# How we made the wireless network

Electronic devices today are untethered and always connected, and wireless networks have enabled this free flow of information. John O'Sullivan details the developments leading up to the establishment of the wireless network standard 802.11a, which is more commonly known as Wi-Fi.

John O'Sullivan

In the early 1990s, a few computing visionaries were starting to paint a picture of portable screens and intelligent assistants. I was taken by their vision, as were others including my collaborators David Skellern and Craig Mudge. At that time, it was the early days of portable computing, with large laptops and networking. It was several years before the World Wide Web became a dominant force, but e-mail and easy access to networked data were making an impression in research environments. The idea of cutting the wires, and creating a wireless network with speed equal to the best cabled networks, rapidly gained traction and support within CSIRO (the Commonwealth Scientific and Industrial Research Organisation), an Australian research agency. Bob Frater, Denis Redfern and Dennis Cooper were fervent supporters and funding was granted to set up a small group to develop a high-speed wireless network.

We were part of the CSIRO Division of Radiophysics, which researched areas ranging from astronomy and antennas to computing and processing hardware. I had joined Radiophysics with a challenge from Frater to use our skills from radio astronomy research to "make a difference" and to address commercial challenges. The wireless network project was a perfect fit to the breadth and depth of skills in our division. Moreover, the project was exciting and immense in both the effort needed and its potential impact.

A small team of people with backgrounds in physics, mathematics, wireless and digital engineering and software engineering came together and grew. The aim was to achieve 100 Mbit $s^{-1}$ data rates in indoor environments ranging from offices to lecture rooms. We quickly realized that sending bits one after another would run afoul of reverberation or echoes of previous bits, causing great confusion. After all, each bit would be roughly three metres long and typical echoes could traverse many times that length!

While it was, in principle, feasible to unscramble the received signal, we thought it would not be practical. Therefore, we started to consider the possibility of sending many bits at the same time using different frequency channels. It was in fact rather common for some of us to think in both time and frequency terms — a sort of mental double bookkeeping — so we started trying to understand the problem in terms of both time and Fourier domains. A core team consisting of myself, Diet Ostry, Graham Daniels, Terry Percival and John Deane actively pursued the frequency channel approach. We rapidly progressed from clumsy analogue multichannel architectures to digital using Fourier transforms. Indeed, I had previously led a different team in building a fast Fourier transform (FFT) processing chip, which we had developed in partnership with Austek Microsystems. This chip could function as a multipurpose signal processing tool with applications ranging from radar to medical imaging to astronomy. We realized that not only could we apply the multichannel approach to the wireless problem using a FFT, but it was both simple and practical given the steady advances in digital size and speed, as described by Moore's law.

As an aside, I had originally been inspired to look into FFT solutions after a series of astronomy experiments looking for the micro black holes that Stephen Hawking had predicted might evaporate and explode. We didn't find any, but the increasingly complex experimental set-up suggested to me that digital FFT engines would have many applications in astronomy and elsewhere.

The invention of a successful high-speed wireless network technology required a number of further significant developments. For example, coding was necessary to repair missing frequency channels and cyclic extension was used to simplify the receiver design. Like so many new technologies, the pieces were already in existence but the combination of these different elements to satisfy a demanding application was missing. The Australian patent application for a wireless network was filed in 1992 and the US patent was granted in 1996.

The collaboration with Skellern at Macquarie University and the CSIRO team grew. A test bed able to transmit signals over the air and demonstrate the technology at a range of frequencies allowed us to verify the performance in a variety of locations (Fig. 1). This collaboration achieved the first real-time implementation of the technology, which subsequently led to the start-up Radiata, founded by Skellern and Neil Weste from Macquarie University along with Percival. I later joined Radiata and had the immense thrill of being part of the team that, in 2000, demonstrated the first chips meeting the new wireless network standard 802.11a (the family of standards underpinning what later became known as Wi-Fi).

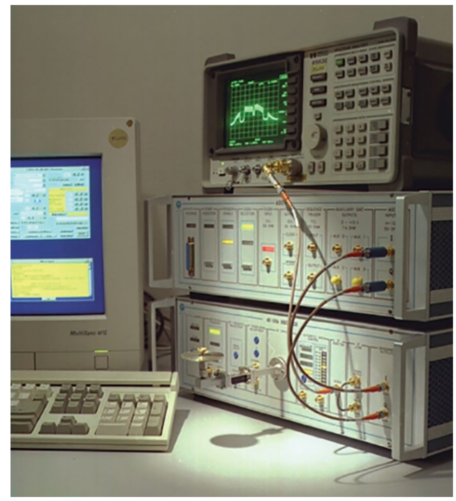

**Fig. 1 | The wireless local area network test bed that was built in 1992–1994.** The test bed was used to experiment with the technology at CSIRO Division of Radiophysics and Macquarie University. Credit: CSIRO.

Nowadays, connected devices are indispensable to many, and the legal efforts of CSIRO have led to substantial royalties from the wireless network technology, which have funded the next generation of researchers. A number of the team involved in the establishment of the technology are also still involved in the world's leading Wi-Fi companies. Many of us, I believe, owe a debt to those who gave us space to play, to learn and ultimately to make a difference. ❒

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