Wirelessness

Radical Empiricism in Network Cultures

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1 Introduction

Motion, to take a good example, is originally a turbid sensation, of which the native shape is perhaps best preserved in the phenomenon of vertigo. (James 1996a, 62)

Between 1999 and 2009, a "turbid" or disordered sensation of change was felt as wireless connections expanded and eroded the edges of the Internet and mobile telecommunications. Wireless connections in the making were unraveling networks as the dominant fabric of contemporary media. A vertiginous, chaotic movement zigzagged across devices (routers, smartphones, wireless memory cards, netbooks, wireless radios, logistics tags, etc.), cities, diagrams, people, databases, logos, standards, wars, crimes, towers, Pacific Islands, Guangzhou workshops, service agreements, toys, states, bicycles, "exotic places" such as Timbuktu, theme parks and chip foundries. This book is a set of experiments in connecting movement of wireless to the "native shape" of turbid sensations. It draws on philosophical techniques that are almost a century older. The radical empiricism associated with the pragmatist philosopher William James offers techniques for matching the disordered flows of wireless networks, meshes, patchworks, and connections with felt sensations.

Wireless networks have been most often set up, used, configured, and figured in everyday locales such as railway stations, trains, airports, public parks, cafés, schools, and, above all, houses as a way of connecting to the Internet and the many modalities of communication that it supports—the Web, email, streaming audio and video, news groups, data transfer, voice and video calling, instant messaging, rss feeds, blogs, and so on. Wireless connections have found myriad uses—streaming audiovisual materials throughout the home, tracking children in Legoland, monitoring the growth of grapevines or wildfires through wireless sensor networks, participating in multiplayer console games, or more ambitiously, replacing corporate-owned telecommunications infrastructure with community-owned communications networks (PPA 2003). Well-known remote

locations have been selectively targeted by wireless networks. Between 2001 and 2004, wireless networks for computer communications appeared in settings ranging from Everest Base Camp and Nepalese yak farms (Waltner 2003), to rural villages in Cambodia or the "first wireless nation," Niue in the South Pacific (St. Clair 2003).

The Insignificance of Wi-Fi

We recognize wireless devices, locations, connections, services, and networks in many guises, but perhaps above all in the form of Wi-Fi®. Wi-Fi is a registered trademark of the industry confederation of equipment manufacturers and service providers called the Wi-Fi Alliance: "The Wi-Fi Alliance created the term Wi-Fi, which has come to represent a cultural phenomenon" (Wi-Fi Alliance 2003). The Taoist-influenced yin-yang design trademark appears on many wireless devices and at many wireless hotspots. It "certifies" that devices for local area networking over several hundred meters meet particular technical standards; "consistent use of these [Wi-Fi Alliance] marks is fundamental to the growth and recognition of Wi-Fi products and services" (Wi-Fi 2009). Although the yin of "Wi" and yang of "Fi" probably do not mean very much in terms of the cosmic balance of opposing powers, the design of the logo signals the functional importance of "i." The lowercase "i" (particularly prominent in the names of Apple Corporation's recent products) defines the space around "Wi-Fi." The logo style guide specifies that the clear space around the logo shall be equal to three times the width of "I" (see figure 1.1). That seems apt. Wireless networks very much concern the interval between people, or the space around "I."

Figure 1.1
The Wi-Fi brand (Wi-Fi 2009)

Wi-Fi is a trademark for a high-speed local area networking standard developed during the 1990s by the Institute of Electrical and Electronics Engineers, an international standards-making body (IEEE 1999, 2003). A networking standard dating from ten years ago is in some ways a very unpromising candidate for network and media theory. Ten years later, many Wi-Fi devices surround us in urban settings, especially in homes, apartments, offices, and increasingly outside in public places, but how do we have any sense of them? There are numerous gadgets as well as software designed to detect Wi-Fi connections in the vicinity.[1] I bought a "Wi-Fi watch" that carries what looks like the logo of the Wi-Fi Alliance (I Want One Of Those Ltd, 2008) on the promise that it would make visible wireless networks in the vicinity. Although the watch tells the time, it is relatively ineffective as a wireless detector. It often does not detect the presence of a wireless access point, even when I am convinced there must be one there. When it does detect one, it does not say much about it. It displays signal strength as a number between one and eight without any other information—the name of the network, whether access to it is open or encrypted, and so on. It says nothing about how many other wireless access points are in the vicinity. The disappointing Wi-Fi watch, despite being well reviewed on various gadget sites on the Web, displays to an annoying extent many of the limitations of wireless devices more generally. The promise of wireless access to the Internet sometimes shrivels to an impassive demand for connectivity. The banal limitations of the watch consign it to oblivion in a drawer somewhere. However, its limitations might apply to wireless devices more generally. A certain undoing of networks occurs here. Wireless devices promise expanded network connectivity, but this expansion is provisional, uneven, and patchy. People are not always aware of the existence of wireless connections, nor do they need to be. Someone buys a new digital camera or mobile phone, and uses it for several months without ever noticing that it is Wi-Fi-enabled. The camera can connect to a wireless access point and upload images to another computer or photosharing Web site such as flickr.com. However, there is no need to do that, and many people might even be unaware of the possibility. So, it is very possible that soon very little will be known about wireless networks as they sink into a banal media-technological background.

Despite their insignificance and blandness (or perhaps because of it), wireless networks effervesce on the edges of media change, activating and catalyzing experiential modifications. The vigorous proliferation of wireless devices and products evidences some kind of ferment. For instance, in 2009, the online store Amazon.com displayed almost 22,000 different

products under the category "wireless." These range from a Cisco WLAN (Wireless Local Area Network) controller worth tens of thousands of dollars to a GZ Wireless FM transmitter for an iPod or a Sierra Wireless 595U EVDO USB Modem, both selling for the inexplicably low price of £0.01, presumably because they are tied to service plans or other contractual arrangements. Despite the abundance of Wi-Fi devices—five billion Wi-Fi chips by 2012, according to market analysts (ABIResearch 2007)—the bare fact of network connectivity seems dull and listless. What amid this technological spindrift is worth comment? Across the face of this avalanche of wireless commodities, various degrees of openness, reconfigurability, or plasticity can be found. In general, Wi-Fi devices exhibit a high degree of openness to modification, hybridization, reconfiguration, and the widest variety of instantiations (commercial, personal, portable, citywide, environmental, etc.). Wi-Fi connections, intermittent, unstable, and uneven as they often are, act as a kind of patch or infill at the edges and gaps in telecommunications and network infrastructures. Wi-Fi is seen as most likely to practically deliver on the promise of the "Internet of things," the idea that all electronic devices will connect to the Internet (Itu 2006). Although many competing wireless "solutions" to the problem of connecting devices to the Internet can be found (Bluetooth, Zigbee, femtocells, pico-cells, 3G, LTE, WiMax), Wi-Fi continues to grow in popularity, partly because it is relatively cheap, and partly because it is "out of control" (that is, it requires little centralized infrastructural management).

Sometimes a single wireless device crystallizes something of the undoing and intensification of networks. It can superimpose waves of media practice and network culture on each other, with sometimes surprising effectiveness. A Wi-Fi Internet radio refers at once to the history of broadcast radio, Internet media and contemporary wireless culture. Historically, the very term *wireless* dates from the late nineteenth century, yet it languishes on the periphery of media studies and media theory. As Timothy Campbell argues, apart from voice-centered radio, wireless media have largely been occult in cultural and media studies (Campbell 2006, x–xi), even though wireless devices precede broadcast radio by several decades.[2] Radio communication and information networks have an intimate historical association. AlohaNet, a packet radio system developed in 1970 to allow communication between computers at seven island campuses of the University of Hawaii, furnished a basic approach to network traffic handling and collision avoidance still used in many parts of the Internet, and in particular, in all local area networks such as Ethernet (Abbate 2000, 115–117). The configuring of the Internet as space of reroutable flows of infor-

mation owes something to wireless here. Finally, from 1999 onward, a set of very rapid changes associated with wireless devices affected how people use the Internet, where the Internet can be found, what kinds of devices belong to the networks, and indeed, what the Internet is for.

