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Adaptive Rate Technology Goes the Distance

Advancements in adaptive rate technology provide a more compelling solution for high frequency bands.

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By Gregg Levin, BridgeWave Communications Inc.

As more and mission-critical voice and data traffic traverses high-capacity wireless networks, high-speed millimeter wave RF systems are gaining ground for improved security, reliability, availability and value. The most-recently allocated 60GHz and 80GHz wireless frequency bands are becoming accepted as preferred solutions for extending gigabit LANs between sites, connecting locations to fiber-optic backbones as well as creating "virtual fiber" backbones through a metropolitan area, without the costs and delays of new metro fiber runs.

These upper millimeter-wave frequency bands feature multi-gigahertz spectrum allocations that can be used on an un-channelized basis, providing multi-gigabit data transmission utilizing simple, low-order modulation techniques. The use of "pencil beam" antennas enables large-scale frequency re-use and provides interference immunity, making the need for traditional narrow RF channel assignments unnecessary.

The laws of physics dictate that rain downpours attenuate RF signals by scattering energy off of the desired path. This is especially true for radios with operating frequencies of more than 10 GHz, so itâ€™s important to provision links with sufficient RF link margin to prevent outages during severe rainfall. Traditional tools for adding link budget involve larger antennas or decreased link data rates. Larger antennas improve the focus of energy between two end points, enabling provision of links with enough RF link margin to prevent outages during heavy rain. Still, they add installation time and expense to deployment. Reducing data capacity is another way to improve link budget by using narrower frequency channels and/or permitting the use of lower-order modulation, but this is accomplished at the cost of reduced application performance.

Adaptive Modulation

Rather than permanently reducing link data capacity or link availability, it is preferable to decrease link capacity during brief periods of intense rainfall, thereby maintaining full link performance for the vast majority of the time. The traditional means of temporarily providing additional link budget to overcome rain fades has been "adaptive modulation" rate schemes. These permit radio links to switch dynamically from higher-order modulation (e.g., 64-to-1024 QAM) to lower-order (e.g.,

QPSK, BFSK or 16 QAM) to provide improved receiver sensitivity when

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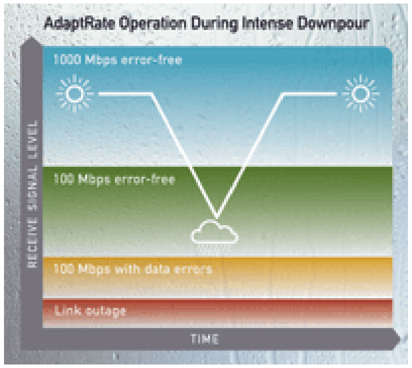

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Figure 1. Adaptive Rate technology automatically switches between full GigE and 100 Mb/s data rates when needed to overcome the temporary effects of intense rain downpours.

needed. These approaches are effective for radios operating in 11-38GHz frequency ranges because changes in modulation can provide sufficient increases in link budgets to overcome rain fades. In addition, the cost of highly linear transmit power amplifiers, required for high-order modulation, is acceptable in these ranges.

The Emergence of New Adaptive Rate Technology

Adaptive modulation is not attractive, however, in the case of gigabit speed radio links in the newer 60 GHz and 80 GHz ranges. The cost of providing highly linear transmit power amplification is much greater here than in the lower frequencies. Therefore, it is more desirable to use only lower-order modulation, while taking advantage of massive spectrum allocations available in these frequency ranges.

Recently, advancements in adaptive rate technology provide a more compelling solution for these high frequency bands. Temporary increases in link budget can be achieved, when needed, by reducing over-the-air signal bandwidthâ€”instead of changing modulation order. Decreasing air signal bandwidth by a factor of 10 (e.g. from 1.4 GHz to 140 MHz, as shown in Figure 2) lowers the amount of background noise the received RF signal must exceed by a factor of 10 (or 10 dB). This reduction provides an additional 10 dB of rain fade link budget, which is enough to improve availability significantly when strong rain presents challenges.

This breakthrough permits links that normally run at full-rate, full-duplex GigE speeds to shift automatically to an over-the-air 100 Mb/s data rate during heavy rainfall, thus gaining 10 dB rain fade budget. The RF bandwidth reduction of adaptive rate technology permits the links to remain connected at the maximum error-free data rate — despite severe rainfall. As shown in Figure 1, the switch from GigE to 100 mb/s occurs when the radioâ€™s RF-receive signal level (RSL) approaches the minimum for the link to operate error-free at full GigE data rates. When the rain subsides and RSL increases beyond the minimum for error-free GigE operation, the links immediately shift back to full GigE.

Not only does adaptive rate make possible remaining in operation during downpours, the technology can permit link operation over distances that previously would only be supported reliably by reduced data rate links. For example, a 60GHz link covering one kilometer in Miami (the heaviest rain region in the U.S.) that must deliver 99.99% availability (i.e., less than one hour a year in downtime due to rainfall) previously had no alternative to achieve "four nines" at much above 100 Mb/s. With adaptive rate, desired uptime could be met 99.9% of the time at full GigE, while operating at 100 mb/s for the remaining 0.09%.

For another example of adaptive rate products in the real world, consider an 80 GHz GigE link with a one-foot antenna installed in Los Angeles. While such an implementation normally can provide 99.99 percent availability at up to 2.4 miles, with the addition of adaptive rate capability, the link can operate at 3.6 milesâ€”a 50% increase without using larger antennas.

