THREE

Geeks, Cowboys, and Bureaucrats: Deploying Broadband, the Wireless Way

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ABSTRACT: The advent of new unlicensed wireless technologies allows a variety of new actors – from co-operatives to municipalities – to deploy and operate communication networks. This article reviews the evolution of the new breed of wireless technologies, in particular Wireless Fidelity (Wi-Fi), and discusses its implications for the architecture and control of emerging wireless broadband networks. Drawing on the social constructivist history of large technical systems and the work of economic historians concerned with the evolution of technology, the article explores the largely unexpected success of Wi-Fi. It then reviews the evidence to date on the bottom-up deployment of wireless networks by local actors in the United States, focusing on three types of initiatives driven by different deployment dynamics: end-user co-operatives (the "geeks"), wireless internet service providers ("cowboys"), and municipal government ("bureaucrats"). The conclusion discusses the policy and institutional issues most likely to affect the balance between centralised and decentralised deployment of wireless broadband networks in the near future, and suggests possible implications for the developing world.

Introduction

The deployment of communication infrastructure has traditionally been associated with big investment programmes undertaken by large entities such as telecommunications operators and Government agencies. The reason is quite simple: only these entities were able to amass the sizeable capital and attain the necessary economies of scale involved in deploying wired networks. However, three parallel trends are converging to permit departure from that tradition: the emergence of more flexible spectrum policies, which has removed regulatory barriers to entry; the advent of new wireless technologies, which has fundamentally changed the cost equation in favour of wireless solutions; and the entry of many small business and non-profit actors eager to play new roles in the creation and management of wireless communication networks.

While advances in wireless technologies have significantly reduced the deployment costs for communications infrastructure, their transformative impact on the architecture and control of communication networks is often overlooked. Because wireless technologies are not subject to the same economies of scale as traditional wireline technologies, they allow end users – often acting collectively through co-operatives and other local institutions – to deploy and manage systems themselves in ways not previously possible. This in turn pushes the boundary that divides control between users and providers much deeper into the network, opening the possibility of a radically decentralised approach to system expansion, based on the integration of local wireless networks built and managed by users. While most of today's networks continue to be built by large organisations, the evidence increasingly points to a potentially disruptive shift in the way wireless communication networks are being deployed and operated (Best, 2003; Bar & Galperin, 2004).

The tension between these two alternative logics of network deployment is well illustrated in the case of wireless Internet access services. One the one hand, mobile telephony operators have made considerable investments to deploy third-generation (3G) networks that allow mobile customers to access a variety of services based on the Internet Protocol (IP). On the other, wireless enthusiasts, small entrepreneurs, and local Governments are increasingly taking advantage of a new breed of wireless networking technologies to build wireless local area networks (WLANs), particularly in areas neglected by large operators. 3G networks follow the traditional model of large investments in infrastructure equipment for centrally-planned and controlled networks; WLANs on the other hand consist of small investments in terminal equipment by independent actors at the local level without co-ordination or a pre-conceived plan. While both are evolving in parallel (and some argue, are complementary), the tension is evident in recent policy debates about how to allocate limited resources (notably the radio spectrum), and the role played by local Governments and co-operative organisations in the deployment of advanced wireless networks.

This article is organised as follows: in the first part we review the evolution of the new breed of WLAN technologies, in particular Wireless Fidelity (Wi-Fi), and discuss its implications for the architecture and control of emerging wireless broadband networks. We draw on the social constructivist history of large technical systems and the work of economic historians concerned with the evolution of technology, to understand the largely unexpected success of Wi-Fi. Next we review the evidence on the bottom-up deployment of wireless networks by local actors, focusing on three types of initiatives driven by different deployment dynamics: end-user co-operatives (affectionately referred to as "geeks" in our title), wireless internet service providers or WISPs ("cowboys"), and municipal Government ("bureaucrats"). The conclusion discusses the policy and institutional issues most likely to affect the balance between centralised and decentralised deployment of wireless broadband networks in the near future.

From the cordless Ethernet to the wireless mesh: The unexpected evolution of Wi-Fi

"WLAN technologies" refers to a broad family of non-cellular wireless communication solutions, which in practice includes most of the technologies currently under the purview of the IEEE 802.xx standardisation activities. While this encompasses a range of technologies with different attributes and at various stages of development, the focus of this article will be on the suite of IEEE 802.11 standards also known as Wi-Fi. The reason is simple: this family of WLAN standards has gained broad acceptance, leading to significant cost reductions due to volume production, and the level of penetration in a variety of consumer devices (from personal computers, to personal digital assistants or PDAs, to mobile phones) is fast reaching infrastructure scale.