The key claim of this book is that the contemporary proliferation of wireless devices and modes of network connection can best be screened against the backdrop of a broadly diverging and converging set of tendencies that I call "wirelessness." Wirelessness designates an experience trending toward entanglements with things, objects, gadgets, infrastructures, and services, and imbued with indistinct sensations and practices of network-associated change. Wirelessness affects how people arrive, depart, and inhabit places, how they relate to others, and indeed, how they embody change. In floating such an awkward term as *wirelessness*, I would invite readers to attend mostly to the suffix *ness*. *Ness* seems to me to do a better job than *wireless* of capturing the tendencies, fleeting nuances, and peripheral shades of often barely registered feeling that cannot be easily codified, symbolized, or quantified. As a suffix, *ness* also tends to convey something about a state, condition, or mode of existence (*light-ness*, *heaviness*, *weak-ness*, *happi-ness*, etc.). In this respect, the messy, fragile, and often ill-suited aspects of Wi-Fi are actually useful. Wi-Fi's limitations and surprising potentials highlight wirelessness as a composite experience animated by divergent processes, by relations that generate transitions and create expectations of more change to come. "More" includes the "less" of wirelessness: there will be less wires, less obstacles, less difficulty, less weight, and in general much more of less. The diaphanous fabric of wirelessness spans several strands of media-technological change. The structure of this experience is diffuse, multiple and hazy in outline.[3]

Peripherals and Peripheries: Wirelessness and Networks

Accepting that the banality and inadequacies of Wi-Fi are worth thinking about, what would this mean practically? In writing this book, the Wi-Fi watch was not the only form of minimal connectivity I encountered. Another connection problem ran across the desk I often work at. It concerns a wireless keyboard and mouse, licensed by the U.S. Federal Communications Commission to operate at radio frequencies around 27 MHz (Federal Communications 2004). Although the wireless connection between the mouse and computer, or keyboard and computer, works well most of the time, sometimes it mysteriously fails. Wireless mice often share radio spectrum with cordless phones, remote control toys, microwave

ovens, as well as other Bluetooth devices. For a long time, I thought the metal in-tray next to the computer monitor somehow acted as an electromagnetic Faraday shield for the wireless mouse receiver near the computer. I moved the in-tray around a lot until one day crawling under the desk, I found that the receiver's plugs into the back of the computer were slightly wobbly, and that by touching them lightly, the keyboard and mouse started working again. Sometimes I have to crawl under my desk to touch the plugs running into the back of the computer.

Is crawling around in the dust jiggling plugs a matter of wirelessness? For a start, it suggests that there is no pure experience of wirelessness, no subject whose interiority could be the foundation or anchor point for such an experience.[4] Feelings of wirelessness are site-specific and attach to a mass of things, images, projects, products, enterprises, plans, and politics concerning not only wireless networks but forms of urban, economic, work, institutional, and everyday life more generally. So the "subject" who experiences wirelessness is not very salient. Wirelessness is not a strongly personal or intimate zone of experience, at least in the usual senses of these terms. The layers, intensities, resistances, and vectors of a wireless subject have a somewhat ephemeral and nebulous character. In all the variations in tendency and direction it triggers, wirelessness puts detours and obstacles on the path toward the point where all differences converge and coalesce in pure, total networks.

Many, if not all, readers of this book will have wide-ranging, firsthand experience of wireless connections. They will have sat in airport terminals and hotel lobbies using a laptop or some other device (BlackBerry, iPhone, netbook, etc.) to do e-mail or browse the Web. In houses and apartments, they might have set up or found a wireless network to access. They might have heard of a café shutting their wireless networks off on weekends to discourage all-day occupation of tables or they might have complained to their friends about the exorbitant cost of using in-room hotel wireless networks in business hotels. Someone living in the countryside might have established a long-distance wireless connection allowing them to work from home. Who hasn't felt annoyance and frustration at the sudden, seemingly random difficulty of connecting to a wireless access point? Or perhaps they will have noticed access-point lights flickering rapidly in the middle of the night when no one in the house is using the Internet.

Many people will have seen the accounts, anecdotes, and reports of wireless network use. Wireless networks such as Wi-Fi have been heavily discussed in electronic, print, and online media, especially as different kinds of wireless connections coalesce in single devices. So much media

phosphoresces around wireless network infrastructures, devices, and products that it is difficult to isolate wirelessness as such. The news media have often reported on crimes, accidents, and dilemmas of wireless networking (for example, debating the ethics and legality of piggybacking on a neighbor's open wireless network). Occasionally, media attention has concerned crimes, terror, fear, and insecurity associated with wireless networks (for instance, the use of unsecured wireless access points to send e-mails by bombers in India in 2008, the theft of millions of customer credit card details from a U.S. retailer's wireless networks in 2006, and so on). Much more often, attention to wireless networking has taken the form of reviews, recommendations, and advertising of wireless devices and services.

These manifestations of wirelessness could be multiplied indefinitely without ever coming to a core problem of wirelessness. What are we to make of the morass of contemporary experience of wireless connections, devices, and networks in use? It sprawls across a diffuse, spatial, politico-economic, and, shall we say, philosophical periphery. Peripheries and peripherals are not without importance. For instance, much commercial and noncommercial attention, effort, thinking, and indeed feeling in wirelessness relates to versions of the so-called last-mile problem, a problem that many telecommunications operators face today. While central infrastructures and network backbones can mostly be constructed speedily and expediently, the sheer number and variety of connections needed to hook every room, desk, village, chair, building, bag, pocket, pole, cabin, footpath, or other place to a telecommunications network often entail vast expense, upheavals, or complications. From the late 1990s on, wireless networks and wireless techniques of various kinds have been championed as the most economical solution to this problem, a problem that actually ranges in scale from hundreds of kilometers (as in development projects in remote locations) down to centimeters (as in personal devices carried in a bag or pocket). The last-mile problem might seem peripheral to the turmoil of change associated with network media and communication in general. It seems that it might only concern practical problems of access and connectivity rather than the more absorbing, immersive experiences of working, shopping, communicating, playing, and socializing online. The latter certainly draw the attention of most critical work on networks and digital media. However, this peripheral aspect of wirelessness and wireless devices as peripheral to networks is precisely the focus of the book. Everything here begins at a periphery, a periphery that, like my cordless mouse, is often vexed by weak connections, the residual weight of wires, and barely felt interference.

Wire: A Struggle against Dispersion

Wirelessness struggles against wires, and the extensive tying and knotting of wires called "networks." In this struggle, the question is: Which wires go where, or who wires what? In 2002, Nicholas Negroponte, founder of MIT's Media Lab and long-standing contributor to *Wired* magazine, announced in an article titled "Being Wireless" that "everything you assumed about telecommunications is about to change. Large wired and wireless telephone companies will be replaced by micro-operators, millions of which can be woven into a global fabric of broadband connectivity" (Negroponte 2002).

The global fabric Negroponte envisions will be made of free-associating Wi-Fi access points. In 2009, many aspects of this change are tangible. Take the Cradlepoint PHS300 Personal Wi-Fi Hotspot, an ideal piece of technology for the mobile "micro-operator": "The PHS300 Personal WiFi Hotspot is a true plug 'n' play solution that creates a powerful WiFi network almost anywhere. Connect all your WiFi enabled devices by simply plugging in your activated USB data modem and turning on the PHS300. It's that easy! No more searching for a hotspot, you are one!" (Cradlepoint 2009).

Micro-operators do not search for or connect to networks, they make networks for themselves. The PHS300 fits a niche in the contemporary wireless ecology since it links Wi-Fi networks to 3G/4G mobile broadband services provided by telephone companies. It bridges the computer industry and the telecommunications industry. The hitch here is that the devices requires an additional USB data modem—that is, "a 3rd party data modem and active data plan." Instead of the complete replacement imagined by Negroponte, the PHS300 represents the interface between different wireless networks in the same space. Rather than a "global fabric of broadband connectivity," wireless networks became one style of connection among many. There are so many ways to connect: Bluetooth, Wi-Fi (a, b, g, n), WiMax, GSM, LTE, EVDO, 3G, 4G, and so forth. The average home user may discover half a dozen "wireless networks" in the vicinity, their mobile phone may also be a Wi-Fi and Bluetooth device, and their laptop computer may have a mobile broadband USB data modem that connects it to mobile broadband networks operated by telephone companies.

Any struggle against wires faces the fact and figure of existing networks, particularly the Internet but also those of commercial telecommunications operators, broadband service providers, and institutional network administrators on which the Internet actually relies. Networks of different kinds overconnect a given location.[5] Hence, wirelessness in all its contemporary

guises encounters a plurally networked universe. Moreover, the trope or figure of the network as expansive relationality affects wireless devices and infrastructures at almost every level. Since the 1980s, network-oriented theorizing has pounced on every scale, order, and variety of phenomena ranging from the subatomic to the global, and wrapped them in network form. The standard sociological definitions of a network from sociologists such as Manuel Castells and Jan Van Dijk are terse yet indefinitely expansive: "a network is a set of interconnected nodes" (Castells 1996, 470). They can also be slightly more restrictive: "a collection of links between elements of a unit" (Van Dijk 2006, 24). Any number of more or less adorned variations stress that relations come before substance, identity, or essence.