Application Interfaces

When faced with strong rain fade, these GigE adaptive rate links reduce their RF air interface bandwidth and data rate, but do not make corresponding changes to their fiber or copper (wired) interfaces. The wired interfaces continuously operate at full GigE speedâ€”regardless of air interface speed. In addition, thereâ€™s no immediate impact on wired interface traffic because radios using internal Ethernet switches can buffer inbound and outbound traffic between wired and air interfaces.

TCP/IP traffic entering the radio via wired interfaces will naturally slow, if needed, in response to delays in peer acknowledgements and/or momentary packet losses due to short-term traffic congestion. If the radioâ€™s wired port is

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configured with flow control enabled and traffic inbound to the radio exceeds 100 Mb/s, the radio will send the end-userâ€™s network equipment an Ethernet pause request to prevent data overflow within the radio. This lets the network equipment provide back-pressure through the network and prioritize the radioâ€™s traffic flow.

When traffic sent through the link contains both high priority (e.g., VoIP) and lower-priority (e.g., web browsing) packets, and the userâ€™s network equipment is configured to prioritize high priority packets, the result is high-priority packets continue to flow without impact (assuming traffic is less than 100 mb/s), while lower-priority traffic will throttle back to accommodate reduced bandwidth. This capability makes adaptive rate technology suitable even for the most demanding applicationsâ€"such as mobile backhaul, where high-value voice traffic typically consumes much less bandwidth than general end-user data traffic.

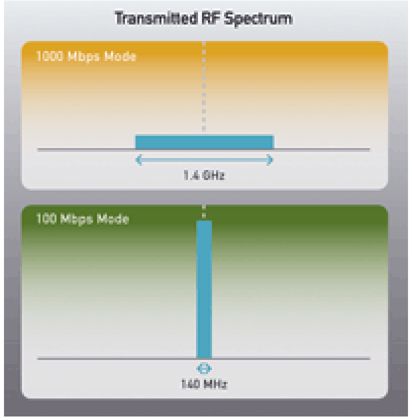

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Figure 2. This diagram illustrates the differences between transmitted RF spectrum at 1000 Mb/s and 100 Mb/s data rates. When operating in 100 Mb/s mode, over-the-air signal bandwidth is reduced by a factor of 10, which improves the signal-to-noise ratio of the received RF signal by a corresponding factor of 10.

Real-World Adaptive Rate Benefits

For Bayonne Medical Center (BMC), a 278-bed hospital in Hudson County, N.J., adaptive rate technology has delivered undeniable real-world benefits. In January 2007, when the facility needed to establish connectivity with recently acquired Richmond University Medical Center (RUMC), the decision was made to link the two locations, which are approximately 2.25 miles apart across a busy waterway that spans Upper New York Bay and Newark Bay.

Bayonneâ€™s IT team first rejected a bandwidth-constrained 45 Mb/s leased-line solution that would exceed $5,000 in monthly fees. They also ruled out aggregating multiple 52 Mb/s wireless radios as well as optical wireless using free-space optics because neither technology met reliability or distance requirements. However, they learned an 80 GHz millimeter wave product, from BridgeWave Communications, that includes an AdaptRate™ capability could bridge the 2.25 miles between the hospitals, while meeting stringent criteria for security, uptime and capacity. The AR80X wireless links momentarily switch from GigE to 100 Mb/s to provide continuous operation during heavy rain.

Relying on a rain model developed by the International Telecommunication Union (ITU), BMC was able to determine the GigE link could be impaired less than 30 minutes a year. If the occasional norâ€™easter occurred, the adaptive rate feature would automatically switch connectivity from GigE to 100 Mb/s to further reduce the likelihood of network downtime. For BMC, the unprecedented availability provided by an adaptive rate solution clinched the deal while delivering outstanding value-for-performance with a projected ROI of two years when compared to slower fiber-optic based alternatives.

Medical X-Ray Center, a practice radiology center that serves hospitals and clinics throughout South Dakota, Minnesota and Iowa, also relies on a millimeter wave link with adaptive rate technology to support a secure, HIPAA-compliant metropolitan area network. Having reliable, highly available connectivity between the center and a nearby hospital was critical to daily patient care as well as the continuing success of the business.

In seeking replacements for an aging, inadequate wireless bridge, Medical X-Ray Center determined at least 700 mb/s of bandwidth was needed to ensure access to a Picture Archiving Communications System (PACS) and customized patient treatment plans. Fiber-optic services were considered but rejected after discovering Gigabit Ethernet leased lines would cost approximately $10,000 a month.

After a thorough evaluation of wireless alternatives, Medical X-Ray Center deployed a combination of license-free 60GHz and licensed-band 80 GHz wireless links with adaptive rate technology for increased link availability. The links have performed flawlessly, with adaptive rate ensuring maximum uptime with transparent switch-over during heavy rainfall. All the Gigabit wireless products have exceeded Medical X-Ray Centerâ€™s expectations in terms of capacity, security and reliability while boosting overall productivity and yielding a seven-month ROI.

Gigabit Wireless Gains Momentum

The ability to go farther with high availability will continue to create unprecedented opportunities in the GigE wireless market for an assortment of implementations, including inter-building LAN extensions and IT consolidations; fiber redundancy and business continuity; IP video entertainment, conferencing and video surveillance; low-latency, high QoS VoIP; medical imaging and electronic records; IT outsourcing and 4G/WiMAX mobile backhaul. When the impact of heavy rainfall is a top consideration, adaptive rate technology is providing a "future proof" solution that delivers up to "five nines" link uptimeâ€"in all weather conditions. About the Author

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