White Paper

Overcoming Interference in the Unlicensed Wireless Spectrum

Overview

Wireless communications affords numerous advantages, even in the industrialized world where wiring is abundant. Wireless is flexible and affordable. The standards involved are now mature, secure, and fully interoperable. Wireless access is now a standard, integral feature in most laptop PCs and PDAs. Users enjoy the untethered freedom to move about while staying in touch. Performance is very good—and getting better. So good, in fact, that broadband wireless now competes successfully against digital subscriber line (DSL) and cable technologies in the access market. With these and other advantages, WinterGreen Research expects the market for broadband wireless access to grow to $12.4 billion by 2010.

But many wireless technologies fall short of the carrier-class capabilities needed to support commercial and consumer access. Radio frequency (RF) interference plagues some deployments, especially in the crowded 2.4 GHz spectrum. The main sources of this interference include other RF equipment operating in the vicinity and nodes in the wireless network itself (both direct transmissions and multipath reflections). Line-of-sight obstructions block and attenuate RF signals, creating voids in the service area and unsatisfied users. Government regulations, which place strict limits on transmission power levels, make it difficult or impossible for some solutions to overcome these challenges. The result is poor performance, a lack of scalability, and undependable service in much of today's broadband wireless access infrastructure.

Recognizing that these obstacles are not insurmountable, SkyPilot Networks advanced the state-of-the-art in four areas to achieve carrier-class capabilities for both metropolitan and rural wireless access networks. Like many other solutions, the SkyPilot Carrier-Class Broadband Wireless System operates in the unlicensed spectrum available (without fees) worldwide. But unlike any other solution, SkyPilot has overcome every wireless obstacle to enhance performance, scalability and dependability, while preserving the interoperability, affordability, and other benefits of wireless communications.

The four SkyPilot innovations—involving directional power, link modulation optimization, network-wide traffic synchronization, and mesh networking—each represents a significant advance in technology. Taken together, the combination represents a major breakthrough that puts broadband wireless access on a carrier-class footing with the likes of the Public Switched Telephone Network (PSTN) and the cable infrastructure.

Sectorized Antenna Array with Directional Power Control

The SkyPilot system employs sectorized, directional antenna technology. The sectorized array consists of eight antenna elements, each with a 45° spread providing a total of 360° of coverage. By utilizing these individual, narrowly-focused antenna elements, the system can take advantage of the higher transmission power levels permitted under point-to-point regulations. Other topologies that consist of multiple point-to-point links, including point-to-multipoint and mesh, also benefit from these higher power levels that increase range, increase penetration, and improve the signal-to-noise ratio. When utilized individually, a single antenna sector can transmit at 28.2 W / 44.5 dBm EIRP (under FCC regulations), resulting in much longer range (up to 10 miles or 16 kilometers between nodes) and/or greater penetration through obstacles that attenuate RF signals.

The directional capabilities of the antenna array also permit more effective utilization of available spectrum by allowing simultaneous communication between nodes in neighboring areas. By directing its RF energy through narrow sectors in an optimal fashion, the SkyPilot design greatly reduces susceptibility to both internal and external interference. Mitigating self-interference allows for spectral and spatial re-use within the network, which increases aggregate capacity and permits densities not possible with other broadband wireless access solutions.

Dynamic Link Optimization with Variable Modulation

The SkyPilot system supports a full set of modulation techniques, including BPSK at 6 or 9 Mbps, QPSK at 12 or 18 Mbps, 16QAM at 24 or 36 Mbps and 64QAM at 48 or 54 Mbps. On a per-link basis, the SkyPilot system is able to select the optimal type of modulation—the one that strikes the best balance between error rate and throughput.

When a link is first established between two SkyPilot nodes, the various modulation rates are all tested with the receive power and packet error rate monitored for each. After this brief test period, the highest modulation rate with less than 0.5% packet error rate is selected. In an operating network, of course, retransmissions eliminate all errors in the actual traffic.

The quality of every link, as determined by its packet error rate, is monitored constantly and adjusted as necessary. In a period of heavy interference, for example, the modulation rate will be adjusted lower to improve link margin and reliability. If and when the interference is reduced, the modulation rate, and therefore link capacity, is automatically increased.

Traffic Synchronization to Deliver Peak Performance

SkyPilot added a synchronous, WiMAX-like Time-Division Duplex (TDD) transmission control protocol that schedules transmissions throughout the network, which, when combined with the directional antenna, virtually eliminates self-interference.

The ability to synchronize traffic on a network-wide basis overcomes the performance degradation caused by the half-duplex nature of wireless communications. As with any shared medium protocol, including Ethernet, all nodes within range of one another must "listen" before transmitting, and only one can transmit at a time. Without this process, "collisions" would occur regularly, halting all transmissions until the affected nodes recover. Naturally, this multi-access protocol is terribly inefficient. With wired Ethernet, the problem can be mitigated using brute force bandwidth. But in an RF environment, where bandwidth is not as copious, another approach is needed.

The SkyPilot TDD protocol leverages the directional antennas to schedule transmissions between nodes to avoid localized collisions and minimize the other self-interfering inefficiencies of sharing the air. A GPS receiver in each node provides the common clock to ensure precise synchronization. This makes the SkyPilot network inherently deterministic, which affords the low latency and low jitter needed to support demanding video and voice over IP (VoIP) applications.

Robust Mesh Topology for Scalability and Reliability

Mesh network topologies are not new. Indeed, both the PSTN and the Internet employ mesh topologies to achieve greater resiliency and scalability. The mesh topology has also been used in wireless networks, but with less success. Ironically, the problems with initial attempts at wireless mesh networking were all caused by what is normally a wireless advantage: the ability to communicate omnidirectionally. But omnidirectional traffic patterns inevitably turn a mesh into a mess as self-interference cripples throughput and undermines scalability.

All three innovations covered above, along with a few others, combine to make a SkyPilot mesh network topology the most efficient, scalable, and reliable to date. Like other mesh solutions, the SkyPilot system allows for multiple, redundant links among nodes. Unlike the others, however, SkyPilot adds the ability to select the best route end-to-end based on a "cost" assigned to each constituent link. The link cost takes into account the current bandwidth available in both directions (upstream/downstream), as well as the throughput available further along the route to the ultimate destination. The performance via these optimal routes is improved even more with directional transmissions that are synchronized network-wide at the maximum possible modulation rate.

Also like other mesh solutions, the SkyPilot system reroutes around links that fail completely or degrade significantly. But unlike the others, the SkyPilot Carrier-Class Broadband Wireless System can do this quickly, intelligently, and all the way to the egress point of the mesh. A complete failure triggers the necessary rerouting in under three seconds. Degradation is handled more gracefully, first with changes in modulation rates and link costs, and then (if necessary) with rerouting along a better path. At the egress point, the mesh topology is exploited to provide load-balancing and automatic failover among multiple base stations—thereby eliminating the need for a separate (and costly) load-balancing switch.

Conclusion

The SkyPilot Carrier-Class Broadband Wireless System is the first access solution in the industry to live up to what its name promises: wireless communications at broadband data rates with carrier-class reliability, scalability and manageability. And just as importantly, the SkyPilot approach to wireless service provision is both remarkably flexible and surprisingly affordable. To learn more how your access offering can benefit from the state-of-the-art advances in the SkyPilot system, visit SkyPilot on the Web at www.skypilot.com.

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