No doubt it is hard to shun networks as "the new social morphology of our societies" (Castells 1996, 469) and as one of "the dominant processes and functions in our societies" (Castells 1996, 470). In the course of this book, I accept that it is impossible to understand wirelessness apart from networks. It is hard to argue against a hard-won focus on relations and relationality associated with network analysis. Furthermore, wirelessness comes into being within network cultures, the Internet, software, and the electronics industries. However, after a decade of heavily network-centric social, cultural, organizational, and mathematical network theory, there are reasons to begin to approach networks a little more diffidently. While it exhorts attention to relations, network theorizing can deanimate relations in favor of a purified form of networked stasis. Much network theorizing expects networks to have well-defined links and to afford unmitigated flow between distinct nodes. While pure flow might sometimes occur when a lot of aligning and linking work is done, very often it does not. Network flows are actually quite difficult to manage and to theorize. Media theorists Anna Munster and Geert Lovink (2005) put the very figure of the network into question. "Theorising networks . . . must struggle with the abstraction of dispersed elements—elements that cannot be captured into one image. The very notion of a network is in conflict with the desire to gain an overview."

The figure of the network struggles to contain an always-already abstracted dispersion. Despite the extraordinary contemporary investment in networks as the epitome of the contemporary real, they are, as Munster and Lovink (2005) suggest, "unpredictable, often poor, harsh, and not exactly 'rich' expressions of the social." If "struggle with the abstraction of dispersed elements" runs through networks, wireless networks might make the internal conflicted desire to network more visible, and in that sense,

save the network from itself. As the sociologist Andrew Barry (2001, 16) also argues, "The social world should not be imagined and acted upon as if it were a system of networks and flows, which can be grasped and managed as a whole. This is a typically modern political fantasy. The specificities and inconsistencies of the social demand careful attention."

Wireless networking could be seen as one venue in which the contemporary world is both imagined as a network flow that can be grasped and managed, and yet falls prey to constant inconsistencies and interruptions. Barry highlights that networks will always be "a part of, and yet not contained by, other collective arrangements or networks" (p. 18). Inconsistency and lack of containment very much typify wireless networks as they float in a foam of other media, settings, and environments, including the Internet and cities.

Recent work on networks such as Shaviro 2003, Galloway and Thacker 2007, Terranova 2004, and Chun 2006 alloy an awareness of the minimalist sheen of network formalism with sober attempts to identify edges and creases where the fabric of the network frays, and the crisp figure of network relationality crinkles. I take as a crucial point of departure Steven Shaviro's (2003, 249–250) conclusion that "what's missing [from life in the network society] is what is *more than information:* the qualitative dimension of experience or the continuum of analog space in between all those ones and zeroes. From a certain point of view, of course, this surplus is nothing at all. It is empty and insubstantial, almost by definition. . . . But this *nothing* is precisely the point. Because of this nothing, too much is never enough, and our desires are never satisfied."

In that case, what remains to be done with the figure of the network? Alexander Galloway and Eugene Thacker (2007) urge attention to protocol in network analysis and network politics. Their notion of "protocological control" enjoins detailed attention to, for instance, the "question of how discrete nodes (agencies) and their edges (actions) are identified and managed as such." From a different angle, Tiziana Terranova (2004, 90) suggests that the glitz and dazzle of high-profile websites such as MySpace.com or Facebook.com should be understood in relation to the practices and pattern of network labor that animate them: "It is the labour of the designers and programmers that shows through a successful web site and it is the spectacle of that labour changing its product that keeps the users coming back." Or turning to the "user," the slightly careworn figure who lingers around any discussion of contemporary digital media, Wendy Chun (2006, 249) draws our attention to the ways many accounts of networks dim our awareness of the uncomfortable fact that "all electronic

interactions undermine the control of users by constantly sending involuntary 'representations.'" The network user is a troubled figure, plunging and ascending between freedom and control, sometimes configured as windowless monad, and sometimes a locus that disrupt all closures.

Wirelessness offers a chance to pursue network gaps, frictions, and overloads, and to develop less pervasive, less expansive or ubiquitous figures of being-with each other. Although they are certainly not the most luminous hotspot of practices or changes associated with media technological cultures, wireless devices and wireless connections might undo from within valorized, and inescapable discursive figures of the network, just as they intensify and extend it. The commonly used term *wireless network* has an inherent tendency toward both self-erasure and multiplication. If a network has no wires, if it has few wires, then is it still a network to the same extent? Does the substitution of radio signals for cables and wireless dissolve the figure of the network? Dynamics at the level of network protocol, production practices, and user subjectification play out in multiple forms in wireless networks. In some respects, wirelessness could almost be nothing, just the bland, pure, insatiable connectivity represented by the many available wireless networks or the many overlaid network connections. Wirelessness affords no strong ontological affirmation of networks or reassertion of the primacy of the network as the essence of the age. I see the morass of wirelessness rather as an opportunity to "give the network back to the world."[6] If wirelessness does not augment the network as a figure of "a single and yet multidimensional information milieu—linked by the dynamics of information propagation and segmented by diverse modes and channels of circulation" (Terranova 2004, 41), if wirelessness does not readily support a "philosophy for new media" (Hansen 2004) (although wirelessness is certainly dazzled by effects of "newness"), what does it offer?

"Less": Pragmatic Patches and Fields

> Enormous as is the amount of disconnexion among things. (James, 1978)

In the United Kingdom and United States, the presence of radio-frequency waves emitted by wireless networks in schools, daycare centers, and homes is increasingly regarded as problematic (see WiFiinschools 2009). This attention echoes long-standing uncertainties around radio waves and electrical fields associated with electric power networks and mobile phone towers. Wi-Fi, it seems, makes some people sick (Hume 2006). An episode

of the BBC television prime-time current affairs show *Panorama* titled "Wi-Fi Revolution" frames the problem as the "martini-style Internet," "fast-becoming unavoidable," "but there is a catch: radio-frequency radiation, an invisible smog. The question is, is it affecting our health?" (BBC 2007). Whether wireless signals substantially modulate the expression and regulation of certain proteins in neurons, whether they damage reproductive or immune system function, is open to ongoing scientific debate (Blank 2009). Regardless of how that debate is resolved, the court actions in the United Kingdom and United States, as well as the BBC program, indicate that people experience an increasing density of wireless devices and signals as affecting their bodies and their health.

Wireless devices and infrastructures create zones or fields of equivocal and indistinct spatial proximity. Many events in recent years have broadcast awareness of this equivocal proximity. Publicity about war chalking, the short-lived practice of marking the presence of nearby wireless networks on pavements or walls (Hammersley 2002), was an early sign. War chalking continues in many online wireless mapping projects, ranging from industry-sponsored maps (such as the Wi-Fi Alliance's "Zone Finder" (Wi-Fi Alliance 2003)) to war-driving or war-flying maps. War chalking crosses boundaries between public and private. In the last five years, there has much debate, somewhat inconsequential probably, about the ethics and legality of accessing open wireless networks. High-profile cases have occurred. The fifteen-month sentence of a teenager in Singapore for using a neighbor's wireless network to play games (Chua Hian 2007), the theft of 45 million customer records via the wireless networks connecting checkouts to back-office databases at T.J. Maxx stores in the United States (Espiner 2007), and the conviction of a U.S. man who parked outside the local coffee shop every lunchtime and checked his e-mail using a wireless network advertised as "free and open" (Leyden 2007) suggest that the equivocal proximities generated by wireless devices lead to many kinds of uncertainties: What properly constitutes a network when its edges and nodes tend to blur into a patch or a field of connections?