Wi-Fi has evolved in a somewhat accidental manner, through an evolutionary path not envisioned by its original creators and early backers. This is a rather consistent pattern in the evolution of technological systems (e.g. Nye, 1990; Fischer, 1992). In the case of Wi-Fi, it was initially conceived as a wireless alternative for short-range connections between computers within homes and offices (i.e. a cordless Ethernet). However, it soon became clear that Wi-Fi could also be used to extend the reach of computer networks into public spaces. Moreover, both equipment vendors and wireless enthusiasts also realised that, with the appropriate hardware and clever tinkering, point-to-point connections could be made over several kilometres. The important role played by early adopters in the innovation process and testing of the technology under different conditions is again consistent with previous patterns of technological evolution – the best known case being that of amateur radio operators in the early 20th century (see Douglas, 1987).

Wi-Fi has experienced extraordinary growth since 1997, when the IEEE finalised the original 802.11 specifications.[1] It is worth noting that the technology emerged amidst competition from alternative standards for WLANs, notably HomeRF and HiperLAN. Interestingly, because these standards emerged from within the computer rather than the telecom industry, the standardisation process has been largely led by the private sector, organised around industry consortia such as the HomeRF Working Group, and semi-public organisations such as the IEEE. Compared to the contentious case of 3G standards (see Cowhey, Aronson & Richards, 2003), the role of Governments and multilateral organisations such as the International Telecommunication Union (ITU) has been rather minor.[2]

It is estimated that there are currently about 60 million Wi-Fi-enabled devices worldwide (Srikrishna, 2004). Among the many factors that explain the success of Wi-Fi, three are

1 Today, Wi-Fi comes in three basic flavours: 802.11b, which operates in the 2.4GHz frequency range and offers speeds of up to 11Mb/s; 802.11a, which operates in the 5GHz frequency range and offers speeds of up to 54Mb/s; and – the most recent – 802.11g, which is backwards compatible with 802.11b but offers speeds of up to 54Mb/s. Work continues on new variations that will improve the range, security and functionality of Wi-Fi, such as 802.11e (quality of service), 802.11r (roaming), and 802.11s (meshing).

2 The development of HomeRF has by now been abandoned for the most part. While the new generation of the HiperLAN standard (HiperLAN2) gained some momentum in the European Union (EU) as a result of ETSI (European Telecommunications Standards Institute) rules related to the use of unlicensed spectrum in the 5GHz band that delayed the launch of 802.11a products in the European market, analysts agree that this Wi-Fi competitor will, at best, fill a small niche in the corporate market.

particularly noteworthy. First, Wi-Fi can deliver high bandwidth without the wiring costs, which makes it an effective replacement for both last-mile delivery and backhaul traffic where the installation and maintenance cost of wired infrastructure is prohibitive (it is estimated that wiring expenses can comprise up to three-quarters of the upfront costs of building traditional telecom networks). Second, there is widespread industry support for the standard, co-ordinated through the Wi-Fi Alliance, an industry organisation including over 200 equipment makers worldwide.[3] As a result, equipment prices have dropped rapidly, and users can expect compatibility between Wi-Fi client devices and access points (APs) made by different vendors. A third key to the technology's success lies in the lack of regulatory overhead: Wi-Fi networks have blossomed on unlicensed bands, namely, thin slices of radio spectrum reserved for low-power applications in which radio devices can operate on a licence-exempt basis – though this is not always the case in the developing world (see Galperin, 2005). This has allowed for a wide variety of actors to build WLANs without any of the delays and expenses traditionally associated with obtaining a radio licence from telecommunications authorities.

The major drawback of Wi-Fi is the short signal range. Even though point-to-point connections have been made over several kilometres, Wi-Fi networks typically extend for a few hundred metres at most. This makes the technology generally unsuitable for long-haul transmissions. Nonetheless, related technologies are emerging to address this problem, notably 802.16x (also known as WiMax). This new standard is expected to offer point-to-point connectivity at 70Mb/s for up to 50 kilometres, making it an ideal alternative for traffic backhaul. Nonetheless, establishing baseline protocols for WiMAx that would allow interoperability between equipment from multiple vendors has proved more complex than in the case of Wi-Fi. Interestingly, the unexpected success of Wi-Fi, coupled with the potential challenge that new WLAN technologies represent to 3G networks being deployed by mobile telephony operators (Lehr & McKnight, 2003), has significantly raised the stakes in the standardisation process, bringing many more players to the bargaining table and making agreements more difficult to reach.

