The Riches of White Space

The identification, control, and economic exploitation of new resources is the time-tested path to wealth: from the development of agriculture in Egypt leading to the Pharaohs, the conquest and control of the New World enriching the citizens of Europe, to the recent invention and commercialization of cyberspace, catapulting a gaggle of geeks to the ranks of the world's billionaires. A little-understood resource that has been discovered and heavily exploited during the last hundred years or so--leading to trillions of dollars in newfound wealth--is the radio spectrum. The radio spectrum is what allows us to transmit information in the form of radio waves. It is the resource underlying technologies such as AM and FM radio, TV, cell phones, WiFi, and Bluetooth headsets. In this article, I will explain the nature of this resource, its current monopolistic control, and the advent of shape-shifting technology that might lead to a fundamental change in the status quo.

Let's start with the basics. Each radio wave is associated with a frequency, which indicates how many wave crests or troughs go past a fixed point in one second. The highest-frequency waves in the spectrum whizz past at the rate of a trillion crests per second. These are the terahertz waves, used at some airports to see through baggage, and yes, clothes. Less frantic are the gigahertz waves that are used to heat food in microwave ovens, which oscillate at a mere billion times a second. Gigahertz waves are also used for WiFi transmissions. Slower yet are the megahertz and kilohertz waves that are mostly used for radio and TV transmissions.

The biggest problem with radio transmission is interference: if two transmitters transmitting at the same frequency can both be heard more or less equally well at some receiver, then that receiver cannot decipher either transmission and receives only noise. To prevent this problem, each country's government regulates the spectrum, allocating a chunk of spectrum to a single transmitter. Thus, spectrum allocation is inherently monopolistic (the spectrum allocation map for Canada can be found at http://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/spectallocation-08.pdf/$FILE/spectallocation-08.pdf).

Spectrum allocation would not be such a contentious issue if all frequencies were equally desirable. Radio waves at each frequency, however, have their own characteristics, such as how far they travel through the atmosphere (a good thing), the degree to which they are absorbed by water (a bad thing), and the amount of information they can carry (the higher the frequency, the better). Radio waves in the 50-1500 megahertz range hit the sweet spot, with a range of 10-30km, little water absorption, and tremendous information-carrying capacity. These are the ranges dominated by radio, TV, and cell phone communication. Bluetooth and WiFi, in contrast, are carried in a frequency band that was thought to be too marginal to be worth licensing: a range of only 100-300m, heavily absorbed by water, but with excellent information-carrying capacity. Using an analogy from real-estate, if TV stations are prime beachfront property, then WiFi is in the swampy, malarial lowlands.

How were fortunes made on the radio spectrum? In some countries, private radio and TV broadcasters got access to prime spectrum at no cost. Claiming to carry 'educational' content, these broadcasters got national governments to grant them lucrative monopolies at no charge. This allowed them to reap billions in advertising dollars at the expense of citizens who did not understand that their birthrights were being given away. Even in countries where the government itself took on the role of a broadcaster, privatization happened recently, when the Reagan-Thatcher mindset took hold, allowing private profit from public commons. Unlike radio and TV broadcasters, cell phone providers, for the most part, bought their spectrum resources in auctions. Although some countries were able to sell prime spectrum for tens of billions of dollars, cell phone providers recouped their costs in just a few years, and are now raking in the profits. It is no coincidence that the largest advertisers today are cell phone providers.

Surprisingly, despite being consigned to 'marginal' spectrum, WiFi and Bluetooth technologies have done very well for themselves. Lacking monopolistic allocations and onerous licensing requirements, computer networking companies have shown tremendous innovation, using marginal spectrum to support an industry that sells a billion WiFi devices a year.

In recent years, two advances in technology have brought the issue of spectrum allocation back into the public eye. First, digital TV transmission allows TV channels to be carried more efficiently, opening up 'white spaces' at a prime location (at the 700 megahertz range) in the spectrum map. Governments in the US and Canada are forcing their citizens towards digital TV so that they can auction off this portion of the spectrum and raise funds for themselves. Second, and more interestingly, computer networking researchers have developed techniques to rapidly detect the presence of a primary spectrum user so that secondary spectrum users can use this spectrum when it is otherwise idle. Like beach bums trespassing on hotel property disappearing when the guests arrive, these opportunistic spectrum users, using software rather than hardware to process radio signals, will allow what Larry Page, co-founder of Google, calls "WiFi on steroids" - cheap wireless broadband Internet. Last year, the US FCC sanctioned the presence of such secondary devices, and developing so-called 'white space devices' is an active area of research.

Together, these two developments indicate a move towards a more rational use of spectrum resources. It will be interesting to see how software-defined radios, with their ability to opportunistically use spectrum, change the established power structure: will Google and Microsoft become the new NBC and CBC? Only time will tell.