The intimacy of wireless connections is embodied in remarkably abundant and literal ways—for instance, Wi-Fi monitored cardiac pacemakers now being tested in the United States (Shapiro 2009). People attune themselves to signal availability and signal strength as they move around the world. Subtle and sometimes gross alterations in everyday habits form primary components of wirelessness as experience. Wireless signals are experienced unevenly—as sickness, as frustration, as opportunity, as necessity, as hope. People have an inchoate sense of how the signal-processing

algorithms in their many devices are expanding and multiplying relations, continually propagating signals outward in crowded urban settings, overflowing existing infrastructures and environments and realigning senses of personhood at many junctures and on different scales. They are strangely composite or mixed experiences of indistinct spatialities. They trigger various attempts to channel, amplify, propagate, signify, represent, organize, and visualize relations—antennae are modified to exponentially increase the range of networks (Greene 2008), new software is coded to replace the preinstalled software on consumer wireless equipment (OpenWRT 2008), databases of wireless nodes appear on the Web (WeFi.com 2008), and Wi-Fi fractalizes into hundreds of minor and major devices, applications, and projects. Despite its mundane existence, or perhaps because of it, Wi-Fi displays constant contractions and dilations, and multiple instantiations, sometimes awash in broader shifts in mobility, sometimes stretched or frayed by contact with other infrastructures, media, and events. Its plurality and lack of coherence offers a way to tap into networks-in-formation.

Any attempt to make sense of the banal plasticity and abundant unfolding of wireless networks, I would argue, would benefit from a pragmatist approach, or at least, from that variant of pragmatism associated with William James called "radical empiricism." Pragmatism argues for no particular *Weltanschauung* or worldview. It has therefore often been understood as a method of evaluating ideas in terms of their practical usefulness: "Consider what effects that might conceivably have practical bearings you conceive the objects of your conception to have. Then, your conception of those effects is the whole of your conception of the object" wrote (Peirce 5.438, 1878/1905). For James (1996b, 263), "What really exists is not things made but things in the making." Recent work on James as well as on Charles Sanders Pierce and John Dewey in various parts of architectural and cultural theory, science studies, and contemporary political philosophy probes the undercurrents of this (see Lapoujade 2000, Ockman 2001, Massumi 2002, Grosz 2005, Ferguson 2007, and Debaise 2007). What opens out in James's thought from this starting point is an exceptionally vivid conceptualization of the processes of moving, making, changing, altering, and connecting of feelings, things, events, images, textures, ideas, and places. As Didier Debaise (2007, 8) writes, "We would certainly not deny the importance of the [pragmatic] method which joins together a redefinition of experience and a transformation of modes of knowledge, but it seems to us to be animated by a more profound intuition which gives it meaning [*sens*]."

What is this more profound intuition? It could be expressed in many different ways. First, it concerns the relation between thinking and things. One of the key traits of James's (1996a, 125) radical empiricism is a plural conception of things: "One and the same material object can figure in an indefinitely large number of different processes at once." Things themselves belong to diverse processes. Elizabeth Grosz (2005, 132) observes: "As the pragmatists understood, the thing is a question, provocation, incitement or enigma. The thing, matter already configured, generates invention, the assessment of means and ends, and thus enables practice."

Indeed, rather than reducing thought, concepts, or perceptions to instrumental ends, as if thoughts were just tools for living, pragmatic thought problematizes the mode of existence of things as distinct from thought. "Things neither commence nor finish, there is no entirely satisfying denouement," writes Henri Bergson (1934, 241) in his preface to a volume containing James's essay "On Pragmatism," which had been published in France in 1911. A feeling of incompletion or openness that James attributes to all things is very present in wireless networking. The configurations of matter and energy in wireless networks are complicated. Their overflow provokes, or incites, for instance, court cases against wireless networks in schools. Their potential for reconfiguration incites practices, reassessment of means and ends, and inventions. In their many variations, from 2000 onward, wireless devices and infrastructures augured a more down-to-earth, located, field-tested, and service-packaged form of the relatively abstract schemes of the network or the virtual so popular in the 1990s.

So, pragmatic thought is not just provoked by things. It affirms the practical inseparability of thinking and things. They are only separable in principle, never in experience. As James (1996a, 37) says, "Thoughts in the concrete are made of the same stuff as things are." (This implies that this book itself is no different in nature from wirelessness—it is another process diverging out of wirelessness, one among many.) Thinking amid things is vital to pragmatism. While it runs deep throughout pragmatist thought (Peirce, James, Dewey), it expresses itself most richly in James's "radical empiricism." Why should things and thinking be so entwined? Every experience, including any thinking we might do as analysts, results from interaction between life and its milieu. As David Lapoujade (2000, 193) writes, "Experience must therefore be understood in a very general sense: pure experience is the ensemble of all that which is related to something else without there necessarily being consciousness of this relation."

The lightly structured, apparently subjectless account of experience proposed by James seeks to account for a certain overflowing, excessive, or propagative aspect of experience that occurs in the absence of any pregiven form. It focuses closely on "change taking place," on the continuous reality-generating effects of change, and on the changing nature of change. As James writes, "'Change taking place' is a unique content of experience, one of those 'conjunctive' objects which radical empiricism seeks so earnestly to rehabilitate and preserve" (p. 161). While notions such as "conjunctive object" remain to be developed, the key point here is that experience itself is immersed in shifting settings or sites.

The cultural theorist Brian Massumi (2002) highlights this strand of James's thought in his account of the *transcontextual* aspects of experience. In reflecting on James's reformulation of an expanded field of experience that includes things and thinking, Massumi describes the streamlike aspects of experience: "We become conscious of a situation in its midst, already actively engaged in it. Our awareness is always of an already ongoing participation in an unfolding relation" (pp. 13, 230–231). Experience overflows the borders and boundaries that mark out the patched-in principal lived forms and functions of subjectivity-self, institution, identity and difference, object, image, and place. To become conscious of what it means to be engaged in a situation is to discover what makes one part of its fabric or tissue. This implies particular attention to edges: "Experience itself, taken at large, can grow by its edges. That one moment of it proliferates into the next by transitions which, whether conjunctive or disjunctive, continue the experiential tissue, cannot, I contend, be denied" (James 1996a, 42).

As we have already seen, peripheries are central in wirelessness. Wireless networks and devices are in some ways merely pragmatic continuations of network transitions. However, at every level, from concerns about radiation hazards to hopes for a complete transformation of global telecommunication, this practical extension of networks also provokes and incites, it participates in widening circles of relations, and it draws attention to proliferating and unfolding edges.

"ness": Inconspicuous Tendencies and Transitions

Take for instance the waves of change associated with Wi-Fi as it has moved through different versions in the last ten years. In each version—802.11a, 802.11b, 802.11g, and now 802.11n—wireless networks changed. There were changes in rate as the rate of information transfer increased

(sometimes by large factors). There were variations in direction as community networks, municipal networks, and wireless development projects deployed different tactics, plans, and processes. Wi-Fi technologies spread across a range of consumer electronics and audiovisual media, as well as competing with mobile phones. The access points or wireless routers connected to the telephone or wired network, the network cards, and the antennae still looked more or less the same, or became less visible. Many more gadgets (phones, cameras, music players, televisions, photoframes, radios, medical instruments, etc.) became wireless. Often transitions between different Wi-Fi access points and networks are only distinguishable on the basis of small changes in feelings of connectivity, in variations of celerity, in the rather minute and fleeting flashes of network and signal-strength icons. On other occasions requests to authenticate or pay for connection entail larger "variations in direction." Processes of setting up equipment and connections changed slightly, especially in relation to encryption and security controls, but also on larger scales of network management where new mesh topologies embody forms of collaborative work. What would radical empiricism do with all this?

Although not a particularly scientific or even social scientific empiricism, the empiricism at stake in James's radical empiricism holds that knowledge can be patched into experience more fully if it attends to change, edges, and proliferation. Radical empiricism seeks to tread water in the unfurling of change long enough to become aware of "already ongoing participation" in it. Does radical empiricism simply reassert the primacy of subjective experience, and hence of the subject of experience? While the notion of experience runs very broadly in James's thought, James does not make the subject's experience the foundation of everything else in the way that, for instance, early twentieth-century phenomenological thought did (Edmund Husserl's life world is a totality of experience, a "phenomenon of being" (Husserl 1965, 19)). Experience does function as a platform in James, but a shifting platform for experimentation, not a solid foundation (for instance, of Husserl's "transcendental ego").

A rule of method guides the use of this platform: "To be radical, an empiricism must neither admit into its constructions any element that is not directly experienced, nor exclude from them any element that is directly experienced. For such a philosophy, *the relations that connect experiences must themselves be experienced relations, and any kind of relation experienced must be accounted as 'real' as anything else in the system*" (James 1996a, 42).

The maxim of radical empiricism is to admit only 'directly' experienced elements. Experience serves diverse materials or elements that can be used in patching together knowledge. The criterion of directness is very expansive, since it does not specify who or what experiences. Importantly, for our purposes, what James says of things—that they participate in diverse processes—has a direct corollary in experience in general: "Experience is a member of diverse processes that can be followed away from it along entirely different lines" (James 1996b, 12).