The new generation of WLAN technologies challenges many assumptions associated with the deployment of traditional telecom networks at the local level. Laying conventional fibre and copper wires, or even installing expensive cellular telephony base stations, is not unlike paving roads. It requires large upfront investments, economies of scale are pervasive, and the architecture of the network has to be carefully planned in advance because resources are not easily redeployed. As a result, networks are typically built by large organisations in a top-down process that involves making many *ex ante* assumptions about how the services will be

3 The Wi-Fi Alliance was formed in 1999 to certify interoperability of various WLAN products based on the IEEE 802.11 specifications. Since the beginning of its certification programme in 2000, the group has certified over 1 000 products.

used, by whom, and at what price. However, these assumptions are easier to make in the case of well-understood, single-purpose networks (such as roads and sewage) than in the case of information and communication technology (ICT) networks, where applications and uses often result from the accumulated experience of users themselves (Bar & Riis, 2000). Moreover, outside wealthy urban areas, demand for advanced ICT services is complex to aggregate and difficult to predict.

New WLAN technologies create an alternative to the top-down network deployment model associated with traditional telecom infrastructure. Because of the relatively low fixed capital expenditures, the use of unlicensed spectrum, the wide acceptance of open transmission standards, the scaleability of the technology, and the lack of significant economies of scale in network deployment and management, infrastructure investments in Wi-Fi networks are within the reach of a variety of local actors – from private entrepreneurs to municipal Governments to agricultural co-operatives. Moreover, these investments are for the most part in increasingly powerful wireless terminals capable of adapting to their operating environment, which allows for more edge-base control of network uses and innovation. This allows for a flexible infrastructure to expand from the bottom up, without a preconceived plan, and driven by those who best understand local demand for advanced information services – local users and organisations.

Moreover, it is possible to imagine a future in which *ad hoc* networks spontaneously emerge when enough Wi-Fi devices are present within an area (Benkler, 2002; Agarwal, Norman & Gupta, 2004). Today, most Wi-Fi networks are deployed to replace Ethernet cables within homes and office, with the simple goal of allowing mobility for users within a confined network environment and physical space. This is similar to the way cordless phones allow limited mobility for fixed telephony within a limited range of the base station. Yet, because there is no fundamental difference between Wi-Fi access points and clients, all Wi-Fi devices can be programmed to detect other devices within range and create *ad hoc* connections. Traffic can then be routed through a series of short hops, bouncing from one device to the next until it reaches a backhaul link, and effectively bypassing much of the existing wired infrastructure at the local level. Of course, this only works if there are enough Wi-Fi devices in an area, but this becomes increasingly possible as Wi-Fi prices come down and as Wi-Fi radios are built into more user devices. Assuming a dense enough distribution of such radios, network coverage would become nearly ubiquitous. Collectively, the end-devices would control how the network is used. New communication services could be invented and implemented at the edge of the network, and propagated throughout the network from peer to peer.

Consider the prediction that by 2008, 28 million cars will come equipped with local networking devices (ABI Research, 2003). These would serve not only to connect various systems within the vehicle but also to support communications with outside systems, for applications ranging from telephony to safety and cashless payment systems. Ultimately, since cars are typically always within less than a hundred feet from one another (and have a built-in power supply), one could imagine how they would provide the basis for mobile networks. Of course, many technical issues remain to be solved for such networks to become practical, including the development of adaptive routing software that can keep up with intermittent mobile nodes. But the rapidly growing number of Wi-Fi devices present in the environment creates at least the theoretical potential for such wide-area wireless grids to emerge, with wires progressively receding into the background.[4]

Of course, mesh networks still face some considerable technical challenges. So far, the only successful large-scale mesh networks have been deployed in a highly centralised fashion. The multiple meshed devices are typically deployed by a single organisation, like a municipality, able to keep tabs on exactly where they are and to configure the mesh network so as to define virtual backbone routes linking select devices (Tropos, 2005). While speculative explorations of mesh architectures suggested that increasing the number of nodes in a mesh network would generate extra capacity, further studies indicate that such hopes often rely upon unrealistic assumptions and that, in reality, mesh networks do not scale very well beyond a few hops (Ofcom, 2005.)

