The Precious Radio Spectrum

As a youth reading about the history of radio propagation, I always liked the idea of the “ether.” It was comforting to imagine that there was some mysterious substance throughout space that supported radio wave propagation. I would watch the water ripple when I threw a rock into a pond, and I would have some understanding of how it must be with this substance they called the ether. I had a hard time getting used to the fact that radio signals propagate through empty space. What a miracle it is that we can speak and send signals through nothingness!

As I write, I’m looking out a window at the blue sky above and thinking about what a lot of empty space there is. Surely there is enough for everyone. I sometimes imagine how Marconi must have felt when his coherer detected the first pulses from the spark transmitter across the hill. The possibilities were infinite; a whole new universe had been opened for mankind.

Immediately following Marconi’s experiments, there was a decade at the beginning of the last century when any amateur could build a spark transmitter and get on the air, blasting radiation across the whole radio frequency band. In 1911 there were an estimated 100 radio amateurs in the United States and thousands of stations on the air. But the end of that radio anarchy was precipitated the night of 14 April 1912, when the Titanic sank. Hundreds of lives were saved because the sister ship, the California, had gone to bed. Within a month, a bill was introduced into the U.S. Congress to regulate the use of the radio frequency spectrum. Maybe, after all, there wasn’t enough for everyone.

Now I’m still looking at that blue sky above and thinking how full it must be of radio waves. If we could see those waves, like some kind of laser show, then the sky would be brilliantly lit with a rainbow of bright colors. It seems as if in that vastness of space there is almost no capacity left, and what little there is has become extraordinarily precious.

Last year when the European nations auctioned off the spectrum for third-generation wireless (3G), the auctions brought about US $190 billion. The governments excited in having raised such incredible amounts, but the carriers who bid were saddled with huge debts. In the United Kingdom the companies who bought the 3G spectrum paid enough money to have put a fiber into every home in the country, yet all they got was the right to use this spectrum.

In the meantime, engineers have been designing more efficient methods for the wireless transmission of information. New algorithms for signal processing and the inevitable progress in electronics described by Moore’s Law have opened up the possibility of an orders-of-magnitude improvement in efficiency. Some people are even saying that the wireless capacity is actually infinite, and that there is no reason for regulation at all.

Among the new technologies are adaptive antennas and the concept of space-to-space transmission, where only a narrow corridor of that empty space is occupied. Then there is the array processing of multipath signals, where all of the echoes of all the signals present are collected and optimally disentangled in space and time. Another technique uses successive interference cancellation, detecting and then subtracting out potentially interfering signals.

While all of these signal-processing algorithms promise much greater utilization of the radio spectrum, probably the most revolutionary concept is packet relay, in which each wireless device cooperatively forwards packets received from its neighbors toward their intended destinations. Much research has been done on these so-called ad hoc networks. Interestingly, such networks scale to infinite capacity; as the density of devices increases, each one lowers its transmitted power accordingly. While 3G moves ponderously forward, a quiet revolution is happening around IEEE 802.11, the wireless packet standard.

But all this technology is theory, not practice. In practice, the spectrum is full of legacy devices, blasting energy in the old ways over spectrum bought and owned by watchful tenants. After paying billions for the right to use a small slice of spectrum, owners are unlikely to embrace new invaders having nonstandard formats. The problem with spectrum is that we gave most of it away and then sold the rest.

So is wireless capacity limited and expensive, or is it infinite and free? And how do we get from here to there?