Like things, experience belongs to diverse processes. In particular, experience can be followed into things, perceptions, ideas, feelings, affects, narratives, memories, and signs as well as institutions, inventions, laws, and histories. Debaise (2005, 104) describes the result of the application of the rule of experience: "Everything is taken on the same plane: ideas, propositions, impression, things, individuals, societies. Experience is this diffuse, tangled ensemble of things, movements, becomings, of relations, without basic distinction, without founding principle."[7]

These processes might be commercial, political, personal, organization, military, governmental, leisure, educational, scientific, environmental, industrial, logistical, and so on, in nature. All of these figure in wireless networks at different points. Wireless networks enter into "a large number of different processes" at once. If we accept that experience and things are deeply coupled in the ways suggested by James, wirelessness appears as a composite or mosaic experience, a "member of diverse processes." Wirelessness as experience runs across boundaries between technology, business, politics, science, art, religion, everyday life, air, solid, and liquid. In the light of James's expanded notion of experience as expansion and divergence in full flow, we would need to ask: What diverse processes does wirelessness belong to? A radical empiricism that lived up to its promise would need to engage with experiences ranging from the infrastructural to the ephemera of mediatized perception and feeling. It would find itself moving across a patchwork of exhortatory hype, gleaming promise, highly technical gestures, and baffling or bland materialities.

Rather than being directed toward the endpoint of endless, seamless, ubiquitous connectivity of all media and the pervasiveness of the Internet, we might begin to attend to ways in which wirelessness alters how transitions between places occur. Wireless hotspots are set up in cafés, hotels, trains, aircraft, neighborhoods, parks, and homes. Sometimes they promise to generate revenue or make mobility easier for commuters or travelers. However, the question in all such cases is how such transitions introduce,

as James puts it, "variations in rates and direction." The kind of awareness that might emerge from radical empiricism is distinguished by an experimental interest in tendencies. Radical empiricism does not offer much by way of an ontology, let alone a worldview of a subject. Rather it is a way of inhabiting transitions. James (1996a, 69) writes: "Our experience, *inter alia*, is of variations of rate and of direction, and lives in these transitions more than in the journey's end. The experiences of tendency are sufficient to act upon."

This sounds incredibly general, a flat truism that is hard to disagree with. Is James saying that we inhabit "transitions" more than ends in general, just like people often say, rightly perhaps, that the journey is more important than the destination? James offers more than an opinion on the value of experience. The feeling of continuous or discontinuous transition is, for him, what gives consistency to any experience, what allows it to flow. This feeling of change, transition, or in particular, tendency, is the fabric of any experience of acting or being acted up. Empiricism is radical to the extent that it manages to hold onto "the passing of one experience into another" (p. 50), and this means holding onto tendencies, tendencies that operate like differentials expressing rates and directions of change. The key challenge in adhering to the rule of direct experience is accessing these kernel transitions. They can be minimal, since they tend play a quasi-infrastructural role. The continuity of transition relies on, as James (1996b, 96) puts it, "the through-and-through union of adjacent minima of experience, of the confluence of every passing moment of concretely felt experience with its immediately next neighbors."

Tendencies have something profuse, overflowing, or excessive in them. James's emphasis on variations of rate and direction target apparently nonpractical, nonuseful, excessive, or irrelevant components that appear only as tendencies or potentials in experience. If experience comprises "variations of rate and direction," and if these variations are lived as the passing or transitioning of experience, what can be done with them? How can they be evaluated? How can they be known?[8] How can they be prolonged enough to register consciously?[9]

Conjunctive Relations: Movement and Stasis

In 2008, IEEE 802.16 WiMax (Worldwide Operability for Microwave Access) (IEEE 2004) could be said to embody the state of the art in wireless mobile communication infrastructure. WiMax differs from Wi-Fi in many ways (for instance, it mainly uses licensed spectrum rather than unlicensed

spectrum). It markedly increases the range and speed of network connections, and has quickly been adopted as a way of building "last-mile" network infrastructures in places such as Greece (wimaxday 2008), Vietnam (Vietnam News 2007), Chile, Tanzania (Gardner 2007), Macedonia, Uganda, Bolivia, Turkey, and Nigeria (Patrick 2008). For instance, the "Holy Mountain" of Athos, a self-governing monastic state in northeastern Greece, is home to twenty Eastern Orthodox monasteries. The peninsula, accessible to male-only visitors by boat, is now blanketed with high-speed wireless WiMax coverage powered by solar cells and wind turbines. Mount Athos's monasteries embody a contemporary extreme of stasis and immobility. Yet, as Castells et al. (2007, 248) argue, in contemporary mobile communication, mobility is indexed to stable locations: "The key feature in the practice of mobile communication is connectivity rather than mobility. This is because, increasingly, mobile communication takes place from stable locations, such as the home, work, or school. . . . Mobile communication is better defined by its capacity for ubiquitous and permanent connectivity rather than by its potential mobility."

This statement is meant as an antidote to industry-driven mobility hype that often treats business and work travelers on the move through departure gates as the embodiment of mobile communication. Much more often, we could easily imagine, mobile communication entails finding a place where one can stop moving and sit—a café table, a park bench, a sofa, or some other form of seating. From this perspective, Mount Athos and its WiMax monasteries instance a relatively long-stay form of seating, not an exception to the trend toward mobile communication.

James would argue that even the most rigid stasis is deeply mobile. Experience constantly passes through many different states, ranging from the impersonal to the personal, from the singular to the general. On any scale we imagine, there is no pure flow or pure sensation of transition. Many transitions occur between scales. And every transition is shot through with temporary termini, with snags, resistances, circularities, and repetitions. James (1996a, 4) often speaks of "pure experience" as his main methodological postulate: "My thesis is that if we start with the supposition that there is only one primal stuff or material in the world, a stuff of which everything is composed, and if we call that stuff 'pure experience,' then knowing can easily be explained as a particular sort of relation towards one another into which portions of pure experience may enter." However, this primal material is never experienced as such, since it always partitioned and marked by practices of making, doing, marking and knowing. As David Lapoujade (2000, 193) comments, "Pure . . . points to

an intermediary reality outside of any matter/form relationship." Nonetheless, even if we accept that pure experience in radical empiricism is a kind of methodological postulate, or even "a plane of immanence" as Gilles Deleuze and Felix Guattari (1994, 46) call it, how would such material involve movement, transitions, or variations?

Much hinges here on attending to conjunctive relations. Any radical empiricist attempt to know transition more intimately, to accompany it, or to follow it to its limits, pivots on conjunctive relations. What are they? "With, near, next, like, from, towards, against, because, for, through, my—these words designate types of conjunctive relation arranged in roughly ascending order of intimacy and inclusiveness" (James 1996a, 45).

How then do conjunctive relations help us rethink wireless technologies against their ingrained tendencies toward utility or means? Crucially, conjunctive relations allow transition to occur. Without a *with* or *near* or *toward* or *through*, there can be no tendency and hence no transition. These felt transitions are crucial to "nature" or "whatness" in radical empiricism. All experience unfurls in diverse conjunctive relations. No "knowing" or "doing" can happen without a patchwork of such relations since they are the fabric of transition in general. Felt transitions are neither spontaneous, random, nor completely ordered. The patterns, paths, and trajectories of this passing must include variations in rate and direction.

We have already seen that James treats experience as a "member of diverse processes." As a composite, it is replete with variations in rate and direction. We have seen too that thinking and things are two sides of the same coin for radical empiricism. Now we are in a position to understand why this goes beyond a simple pantheistic assertion of the composite texture of experience, and the inmixing of things and experience. Experience is composite, diverse, inclusive of things and thinking, because it owes more to transitions and tendencies than to endpoints. All of this rests on a very specific treatment of the materiality of transition. "Radical empiricism," James writes, "takes conjunctive relations at their face value, holding them to be as real as the terms united by them" (p. 107). Conjunctive relations embody the differentials of proximity, distance, intersectionality, divergence, and delay. Coming into language, conjunctive relations are voiced by particles such as *with*, *between*, *in*, *before*, *far*, and *so forth*.

These relations are encountered incessantly. Life is lived far more in these relations than in the disjunctive relations associated with things or entities. As James (1996a, 237) writes, "While we live in such conjunctions our state is one of *transition* in the most literal sense. We are expectant of

a 'more' to come, and before the more *has* come, the transition, nevertheless, is directed *towards* it."

