UNLICENSED INNOVATION: THE CASE OF WI-FI*

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Abstract

In this paper we describe the genesis and development of Wi-Fi as a combined result of (1) a change in the US communications radio spectrum policy in the 1980s, (2) the industry leadership provided by NCR, its corporate successors and collaborators, to create a global standard and to deliver compatible products under the Wi-Fi label, and (3) the influence of the users that moved the application of Wireless-LANs from the enterprise to the home, from indoor to outdoor use, from a communications product to a communications service, and from operators to end-users as the provider of that service. In concluding we assess the implications of this case for the formation of government policy and firm strategy. The case exploration and analysis is based on contributions by experts from the field, having been involved 'first hand' in the innovation journey of Wi-Fi.

Keywords: WLAN; IEEE 802.11; Wi-Fi; spectrum policy; firm strategy; sources of innovation; technology diffusion

1. INTRODUCTION

To-day, Wi-Fi has become the preferred means for connecting to the Internet – without wires: at home, in the office, in hotels, at airports, at the university campus.

* This paper draws upon a research project being executed within the Faculty Technology, Policy and Management at the Delft University of Technology (TUDelft) aimed at documenting the genesis and development of Wi-Fi. This is a multi-disciplinary and multi-national research project with a wide range of contributions from the academic community and the industry at large.
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Increasingly Wi-Fi provides access to the Internet for remote communities in developing countries, e.g. in the Himalayan mountains and in the Andes. Even in rural areas of developed countries, for instance, in Denmark a community based Wi-Fi initiative emerged to provide broadband wireless Internet access, as the incumbent operator failed to extend the infrastructure to less profitable areas in a timely manner.

This is a remarkable result as wireless local area networking (WLAN) was not on the radar screen of the US Federal Communication Commission (FCC) when in 1980 it initiated a market assessment that would lead to its landmark decision of 1985, whereby it decided to open up three radio frequency bands designated for Industrial, Scientific and Medical (ISM) applications for the use by radio communication systems, including WLANs.

In hindsight, this should not come as a surprise. The Ethernet, which would become the standard for wired-LANs, was still subject of a major standardization battle within the IEEE in 1980. Moreover, recall that the Apple II had been launched in 1977, while the IBM PC would be introduced in 1981, and the Internet would be named in 1984. Mobile computing equipment like laptops and notebooks still had to be conceived.

The current success of Wi-Fi is remarkable in more ways. Hitherto, the most significant developments in radio frequency technology—radio-relay systems, radio and television broadcasting—had emerged under a licensed regime, whereby a government agency provides exclusive rights to the use of a specific part of the radio frequency spectrum, thereby providing the application protection from interference by other radio frequency applications and users. The success of Wi-Fi, however, emerged under a license-exempt regime, whereby it had to contend with many other applications and users in the same radio frequency band, including micro-wave ovens and radar equipment.

In this paper we will explore the innovation journey that has resulted in the global success of Wi-Fi, in the form of a descriptive longitudinal case study. The case starts in 1980 when the US Federal Communications Commission initiates a study into the public use of spread spectrum techniques leading to its rulemaking in 1985. We describe how this opportunity is used by the industry, thereby focusing on the developments at NCR and its corporate successors to develop, market and sell a new Wireless-LAN product. The choice of NCR stems from the leading role it assumed in the creation and adoption of a global Wireless-LAN standard: IEEE 802.11. Subsequently we will explore how Wi-Fi is being deployed and shaped by the users, as part of commercial service offerings by "hotspot" operators and through deployment as part of community initiatives and municipal networks. We conclude with a discussion of the implications of this case for government policy and firm strategy.

2. TRIGGERED BY US POLICY

A critical input to the development, production and application of any wireless device is the permission to use the radio frequency spectrum. This permission has typically to be granted by a government agency, as in the current spectrum management paradigm the national governments have taken ownership of the frequency spectrum as a natural resource and assign parts of the spectrum to certain applications and users upon request or as a result of policy it executes (Hazlett, 2006). In the case of Wi-Fi the first permission is the Report and Order of May 9, 1985 of the US Federal Communication Commission[1] to "[authorize] spread spectrum and other wideband emissions not presently provided for in the FCC Rules and Regulations" (FCC, 1985).

The political climate was set by the Carter Administration and FCC Chairman Charles Ferris intended to extend the deregulation spirit to the radio frequency spectrum. He would like to end the practice whereby numerous requests for spectrum would be brought forward, based on special cases of technology application. The adagio was 'let us unrestrict the restricted technologies' (Marcus, 2007; 2008). Dr. Stephen J. Lukasik the first Chief Scientist of the FCC, was requested to identify new communications technologies that were being blocked by anachronistic rules. It was Dr. Michael J. Marcus, employed at the Institute of Defense Analysis, who suggested that spread spectrum was such a technology and as a consequence was invited to join the FCC to follow up on the idea. In December 1979 the MITRE Corporation was invited to investigate the potential civil usage of spread spectrum. Their report of 1980 started the public consultation process on the use of spread spectrum technology.[2]

1 The Federal Communications Commission is an United States government agency, directly responsible to Congress. The FCC was established by the Communications Act of 1934 and is charged with regulating interstate and international communications by radio, television, wire, satellite and cable. The FCC's jurisdiction covers the 50 states, the District of Columbia, and U.S. possessions (FCC, 2007).