Overall, however, the evolution of WLAN technologies is today at a critical juncture, with many possible trajectories lying between two extremes. One represents the extension of the established deployment model to the world of wireless broadband communications: licensed by the state, wireless service providers deploy centrally controlled, closed-architecture networks, their economic strategies resting on tight control over spectrum and on the ability to raise massive amounts of capital to secure licences, build out networks, and subsidise terminal equipment. The other represents an alternative approach, whereby users and local institutions make small-scale investments in radio equipment to build local networks from the bottom up, in an unplanned manner, and collectively organise to exchange traffic and share common network resources. While there is much theoretical debate about the feasibility of such alternative network deployment models (e.g. Benkler, 2002; Sawhney, 2003; Benjamin, 2003), this article takes a different approach by examining the actual evidence of such bottom-up network deployment in the case of Wi-Fi networks. The focus in this article is on three

4 There is much historical precedent for the displacement of older technologies by new technologies once considered complementary or feeders to the incumbent system. It is worth recalling that railways were once considered appendices to the canal system, that the telephone was once considered a feeder for the telegraph network, and that the direct current (DC) and the alternating current (AC) electricity systems were once considered complementary (Nye, 1990; Fisher, 1992; Sawhney, 2003).

types of local public Wi-Fi networks, each driven by different sets of actors and based on different logics of deployment: wireless co-operatives, municipal Governments, and small wireless ISPs (or WISPs).

Decentralised models of wireless broadband deployment: Reviewing the evidence

Wireless co-operatives

Some of the most publicised grassroots efforts to provide wireless Internet access to the public have been led by so-called wireless co-operatives. Although they come in many colours and flavours, wireless co-operatives are generally local initiatives led by highly skilled professionals to provide wireless access to the members of the co-operative groups who build them, to their friends, and to the public in general (Sandvig, 2003). Wireless co-operatives comprise for the most part little more than a collection of wireless access points intentionally left open by these wireless enthusiasts and made available to anyone within range, although there are more sophisticated architectures generally based on backhaul connections made between these access points. For example, the Bay Area Wireless User Group (BAWUG) operates long-range connections (two miles and more) linking clusters of access points, while in Champaign-Urbana a wireless community group is building a 32-node mesh network that will function as a testbed for the implementation of new routing protocols.

The goals of wireless co-operatives vary widely: some simply provide a forum for their members to exchange information about wireless technologies, while others (such as the Champaign-Urbana group referred to above) are actively engaged in building wireless networks to experiment with the possibilities of Wi-Fi technologies. While the exact number of community networks is difficult to establish (in large part precisely because these are small community initiatives that do not require licensing by a central authority), there are over 100 documented initiatives in the US alone, each typically ranging from a few nodes to a few dozen nodes.[5] Interestingly, many of these free wireless co-operatives operate in some of the wealthiest US cities, such as San Francisco, San Diego, and Boston. There are also many individuals (or organisations) who volunteer to open their access point to the public without necessarily belonging to an organised co-operative, and advertise this fact on directories such as nodeDB.com.

Despite much publicity, the assemblage of these community networks is today of small significance in terms of the access infrastructure it provides. Further, it is unclear how many people are effectively taking advantage of them. In cases where the community organisations track usage of their open networks, there seem to be relatively few takers.[6] Anecdotal

5 For a seemingly thorough listing see http://wiki.personaltelco.net/index.cgi/WirelessCommunities.

6 See, for example, the usage statistics of Seattle-wireless at http://stats.seattlewireless.net.

evidence indicates that the main users of these community networks are the wireless community members themselves (Sandvig, 2003). Nevertheless, these networks are playing an important role in the emerging ecology of Wi-Fi. If nothing else, they represent a clear disincentive for investments in commercial hotspots operations.[7] Moreover, much like in the case of radio amateurs in the 1910s, wireless enthusiasts have made significant improvements to the reach and functionality of Wi-Fi networks, including routing protocols for mesh networks, authentication tools, and the real-life testing of signal propagation and interference problems.[8]