As a form of knowing, radical empiricism pivots on analysis and untangling of conjunctions. We should recognize that both thinking and things work with and process via conjunctive relations. Wherever we look, we find conjunctions, that aspect of experience that triggers expectations of more to come, in movement. For instance, by sorting and reordering conjunctive relations of "before" and "after" in elements of a data stream, signal-processing techniques handle the "severe channel conditions" found in crowded cities. Or, by sorting and reordering relations of "inside" and "outside," wireless infrastructures affect sensations of the presence of others.

In its insistent attention to conjunctive relations, radical empiricism is intimately stitched into experience, into impersonal, preindividual, and intimate, subjectified dimensions of experience. In much of the following discussion of conjunctive relations, we will see this conjunctive underside of experience overflowing psychological or perceptual engagements. It pervades organizations, institutions, transactions, apparatus, and infrastructures, and it propels a gamut of improvisations, temporary fixes, and modifications associated with wireless communication and networks. It brings different scales into surprising contact. For instance, many people might say that they have no interest in, let alone experience of, the algorithmic signal-processing techniques implemented in wireless networks such as Bluetooth, Wi-Fi, or 3G cell phones. Despite that, their sensations of connection, their awareness of service availability, and their sometimes conscious preoccupation with connecting their wireless devices via service agreements or other devices all derive from the handling of conjunctive relations in data streams implemented in wireless signal-processing chips. No doubt, the paths along which sensations of transition move are highly complex, and cross multiple scales. The passing of experience can take very circuitous routes. Substantive and disjunctive relations backfill the vectors of transition. There are many circuitous conjunctive relations present in wirelessness.

Being-with as Thinking of Conjunction

Conjunctive relations present different degrees and kinds of inclusiveness and intimacy. However, in the transcontextual situation of wirelessness, ordering these degrees is problematic. There are two aspects to this problem. The first is the network. The infrastructural and media conditions under

which James developed radical empiricism were much less extensively networked than today. A key question here is: What happens to radical empiricism under network media conditions? The second aspect is political economy. It is hard to find any analysis of work, capital, economy, commodity, or markets in James.[10] How can we develop a network media aware, politico-economic edge in the free flow of radical empiricism? The scope to do this already exists in radical empiricism. As James (1996a, 94) puts it: "Experience now flows as if shot through with adjectives and nouns and prepositions and conjunctions. Its purity is only a relative term, meaning the proportional amount of unverbalized sensation which it still embodies."

In certain respects, we could see wireless technologies as attempts to extract, organize, channel, and protract the ambient "unverbalized sensation" of conjunctive relations. The conjunctive relations it harnesses (with, near, beside), are surrounded by "adjectives and nouns and propositions" that attach flows of transitions to personal attributes ("your," "freedom," "together"). What shoots through the flow of experience—"experience now flows as if shot through with . . ."—complicates that flow considerably. Although radical empiricism is a general philosophical technique for experimentation with conceptual constructs, it can be reconfigured and oriented to the proliferating, intermediate-level, and multiscale relations present in wirelessness. This means attending to the play of "intermediate factors." In their overview of ethnographic work on contemporary capital, economies, technology, and work, the anthropologists Melissa Fisher and Greg Downey (2006, 24) observe: "One thing that emerges from an ethnographic mode of theorizing is a greater awareness of intermediate-level factors—institutions, legal standards, technical limitations, social alliances, supply chains of particular commodities, subcultural identities, communities of shared skills—in the adaptation of technology to human use."

Under network conditions, the orderings of intimacy and inclusiveness that characterize the flow of experience can become unstable. When networks launch topological reorderings of place, "with" or "near" can become confused with "my" or "for." And it is precisely this instability in orderings of intimacy that invites many different attempts to inject verbal, visual, commercial, and legal orderings into conjunctive flows.

A radical empiricism of wireless networks would need, from this perspective, to take an interest in service plans, node databases, consumer electronics product reviews, or public-private partnerships for wireless network development. It might need to think about how antennae and algorithms work to permit people to walk around a city. In moving through

any of these intermediate levels, the technique of radical empiricism loops through "relations that connect," or conjunctive relations. As James (1996a, 42) says, "The relations that connect experiences must themselves be experienced relations, and any kind of relation experienced must be accounted as 'real' as anything else in the system."

The question then become how to loosen up the tight bounds of what counts as "our" experience of wireless enough to bring different scales of relation into "the system." New, surprising, or affectable senses emerge in various ways, but mostly in making something. As James (2004) says, "We patch and tinker more than we renew." In relation to wirelessness, the praxis of making ranges across literature, art, politics, publics, science, design, economics, media, and the military. There is contemporary wireless fiction (Doctorow 2005; Ryman 2004), wireless art (Savicic 2008; Kwastek et al. 2004), wireless politics (BBC 2003; Bureau d'Etudes 2007), and wireless design (Dunne 2005). While making things wireless differs widely across these different domains, radical empiricism can recruit praxes of making to unearth the limits of experience. Practices of making explore different scales and across scales. At each scale, and between scales, certain verbalizations and partitions are inscribed. They inject aspects, interfaces, systems, maps, sets, groups, plans, images, transactions, services, and infrastructures into the conjunctive situation. From the standpoint of radical empiricism (although it is not a standpoint, it is a treatment), these injections always tend to relaunch conjunctive relations outward, in more or less rigid, static forms. In some cases, making things wireless effects a capture of conjunctive relations in commodity form. In others, it expels them.[11]

While the following chapters will pursue the multiscale mode of existence of wirelessness in more detail, there is a broad-ranging exteriorization of conjunctive relations that can be expressed at a higher-scale ontological level, and in a way that strongly links capital, network, and connection. There is a philosophical reading of the historical circumstances of a particular conjunctive relation, "with," that I find helpful in understanding what is at stake in the exteriorization of conjunctive relations. In a series of writings over the last decade, the philosopher Jean-Luc Nancy has explored the connections between Being and capital (Nancy 2000, 2007). His analysis pivots on the problem of how to think of capital as a potent, corrosive determination of Being today.[12] He regards capital as a historical process of stripping away any foundation in meaning, substance, or subjectivity back to the conjunctive "with": "Capital exposes the general alienation of the proper—which is the generalized disappropriation, or the

appropriation of misery in every sense of the word—*and* it exposes the stripping bare of the *with* as a mark of Being, or as a mark of meaning" (p. 64).

Being without foundation, capital is unbalanced. At the same time, however, capital exposes a vertiginous absence of ontological foundations. Capital brings, for Nancy, an opportunity to become sensible to the barest of all conjunctive relations, what he terms "Being-with." This relation cannot be appropriated, expropriated, alienated, stripped away, or expelled since it has no meaning or interiority as such. It is already alienated as such. Nothing that exists today, in any context—social, religious, economic, technological, scientific, aesthetic, psychological, cultural—can alienate its own alienability, an alienability that stems from the conjunctive relation of "with." As Nancy writes, "If Being is Being-with, then it is, in its being-with, the 'with' that constitutes Being; the with is not simply an addition" (p. 30).

In the contemporary setting, communication embodies Being-with: "In fact, [what is exposed] is the bare and 'content'-less web of 'communication.' One could say it is the bare web of the *com-* (of the *telecom-,* said with an acknowledgment of its independence)—that is, it is *our* web or 'us' as web or network, an *us* that is reticulated and spread out, with its extension for an essence and its spacing for a structure" (p. 8).

