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Wi-Fi: cutting the cord

The story of the development of wireless local area networks (WLAN) is a good example of how a research project can open the doors to a whole new industry. Back in the 70s, a research team at the University of Hawaii was unsatisfied with the data connections over the telephone network that they used to access the central computers from remote locations. They envisioned a wireless network that transmitted digital data using radio communications. And they built it.

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The traffic pattern consisted of long periods with low traffic levels (keystrokes by the user) and short periods with high levels (output from the central computer to the user's display). So the researchers decided that all remote locations would share a single high-speed channel to transmit to the central Honolulu station. This way, each user would get the benefit of the high speed connection when needed. If two transmissions overlapped, the data was corrupted and had to be retransmitted. This wireless network, which was named AlohaNET, was very successful and it grew over the years. It was even connected to the early Internet.

Some of the fundamental principles of AlohaNET, such as the possibility of collisions and the need for retransmissions, were the cornerstone of the Ethernet wired local area networks (LANs). Ethernet has been an extremely successful technology that was broadly adopted. However, the requirement to be connected to a wire is burdensome for many applications. Imagine a mobile phone with an Ethernet port! So in the 90s, engineers started to work on wireless local area networks (WLANs) to provide Ethernet-like functionality without wires. Two competing standards for WLANs were developed in parallel: IEEE 802.11 and ETSI Hiperlan. The former was relatively simple and straightforward compared to the later, which contemplated more sophisticated features. Eventually, IEEE 802.11 won the market for WLAN equipment and is also known as Wi-Fi. 802.11/Wi-Fi again uses the collision/retransmission scheme used before by AlohaNET and Ethernet.

The Wi-Fi Alliance is a trade association where companies with interests in WLAN manufacturing and commercialization get together. A certification program is established and those IEEE 802.11 products that comply with the certification criteria and pass the interoperability test can use the Wi-Fi logo. Of paramount importance for the success of WLANs was the existence of an ISM frequency band. This band was initially reserved for free use for industrial, scientific and medical applications. The devices operating in this band have some restrictions regarding the maximum radiated power and the use of spread spectrum techniques, but are otherwise free to operate without paying any fees or requiring any license.

The aforementioned restrictions are in place to reduce the amount of interference that different devices cause to others using the same ISM band. With spread spectrum techniques, the frequency profile of a transmission is extended, widened and flattened. A pile of gravel in the middle of the road can be very annoying and interfere with traffic. But if that same pile is spread and flattened, it can be possible for cars to drive over it and the interference will not be as severe. In a similar way, spread spectrum techniques limit and alleviate the problem of interference. Frequency hopping (FH), direct sequence spread spectrum (DSSS) and orthogonal frequency division modulation (OFDM) are different spread spectrum techniques. All of them have been contemplated in IEEE 802.11 standards, even though nowadays OFDM is the only one that is used in new deployments.

The IEEE 802.11 standards have evolved to keep track of the progress of technology. This evolution takes the form of standard amendments, such as IEEE 802.11b (11 Mbps), IEEE 802.11a (54 Mbps), IEEE 802.11g (also 54 Mbps), and IEEE 802.11n (65 to 600 Mbps). The a, g and n flavors of the standard support OFDM. The standard amendments upgrade the standard to offer higher data rates or other features such as security or traffic differentiation. As an example, IEEE 802.11n products that we can find in the market supports multiple input multiple output (MIMO) flows, which means that the equipment can make use of multiple antennas to transmit different data flows in parallel. Nevertheless, to guarantee backward compatibility, new hardware can reduce it transmission speed to coexist with legacy hardware. It may also be necessary to reduce transmission speed if the channel conditions are unfavorable. The presence of many interferers or the attenuation of the signal due to distance (or obstacles) between the sender and receiver reduce the data rate. For this reason, wireless devices have a variable data rate that constantly adjusts to the environment.

When deploying a wireless network, it is worth paying attention to channel planning in order to choose those channels with lower interference. The different channels are not, by any means, isolated from each other. On the contrary, there is a substantial overlap between neighboring channels. Those devices that share the same channel will take turns to transmit. To do so, there is an arbitration protocol that details the behavior of standard compliant devices that permits a fair use of the channel. In principle, all the devices have the same opportunities to access the channel. It can be useful to imagine that the channel is a railway and different companies follow a protocol in such a way that they all can run the same number of trains over the railway. It can still happen that some companies run slow trains and thus occupy the railway for a very long time, while other companies run fast trains and occupy the shared resource for a shorter time. This can lead to a somewhat unfair situation. There is also the problem of the protocol overhead, which means that channel access arbitration consumes channel time. Imagine that the protocol says that two consecutive trains must be separated by, at least, one minute. If trains are long and slow and it takes them nine minutes to pass by, this represents only a ten per cent. But if those trains are short and fast and they require only one minute to pass by, then the overhead represents a fifty percent tax. As speed increases, the overhead problem becomes worse. The current tendency is to use longer packets (longer trains) to alleviate the overhead problem when high transmission speeds are used.

The improvements of IEEE 802.11 over time didn't only come in the form of higher speeds. Security has also been improved with the IEEE 802.11i standard amendment. The early Wi-Fi networks used a broken implementation of the RC4 cipher that used keys and initialization vectors that were too short, making it possible to hijack one of those networks in a matter of minutes of even seconds. With the advent of IEEE 802.11i, also known by its certification name WPA2, these problems were solved. WPA2 uses longer keys, robust ciphers and robust operation modes to guarantee confidentiality, integrity and access control.

A simple original design coupled with continuous improvements in speed and other aspects, as well as the relentless price pressure from wide adoption in the market place, have made 802.11 WLANs extremely successful.

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