Somewhat surprisingly, co-ordination among the various community wireless groups has been relatively limited, with different groups often duplicating efforts in terms of basic access provision over the same area or development of competing software protocols. However, there are recent signs of increased co-operation to pursue common policy goals (e.g. availability of unlicensed spectrum) as well as technical co-operation. (It is worth noting that the inaugural National Summit for Community Wireless Networks was held in August 2004.) There are also grassroots efforts to connect small local networks to share backhaul capacity and exchange traffic in a mesh-like architecture. For example, the Consume project is a London-based collaborative effort to peer community Wi-Fi networks. The group has developed a model contract for co-operation, called the Pico Peering Agreement, which outlines the rights and obligations of peering parties (in essence, it is a simplified version of existing peering agreements between Tier 1 backbone operators).[9]

Much the same as in the case of open source software, wireless community efforts are based on the voluntary spirit of like-minded (and technically-proficient) individuals who agree to provide free access or transit across their network. While simple contracts such as the Pico Peering Agreement might prove useful for peering among small community networks, more complex financial and legal arrangements are likely to be needed for scaling up the current patchwork of community access points into a larger grid that provides a true connectivity alternative for those with limited technical expertise and for local institutions with more complex service demands. Yet, while the impact of wireless community initiatives has yet to match that of the open source movement, experimentation with co-operative models for the deployment and management of WLANs has opened exciting new possibilities for network deployment at the local level.

7 Verizon cites the availability of free wireless access in several areas of Manhattan as the reason for its decision to offer free Wi-Fi access to its existing Digital Subscriber Line (DSL) customers.

8 It is interesting to note that the notorious Pringles “cantenna” used by many Wi-Fi enthusiasts has a precedent in the history of radio, for early radio amateurs often used Quaker Oats containers to build radio tuners.

9 More information is available at www.picopeer.net.

Municipal Governments

A second category of non-traditional actors, increasingly engaged in building and managing wireless broadband networks, is municipal Governments. This is certainly not the first time in US history that municipalities have engaged in the deployment of telecommunications networks or the provision of services (see Gillett, Lehr & Osorio, 2003). Yet the advances in wireless technologies discussed above have created a more attractive environment for local Government involvement in the provision of wireless broadband services, particularly among those communities neglected or poorly served by traditional broadband operators (notably cable and DSL providers). The impetus is particularly strong among communities where municipally-owned public service operators are already present – for example, among communities with Municipal Electric Utilities – for the existing resources (such as trucks and customer service and billing systems) significantly lower the cost of municipal entry into broadband wireless services. In pursuing these deployments, municipal Governments have a considerable advantage over commercial entities or community groups: they control prime antenna locations in the form of light posts and traffic signs, all of which have built-in electrical supply that can serve to power wireless access points.

The number of cities deploying wireless broadband networks has been growing very fast in recent years. According to one estimate, as of June 2004 there were over 80 municipal Wi-Fi networks in the US and the EU, with more in the planning stages in large cities such as Los Angeles and Philadelphia (Muniwireless.com, 2004). The scale, architecture, and business models of these municipal networks vary widely. Some municipalities are simply building so-called "hot zones" (essentially a small cluster of public access points) along downtowns, shopping districts, and public parks. By providing free Wi-Fi access, these cities hope to help attract businesses to these areas, boost customer traffic, or lure conference organisers to their convention centres by making it easy for conference-goers to stay connected. This was, for example, the explicit goal behind the launch of free Wi-Fi access by the city of Long Beach, CA, in its downtown, airport and convention centre areas (Markoff, 2003).[10]

A more ambitious model involves generally small municipalities that seek to deploy city-wide wireless broadband to service Government buildings, mobile city workers, and security and emergency services. This is, for example, the case of Cerritos, CA, a small Southern California community without cable broadband and with only limited access to DSL services. The city partnered with wireless access provider, Aiirmesh, to offer access to local Government workers (in particular mobile employees such as city maintenance workers, code enforcement officers and building inspectors), while at the same time allowing the company

10 Interviews with Chris Dalton, City of Long Beach Economic Development Office, 06 February 2004. It is also worth noting that during our visit to downtown Long Beach we detected several private access points open for public use.

to sell broadband services to Cerritos' residents and businesses. Similar public-private partnerships are mushrooming in a number of small and mid-size US cities, including Lafayette, LA, Grand Haven, MI, Charleston, NC, and others.[11]

A significant number of these municipal networks use a mesh architecture: rather than connecting each Wi-Fi base station to the wired network, as in the case of residential access points or commercial hotspots, devices relay traffic to one another with only a few of them hard-wired to the Internet. They are programmed to detect nearby devices and spontaneously adjust routing when new devices are added, or to find ways around devices that fail. Municipalities have an inherent advantage in pursuing a mesh architecture since, as noted above, they control a large number of prime locations for antenna locations, such as light posts, traffic signs or urban furniture, dispersed through the city and equipped with power supply. A prominent example is Chaska, MN, a city of less than 20 000, where the municipal Government built a 16-square mile mesh network and operates the service on the basis of an existing municipal electric utility.

