minimal payload of eight E1 connections plus 10 Mb/s Ethernet for 99.999% availability. Using the new ACM technology, the system was able to operate most of the time at 130 Mb/s, depending on the link conditions. Most of the time the system could support a 100 Mb/s Ethernet connection instead of a 10 Mb/s connection. The system automatically monitored the link conditions and changed the capacity without interrupting the data transmission (hitless changes), as shown in figure 4.

This example demonstrates how the new technology, based on an ACM mechanism, can play a key role in the development of cost-effective next-generation wireless access networks, by taking advantage of traffic evolution from synchronous TDM traffic to packet IP-based traffic.

End-to-end solution

Provigent's complete, end-to-end ACM solution supports the range of modulation schemes, from quadrature phase shift keying (QPSK) all the way to 256 quadrature amplitude modulation (QAM). It also manages the physical layer and automatically changes the modulation and FEC code rate according to the link conditions. The most suitable ACM profile is chosen in real time – out of a wide range of available ACM profiles – in order to reach maximum spectral efficiency in any given link condition. The bandwidth for each service is adjusted automatically based on the service's CoS. The switching rate is very fast, complying with a fade rate of 100 dB/s to enable maintaining the link even during highly rapid SNR changes.

The new ACM technique enables operators to support high-end 2.5/3G applications – such as video and web browsing – while maintaining low operational and capital expenditures. The technology includes all the key potentials to move cellular networks backhaul to new horizons and stands poised to be one of the baseline features of any 2.5/3G cellular network.

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