While I am wary of investing too much in Nancy's emphatic account of "us," the "*com-*" (or with) expresses in a distilled form, it seems to me, an exterior limit for conjunctive relations in wireless networks. Handled carefully, Nancy's work (along with other related work), in short, allows a specific retrofitting of radical empiricism; it builds out an edge that engages with the expansive operations of capital and its spaced-out productions of value. Equipping radical empiricism with Nancy's conception of the Being-with helps pay attention to the ways in the conjunctive relations are exteriorized.[13]

Determinate Ambulation and Chapter Order

Devices, infrastructures, crimes, court cases, service plans, security, development projects, international standards, spectrum licensing arrangements, wires, antennae, settings, configurations, websites, logos, login screens, and many, many places: as I have said, none of this seems stunningly promising or significant material with which to develop a sense of contemporary network cultures. However, in its burgeoning irreducibility to the figure of the network, in its tendencies to redraw edges and periph-

eries, to ramify and to percolate, in its transitions and variations, in its discomfiting of locations, boundaries, and partitions, and in its many corporeal, legal, physical, architectural overflows, wirelessness bundles tendencies that lend themselves particularly strongly to a radical empiricist analysis of the present. These tendencies take networks into the world along many paths, and at times, render the patchiness and bareness of networks in the world more palpable. Each of the following chapters tracks a single tendency of wirelessness, beginning with attempts to create wireless cities, and ending with quasi-global belief structures concerning the expansion of wireless worlds. In moving from city (chapter 2), through signals (chapter 3), devices (chapter 4), maps (chapter 5), products (chapter 6), world (chapter 7), to belief in wirelessness (chapter 8), the chapters assay conjunctive relations as they undergo adjectival qualification, partitioning, and externalization.[14]

Movement in the city is a key motif for radical empiricism and pragmatism more generally. "Cognition," write James (1975, 81), "whenever we take it concretely means 'determinate ambulation.'" Cities generate particularly intense and varied forms of concrete movement, and strong beliefs and imaginings of controlled movement. Much arriving and departing occurs in them, and on different scales. The movement of people and things in cities has occasioned much analysis in urban studies of mobility, and also much more widely in social and cultural theory. Chapter 2 seeks to locate the most significant figures or forms of movement associated with wireless networks in cities such as London and Taipei. The chapter focuses in particular on the organizing notion of the "wireless city" in London between 2002 and 2007. Although the idea of a wireless city takes various forms, it always seeks to reorganize patterns of urban movement. Rather than trying to identify or convey urban experience directly (as much urban sociology has done) or to converge wireless network with ideas of cities as flow, I situate the idea of the "wireless city" in relation to moments of transition irreducible to the figure of the network. These transitions are strongly felt, and therefore offer multiple paths for a radical empiricist approach. The idea of the wireless city is an attempt to organize and control wirelessness in cities. Over fairly brief spans of time, the idea of the wireless city is affected by substitutions that erode, replace, overflow, and redefine its edges. The pattern of substitutions and site-specific alterations in the idea of the wireless city is an integral component of wirelessness. If ideas such as the wireless city are lived, they are lived to the extent that their apparent fixity allows and even encourages substitutions of various kinds.

Chapter 3 turns to the crucial technical terrain of wireless chipsets and wireless digital signal processing (DSP). Why bother with the sometimes bafflingly complicated techniques and architectures of DSP? Urban life produces problems of noise and interference that lie at the very heart of wirelessness. The complications of DSP are one strong index of the conjunctive patching of wireless networks into urban settings. The history of wireless cultures could be written as a history of how to inhabit urban (and military) electromagnetic environments. As contemporary wireless techniques began to gel around digital signal processing in the 1990s, they confronted the problem of how many signals could pass through the same space at once without becoming mixed up or clashing with each other. Effectively, a wireless signal must tolerate the presence of many others, in the same way that the inhabitants of any city must learn to live amid many strangers. How can the presence of many others be tolerated in communication? How many others can be present before communication is baffled? How can changes in position, in disposition, in concentration and dispersions, in rate and direction associated with movement in cities be accommodated? The digital signal-processing techniques that underlie wireless communication in almost every contemporary form (as well as many other audiovisual media such as video, photography, and sound) display daunting mathematical sophistication and intricate computational processing. Embedded in wireless chips, digital signal processing keeps afloat bodily sensations of movement, lack of constraint, absence of tether and encumbrance. While there is no unmediated access to signal processing, I argue that certain aspects of wireless signal processing tinge contemporary perception with specific conjunctions of movement and of direction. A conjunctive envelope grows around movement and perception. Even the most windowless wireless monad, fully equipped with a connectivity decoupled and unplugged from any particular place, is hedged in by intricately patterned consensus.

Chapter 4 theorizes work done on devices such as routers, antennae, and other wireless components. As something to be worked on, as more or less tangible things, wireless devices occupy an unstable position in the ecologies of infrastructure, architecture media, and consumption. In some respects they belong to network infrastructures. They can be configured as extensions of network culture. In other respects, they act as highly wrought furnishings for monadic bubbles of communication. They fungibly embody cascades of change in the design, making, organization, ownership, and maintenance of existing communication infrastructures and network

media. At the interface between network cultures and communication infrastructure, the chapter examines how devices undergo processes of variation and modification that make these instabilities sensible. This work of variation and modification circulates around standards such as IEEE802.11, but it also brings into play open-source software such as Linux. The standards embodied in wireless devices are not monolithically coherent entities. The standards themselves contain instabilities, gaps, and incompatibilities that trigger new variations. Existing notions of infrastructure as the background of experience cannot accommodate the dynamisms of physical, electronic, and software modifications of consumer wireless equipment. From the radical empiricist standpoint, these modifications inject site-specific mutations into the texture of experience. The fringes of perception tinged by wireless signal processing unfurl here via work done on opening, reconfiguring, and reconnecting devices.

Chapter 5 focuses on the management of wireless networks. It tracks attempts to concretely act wirelessly. The chapter focuses on practices of network building, network mapping, and connecting to networks as they appear at two edges of wirelessness: online wireless node databases and antenna modifications. Node databases have been at the center of community, free, alternative, commercial, and public-private wireless networking projects. They mostly record the geographic location of wireless antenna. Putting antennae in different places—higher, lower, inside, outside, closer, and so on—has been a critical step on the path to wireless networks (not just for Wi-Fi, but for all wireless technologies, ranging from mobile phones to RFID chips). In what sense does making a network, mapping a network, or connecting to a network involve node databases or antennae? How do we make sense of the different aspects of wireless networks expressed in node databases and antennae? Unlike much network theory, I have sought to circumvent the figure of the network in analyzing wireless networks. For reasons discussed above, this chapter remains somewhat skeptical and wary of networks as analytical devices. Instead it asks, when and how are collections of relations concatenated into networks? Are there actual wireless networks, or only tendencies to network and practices of networking? In the latter case, we can expect networks to take very different forms depending on the ways collections of relations are handled. In the course of analyzing some different node databases and their different network forms, the notion of practice or action itself comes into question. From a radical empiricist standpoint, everything has to be viewed from the standpoint of practice. However, as discussed above, there

are antipragmatic practices, practices that patrol and cordon off the buried potentials in any situation for displacement, divergence, and decoupling of contexts.

Nearly every instance of wirelessness has product-related dimensions. Chapter 6 treats wirelessness in relation to products, and the claims, promises, skepticism, awareness, and incredulity associated with wireless products. Wirelessness is pitched in the form of products, as goods and services. What would a radical empiricism do with wireless products? Where is there room for experiment, for construction, for testing of ideas or claims in relation to a tumult of wireless products? The key claim of the chapter pivots on James's claim that the difference between inner and outer aspects of experience depends on a sorting process. "Things" appear as inner or outer depending on how they act on their neighbors. Using techniques of listing and sorting of wireless products, the chapter analyzes how neighbors and neighborhoods of relations take shape. Each product gesticulates a set of promises. Promises—of connectivity, of ease of use, of freedom from constraint, of speed, of pleasurable sensations of touch, seeing, and hearing, and so on—bind the product. Strongly antipragmatist tendencies disguise the potential of products to germinate unexpected change. Yet the presence of many different promises and products in a neighborhood of relations tends to trigger uncontrollable jumps. These jumps blur and erase boundaries, and entangle products, services, and wireless forms of subjectivity. Importantly, maintaining equivocal differences between inner and outer, between pure promise and actual reality, serves the purpose of generating ongoing transitions.

Chapter 7 follows a strand of wirelessness associated with normative notions of "world," "globe," and development. The chapter discusses and contrasts a number of wireless development projects on different scales. Often the most advanced or adventurous wireless platforms are tested in Africa, South America, or South Asia. Since 1999, wireless networking projects have rapidly multiplied in many places and on many scales. These public, private, and public-private partnerships projects sometimes avow global ambitions (for example, "to connect the next billion people"). The arguments of this chapter are framed by existing critiques of technological development, and by a desire to understand the sheer number and variety of globally oriented wireless development projects from the perspective of a spectator. I regard these projects as made to be seen. The question then is how to situation their performance pragmatically. In what ways do wireless networks for global "others" vouch for or validate "our" connectivity? In what ways do wireless networks verify the plural and uncontainable

overflows of any form or figure of world or globe? The coexistence of very different scales of projects creates analytical difficulties that a radical empiricist approach can usefully address.

The final chapter stands back from the different approaches taken in the preceding six chapters. It reframes these approaches in terms of belief in wirelessness. How does a radical empiricist account of the contemporary moment as framed by networks, connections, services, and devices differ from other work on the present, on recent pasts, and on near futures? Here James's account of belief (in conjunction with Henri Bergson's concept of duration) plays a distinctive role. Framing belief in terms of liveness, momentousness, and force allows us to pose the question of what possible relation we can have to change. The discussion contrasts James's radical empiricism with its concentration on conjunctive relations and the overflow of experience with Bergson's method of intuition and its concern with "true" and "false" problems. This contrast differentiates a pragmatist sensibility attuned to the vertigo and turbidity of change. In particular, this chapter offers an alternative reading of the network condition of experience of nothing.