Municipal wireless networks drew little controversy when confined to small cities or communities under-served by major broadband operators, or when these initiatives primarily addressed the needs of Government employees. Yet, as soon as larger municipalities announced plans to build metropolitan area networks (MANs) that would cover large geographical areas, the debate over the proper role of local Governments in the provision of wireless broadband erupted, and incumbent operators swiftly sought legislation blocking municipal Wi-Fi projects. The theoretical case in favour of local Government provision of wireless broadband rests on three key assumptions: first, that broadband access is part of the critical infrastructure for communities to prosper in economic and social terms; second, that for a variety of reasons market forces cannot adequately fulfil the demand for broadband access within the community (for example, because externalities prevent private operators from fully capturing the benefits of widespread broadband access); and third, that under these circumstances local Governments can run wireless networks and deliver these services (either directly or under a franchise agreement) more efficiently than private firms (Lehr, Sirbu & Gillett, 2004).

While the first assumption seems plausible, the other two depend on a number of specific circumstances that prevent overarching generalisations (such as those typically made on both sides of the debate). In communities under-served by existing broadband operators, there is clearly a role for local Governments to play in spurring the availability of broadband at competitive prices. This is particularly the case where other municipal utilities already exist, so that economies of scale and scope can be realised in the provision of a bundle of Government services (e.g. electricity, water, broadband). At first glance, the market failure

11 For descriptions of these municipal wireless projects in the US and elsewhere see www.muniwireless.com.

rationale is less convincing for areas where a competitive broadband market exists, although even in these cases it is entirely possible to argue for a limited Government role in the provision of wireless broadband (for example, in running the fibre backhaul, in specialised applications for Government operations, or in conjunction with economic development projects). Ultimately, a better understanding of the potential costs and benefits of municipal wireless initiatives within different contexts is needed to allow conclusions about the appropriate role of local Government in the wireless broadband environment.

Small wireless ISPs

A third category of new actors taking advantage of the properties of new WLAN technologies are the Wireless Internet Service Providers (WISPs.) These are new for-profit companies providing Internet services to residential and business customers over wireless networks. Services include Internet access and web hosting, and in some cases more diverse options such as virtual private networking and Voice over IP (VoIP). Over the past two years, the Federal Communications Commission (FCC) has taken a keen interest in WISPs, seeing them in particular as a way to bring broadband internet access to rural areas. This regulatory support is further strengthened by rural development funding programmes, such as the United States Department of Agriculture (USDA) Community Connect Grant Program aimed at providing essential community facilities in rural towns and communities where no broadband service exists.[12] In November 2003, the FCC held a Rural Wireless ISP Showcase and Workshop to facilitate information dissemination about Rural WISPs as a compelling solution for rural broadband service (FCC, 2003: Internet reference). In May 2004, FCC Chair Michael Powell announced the creation of the Wireless Broadband Access Task Force, to recommend policies that could encourage the growth of the WISP industry.

In the US, WISPs are present in a diversity of communities ranging from large cities (like Sympel, Inc in San Francisco or Brick Network in St Louis), to rural towns (like InvisiMax in Hallock, MN). However, their impact is perhaps most significant in rural and small towns, where they are often the only broadband access solution. While there is much enthusiasm about this new segment of the ISP industry, little information is available.[13] Different sources cite widely divergent numbers of WISP providers. In September 2003, analysts In-Stat/MDR estimated there were between 1 500 and 1 800 WISPs in the US (cited in Brewin, 2003). During the Wireless Broadband Forum held in May 2004 by the FCC, Margaret LaBrecque, Chairperson of the WiMax Forum Regulatory Task Force claimed there were “2,500 wireless ISPs in the US serving over 6,000 markets” (FCC, 2004: 63). At the same meeting, Michael

12 See www.usda.gov/rus/telecom/commconnect.htm.

13 The authors gratefully acknowledge research help from Namkee Park, University of Southern California, in tracking down some of the available information.