2 When the FCC receives petitions for new rule making, or if they see themselves a need to make a rules change, they have to organise a public consultation in the form of a "Notice of Inquiry, NoI". The public at large is invited to comment within a set period after which the public is requested to provide comment on comments, the so-called Reply Comments.
All comments have to be addressed in the subsequent consultation round, the so called "Notice of Proposed Rule Making, NPRM". In this document, the FCC also provide the proposed new rules with the reasons for their choices. This round is also followed by a comment and reply comment period.
Again, the FCC has the obligation to address all comments and reply comments and publishes the results in a "Report and Order, R&O". Sometimes, a "Further Notice of Proposed Rulemaking, FNPRM" is included when the Order is only partially completed. A comment and reply comment period automatically follows the FNPRM.
Issues found in the Order can only be appealed in Petitions for Reconsideration.

2.1. THE ORIGIN OF SPREAD SPECTRUM

In the Notice of Inquiry the FCC proposed the civil use of spread spectrum (FCC, 1981). Until 1981 this technique had remained officially classified as military technology (Mock, 2005). The invention of spread spectrum, in the form of frequency hopping, dates back to 1942 when a patent was granted to actress Hedy Lamarr and composer George Antheil: U.S. Patent # 2,292,387, issued on August 11, under the title: "*Secret Communications System*". Lamarr, born as Hedwig Eva Maria Kiesler in 1913 in Vienna, had been married to Friedrich Mandl, an Austrian arms manufacturer, which had exposed her to discussions on the jamming of radio-guided torpedo's launched from submarines. In 1937 Kiesler left Austria for America, under a contract with MGM. Here, she met with the composer George Antheil. Their combined insights in technology and music generated the idea to change the carrier frequency on a regular basis, akin to changing the frequency when striking another key on the piano. They presented their idea to the National Inventors Council and subsequently donated their patent to the U.S. military as a contribution to the war effort. However, the first practical application was after the war, in the mid 1950s, in sonobuoys used to secretly locate submarines (Mock, 2005 p11–7). The first serial production of systems based on direct sequence spread spectrum were most probably the Magnavox AN/ARC-50 and ARC-90 airborne systems. There are most probably other early systems that have remained classified (Marcus, 2007).

2.2. THE FCC REPORT & ORDER

Interestingly, the MITRE report that investigated the potential benefits, costs, and risks of spread spectrum communications did not identify a strong requirement or need from the industry to assign spectrum for spread spectrum applications. The report concludes that "many potential spread spectrum applications are likely to be economically unattractive", other potential applications "...may be economically feasible, but may make poor use of the spectrum resources that they would require" and "[i]n certain applications, spread spectrum techniques can make more efficient use of the spectrum than the usual implementation of narrowband techniques... ...when the information bandwidth per user is low and the operating frequency is high" (Mitre Corp., 1980 p6–1 to 6–2). In the analysis it was recognized that spread spectrum is inherently more resistant to interference. The MITRE report had identified the bands designated for Industrial, Scientific and Medical applications (ISM bands) as bands "...in which spread spectrum techniques may be able to improve the utilization of the spectrum...[as these bands] are relatively unsuitable for applications requiring guaranteed high levels of performance. Indeed, since users of the ISM bands are not nominally protected from interference, it can be argued that any productive use of these bands frees other spectrum resources that are needed by applications requiring protection from interference" (1980 p6–4). Typical applications in the ISM bands were garage door openers, retail security systems, cordless telephones and includes the operation of microwave ovens. Hitherto no communications applications were permitted in the ISM bands.[3]

The FCC Notice of Inquiry proposed to use spread spectrum as an "underlay" within other bands, i.e. sharing the frequencies with other services.[4] The Notice triggered comments expressing fear of interference and the difficulty of tracing the source of interference. Based on the responses the FCC proposed two rules changes: one for licensed use of spread spectrum in the police bands and one for unlicensed use. The unlicensed proposal called for an overlay on the spectrum above 70 MHz at very low power (below –41 dBm) and one for unspecified power limits in the 3 bands designated for ISM applications (Marcus, 2007). The Further Notice and Notice of Proposed Rulemaking triggered more comments, whereby many of the respondents favoured the proposed authorization (FCC, 1984). Subsequently the FCC deferred all actions on all but the Police radio service and the use of spread spectrum in the three bands designated for ISM applications: the 902–926 MHz, the 2400–2483.5 MHz and the 5725–5850 MHz bands (FCC, 1985).[5]

This FCC rulemaking that would ultimately lead to the global success of Wi-Fi had an interesting final twist. After the release of the spread spectrum authorization, the whole top leadership of the FCC Office of Science and Technology was exiled, possibly as a result of actions by the industry being concerned about the deregulation that would make the FCC less responsive to major manufacturers who wanted new technology only made available when it was convenient to them. An attempt was made to fire one deputy, and the name of the Office was changed into Office of Engineering and Technology. The position of Marcus was eliminated and an attempt was made to dismiss him from the FCC. According to Marcus: "In the months following the spread spectrum decision three top manager of the Office of Science and Technology were removed and the new organisation took no similar bold initiatives for almost a decade." (Marcus, 2007; 2008).

3. DEVELOPED BY INDUSTRY, WITH NCR IN THE LEAD

Some FCC staff members had opposed the rule changes out of fear that the new rules to be adopted would never be used. The reality proved otherwise. The authorizations

3 In Europe, some communication services were permitted in the ISM bands: video surveillance by police, and news gathering services such as the video connections between mobile cameras on motorbikes and helicopters to follow the Tour de France.

4 This underlay approach was similar to the approach the FCC adopted in 2003 for Ultra Wide Band (UWB), but in 1981 it was an idea ahead of its time (Marcus, 2007).

5 The limitation on peak power was set at a level of 1 Watt for the three ISM bands. No limitations on the antenna gain were specified.

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