Anderson, Chairperson of part-15.org, an industry association for licence-free spectrum users, said there were "8,000 licence-exempt WISPs in the United States actively providing service" (FCC, 2004: 89), most of them serving rural areas. The FCC's own Wireless Broadband Access Task Force puts that number at "between 4,000 and 8,000" (FCC, 2005: 5). While these numbers obviously lack precision, they are also strikingly large. Considering that there are about 36 000 municipalities and towns in the US, of which the large majority are small – 29 348, or 82%, have fewer than 5 000 inhabitants; 25 369, or 71%, have fewer than 2 500 inhabitants[14] – and considering that there are several WISPs serving more than one community (see Table 3.1 below), the coverage that this new breed of access providers is providing in rural and small communities is remarkably extensive.

The small scale of these operators is illustrated in Table 3.1. While the larger WISPs serve fewer than 10 000 subscribers, the majority of them are mom-and-pop operations serving only about 100 customers each (Lawson, 2004). This indicates an extremely fragmented industry structure, largely resulting from very low entry costs: with an upfront investment as low as U$10 000 in off-the-shelf equipment, a small entrepreneur can build a system able to serve about 100 customers, with a payback ranging from 12 to 24 months.[15] In fact, many WISPs have been started by frustrated customers fed up with the difficulty of getting affordable high-speed

Headquarters	WISP	Subscribers	Communities served
Omaha, NE	SpeedNet Services, Inc.	7 000	235
Prescott Valley, AZ	CommSpeed	4 579	-
W. Des Moines, IA	Prairie iNet	4 001	120
Amarillo, TX	AMA TechTel Communications	4 000	-
Erie, CO	Mesa Networks	3 000	-
Moscow, ID	FirstStep Internet	2 709	16
Lubbock, TX	Blue Moon Solutions	2 000	-
Owensboro, KY	Owensboro Municipal Utilities	1 550	-
Orem, UT	Digis Networks	1 516	-
Evergreen, CO	wisperTEL	1 000	31

Source: Broadband Wireless Exchange Magazine (at www.bbwexchange.com/top10wisps.asp, as of 23 February 2005) and company data.

Table 3.1: "Top 10" wireless ISPs (or WISPs)

14 United States Census Bureau (2002).

15 See, for example, How Much Does a WISP Cost?, in *Broadband Wireless Exchange Magazine*, www.bbwexchange.com/turnkey/pricing.asp.

16 As Part-15.org Chairman (and CIO of WISP PDQLink) Michael Anderson recalls, "I think most of the WISPS, the licensed exempt guys, the smaller, less than 10 employees, 100 miles from any metropolitan area, those guys, for the most part, started their business because of the frustration of not having the availability of broadband in their areas, which makes them either suburban or rural. I think in '98, '97, when I started wireless from ISP, I had the same frustrations. I was paying US$1 700 a month for a T-1 at the office and four blocks away at my home the best I could hope for was a 288kb/s connection" (FCC, 2004: 117).

connections in their small communities, and who decide to front the cost of a T1 connection and spread that cost by reselling the excess capacity to neighbours over wireless links.[16] However, one common problem is the availability of T1 lines (or comparable) for backhauling traffic. Unlike urban ISPs, many WISPs have to pay additional long-haul charges to interconnect with Internet POPs located in major cities, which raises provision costs significantly.

The WISP sector is an infant industry, with most players entering the market in the last three years. The availability of both private and public financing, coupled with the slow roll-out of broadband by traditional carriers in most rural and small communities, has fuelled the remarkable growth of this segment. For the moment, there seems to be significant demand from customers, and ample policy support, to sustain the current growth rates. Yet, at least two factors call for attention. The first is the entry of traditional wired broadband providers, such as cable operators and telcos, who in several cases have come to rural areas to challenge WISPs with lower priced offerings. The second is the long-term sustainability of these small-scale operations, which often depend on a few larger customers. In the early days of telephony, grassroots efforts were also critical in extending telecommunications to rural America, yet after a wave of consolidation in the early 20th century only a few remained independent (Fischer, 1992). While new WLAN technologies have similarly spurred a new generation of small telecom entrepreneurs, it remains to be seen how sustainable these networks will be in the long run.

Conclusion

David (2002) has aptly described the Internet as a fortuitous legacy of a modest R&D programme, which was later adapted and modified by various economic and political actors to perform functions never intended by its pioneers. Wi-Fi has similarly emerged from a rather modest experiment in spectrum management launched by the FCC in 1985 that has unexpectedly resulted in the proliferation of local wireless networks in homes, offices, and public spaces. Much as the Internet challenged traditional telecom networks, with this new architecture comes a new distribution of control over wireless networks. However fast new wireless technologies evolve, this will be an evolutionary process whereby various stakeholders – not simply equipment manufacturers and incumbent carriers but also local Governments, start-up providers and especially end users – will interact to shape the technology in different ways. While some battles will be market-driven, other will take place in the courtrooms, in regulatory agencies, and within standards-setting organisations. Having outgrown their original purpose as an appendix to the wired infrastructure, Wi-Fi networks now stand at a critical juncture, for they embody technical possibilities of a potentially disruptive character, and yet it is in the decisively social realm of economic and political interactions that their future is being cast.

With tens of millions of units sold in just a few years, there is now a critical mass of Wi-Fi radios in the environment. All signs point to the continuation of this trend in the coming few years: Wi-Fi devices are becoming very cheap and embedded in a wide array of consumer devices, from cellular phones to televisions, appliances and cars. Once density reaches a certain threshold, the traditional deployment architecture and models of control will need to be revisited, for the system is likely to reach capacity as too many devices compete for scarce resources such as frequencies and backhaul links. This will inevitably lead to regulatory battles about how to reform the existing legal edifice for wireless communications, largely based on the broadcast model of a few high-power transmitters connecting to numerous low-power, limited-intelligence devices. The ongoing policy debate about reforming approaches to spectrum management illustrates this point. It opposes two alternatives for the current licensing approach – the assignment of property rights to spectrum bands, and the elimination of licences through an unlicensed spectrum regime (Faulhaber, 2005.)

One of the central questions for the evolution of WLANs is whether the large, and fast- growing, number of radio devices in the environment could be co-ordinated differently to create a fundamental challenge to existing networks. We believe we are fast approaching a point where this might happen, because of two related developments. The first is the bottom-up dynamics associated with Wi-Fi deployment discussed in this article. As households, grassroots community groups, small entrepreneurs and local institutions build their own networks, the incentives will increase to share resources, reach roaming or peering agreements, and devise new co-operative mechanisms to manage this decentralised wireless infrastructure as a public grid. Of course, such co-operative behaviour is more likely to emerge more easily in relatively small communities, where the various actors know, and are accountable to, each other. Co-ordination of large numbers of anonymous players in more congested environments is more likely to lead to a tragedy of the commons.

The possibility of doing just that is tied to the second development – the recent emergence of open source mesh protocols that can knit together neighboring Wi-Fi devices into a single network. At this point, mesh technology has been worked out for centrally deployed network devices, and much technical work remains to be done for *ad hoc* mesh networks to become a reality. Nonetheless, as with other technologies, experimentation by users and corporate R&D will eventually result in a workable solution. More challenging, however, will be to create new organisational arrangements to manage the wireless grid. As already noted, because it was conceived under assumptions drawn from an earlier generation of wireless technologies, the existing regulatory regime limits the growth of and stifles experimentation with bottom-up WLAN deployment. Revisiting these assumptions is a necessary step for allowing these exciting new ways of building and running networks to flourish.

While the diffusion of Wi-Fi devices in the developing world lags significantly behind that in the more developed countries, the implications of the trends discussed above are no less significant. The US experience reveals that, under the right institutional circumstances, Wi-Fi significantly facilitates market entry into the last-mile segment in thin markets (e.g. rural areas). There is growing evidence that Wi-Fi is similarly lowering the entry threshold in under-served areas in the developing world, despite various regulatory hurdles (including restricted access to suitable spectrum bands) and, in many cases, active opposition by incumbent operators (Galperin, 2005; Proenza, 2005).

As equipment costs continue to decline and robust turnkey solutions become available, the traditional constraints that handicapped broadband deployment in developing nations become less significant. While the lack of skilled resources has limited the spontaneous emergence of wireless communities, active involvement by municipal Governments, local entrepreneurs, and several international donors has given way to numerous local experiments with community-based Wi-Fi networks. These efforts typically aggregate local resources to extend broadband service into markets deemed unprofitable by traditional operators (Galperin & Bar, 2005).

It is too early to draw conclusions from these numerous efforts, which will need careful monitoring to assess their long-term sustainability and broader development impact. Yet the evidence already suggests that new models of network deployment and management, based on small-scale investments by end users and shared use of common resources, may find an even more fertile environment in regions with recurrent underinvestments by traditional operators in telecom facilities. ❑

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