In sum, the pleonasm *wirelessness* designates (1) a sensibility attuned to a proliferating ethos of gadgets, services, opportunities, and enterprises that transmit and receive information via radio waves using Internet-style network protocols; (2) a strong tendency to make network connections in many different places and times using such devices, products, and services; and (3) a more or less heightened awareness of ongoing change and movement associated with networks, infrastructures, location, and information. Wirelessness in contemporary media and cities links directly to the core of James's argument concerning the flow of experience, and this seems a good place to start following the wireless lead.

4 Devices and Their Boundaries: Inventing Wireless as "Vast Space"

For most people, wirelessness means devices—mobile phones, routers, game consoles, media players made by companies such as Apple, D-Link, Motorola, Belkin, Samsung, Netgear, Linksys, or Dell. However, abstract processes—an enveloping conjunction of relations coalescing around problems of spacing, departure, arrival, proximity and being-with others—attach to all contemporary wireless devices. Wireless devices, enmeshed in the psycho-infrastructural economy of network media , undergo constant transitions, processes of modification, and experimentation. Wirelessness agitates, frustrates, and bores, as well as satisfies, excities, and gratifies. These feelings often surface around devices. While changeability is not unique to wirelessness (since it can just as well occur in relation to climate change, reality TV, computer games, finance markets, art exhibitions, political life, biomedical research, music, conferences, etc.), devices present tangible traits that allow wirelessness to be investigated in the making.

A radical empiricist understanding of wirelessness as "turbid sensation" of change would pay attention to how devices are made and unmade in experimental—and antiexperimental—practices.[1] A great diversity of practices could be discussed here. They range from the ways people mundanely modify, configure, or substitute settings on wireless or mobile gadgets, to the estimated 250 million shānzhaìjī or "bandit phones" made in small workshops in southeast China during 2008. In the middle ground, we could discuss the post-dot-com bubble valorization of "making" and DIY technology in North America, Europe, and Australia. The online and print magazine *Make: Technology on Your Time* (O'Reilly Media Inc. 2007) enthusiastically endorses modifying, altering, and reconfiguring (mainly) digital hardware and software in low-cost projects.[2] The advent of open wireless platforms such as the *Open Handset Alliance* and Google's Android for mobile phones (Open Handset 2009) further exemplifies the shifting boundaries of wireless devices. Although all the chapters in this book could

be understood as concerned with experience in the making, this chapter is directly focused on practical work done on particular Wi-Fi devices such as wireless routers. In contrast to the largely invisible intricacies of the billions of mass-produced semiconductor chipsets and algorithmic calculations of the previous chapter, devices such as routers modulate wirelessness into many tangible and intangible forms—products and services, gadgets, and infrastructures. The boundaries, physicality, networkability, and individuality of wireless devices undergo extensive experimentation. Viewed as modulations of the conjunctive envelope in network settings, wireless devices attract extensive efforts at configuration, modification, experiment, and commodification. These efforts are not trivial or superficial. They are often highly generative, deep-ranging, and potent, and quickly trickle back into commercial products. The chapter, then, takes a particular interest in the ways that people handle wireless devices and equipment, and what happens when they do. The materials presented in this chapter focus on a class of devices known as wireless routers, and the Linksys WRT54G wireless router in particular as it appears in policy documents, wireless how-to books, and software such as *OpenWRT* (OpenWRT 2008). (A similar analysis could focus on mobile phone handsets or other wireless devices.)

The Wireless Router as Progression from Bad Network to Good Network

> To progress in knowledge . . . signifies to pass from a bad network to a good network. (Latour 2007, 28)[3]

Much of the work done on wireless devices focuses on the gap between what a network is and what it is not, between what we might call a "bad network" and a "good network." The difference between a bad network and a good network drives many interesting dynamics of wirelessness. Take, for instance, the popular WRT54G wireless routers made by Linksys, a brand name now owned by Cisco Networks, a globally significant manufacturer of networking equipment. A router is a piece of network equipment that decides where on the network to send packets of information it receives. (More technically, a router connects two networks or "subnets." It might connect two wireless subnets or, more typically, a wireless subnet and a wired subnet.) Until the arrival of wireless devices, homes and cafés did not need routers. Their arrival suggests that networks, in the plural, have entered domestic spaces. It might be hard to feel at all excited by Linksys routers since they do not seem to do very much. Their chunky blue-and-black plastic enclosures squat on shelves and tables in houses,

apartments, cafés, and offices. As devices, they entirely lack the sharp design edge of the latest Motorola Razr mobile or Apple iPhone. Their half-dozen small flashing LEDs hardly match the media extravaganza on offer in a Sky+ digital video broadcast satellite television box. They do not upend the living-room furniture like a Nintendo Wii game controller (itself a Bluetooth wireless device). Yet Linksys routinely sells several hundred thousand routers each month (Asadoorian and Pesce 2007, 3), so they can be found in the millions. Given its innocuous status, you would think that Linksys could control the production of the Linksys WRT54G wireless router in such a way as to guarantee a predictable modulation of wireless signals and calculable growth of the Internet. Actually, the Linksys WRT54G wireless router encompasses a series of devices built of many components that are constantly changing, and not always according to the manufacturer's wishes. Since 2002, there have been approximately fourteen major versions of the WRT54G, and each has a number of minor versions, so that overall there are around forty-five versions of this one product line, the Linksys WRT54G (the *Wikipedia* entry gives a good sense of the versioning; see "Linksys WRT54G Series" 2008). The series of devices are all called WRT54G (**W**ireless **R**ou**t**er **54**M/bs 802.11**g**). The devices all look broadly similar, and ostensibly, they do similar things. It is actually sometimes quite difficult to know which one you are buying.

As a variety of pragmatism, we would expect radical empiricism to say a lot about practical differences. Pragmatism has primarily been understood as a method of settling metaphysical disputes in terms of practical differences. As James (1978, 16) define it, "The pragmatic method . . . is to try to interpret each [metaphysical] notion by tracing its respective practical consequences. What difference would it practically make to anyone if this notion rather than that notion were true? If no practical difference whatever can be traced, then the alternatives mean practically the same thing, and all dispute is idle."

For *notion* in the above formulation, we might substitute *device*. The pragmatic method would ask: What difference does it make it to anyone if one version of a wireless router rather than another is made, sold, bought, or brought into existence? Any such difference would only occur if people had different ideas of what makes a bad network and what makes a good network. If they want to move from bad to good networks, a device might make the difference. A gap exists between the ideal of a totally networked world and a provisional, unstable reality tangled with wires, buildings, everyday habits, and the presence of others, between, in short, meaning and *praxis*. That gap exists, according to Jean-Luc Nancy (2007,

54), because meaning does not exist outside practice: "Meaning is always in *praxis,* although no practice is limited to enacting a theory and although no theory is able to diminish practice." Things and practices cannot be fully interpreted or rendered meaningful, and conversely, meaning cannot be entirely put into practice. Consequently, an excess immanent to experience generates work "whose principle is not determined by a goal of mastery (domination, usefulness, appropriation), but exceeds all submission to an end—that is, also exposes itself to remain without end" (Nancy 2007, 54). Although mastery, usefulness, and "appropriation" (of value) are writ large on wireless devices, some of the work done on them cannot be captured by such ends.

From the outside, almost everything about the router is generic. For example, some lights flash to indicate power, connectivity, and network activity (see figure 4.1). Apart from some general physical similarities (although even these are subject to radical alteration, as we will see), the only thing that links different versions of the WRT54G is the quasi-abstract center of envelopment described in the last chapter—the IEEE 802.11a/b/g (and n) WLAN standard. In different ways, all WRT45Gs instantiate that convoluted center of envelopment. Various features of the objects refer to the signal processing and networking protocols. Most visibly, the name of the device, and various Wi-Fi Alliance–approved labels on the different versions all refer to "g" or specifically to "802.11g," a somewhat later, higher-speed version of 802.11 wireless networks.

Despite being so generic, or, perhaps because they are so generic, these devices harbor surprising degrees of relationality and support a wide variety of experimental (and antiexperimental) modifications. Unexpectedly sophisticated webs of relationality unfold out of and around them. They are constantly being remade, both by Linksys and its component suppliers, and by others in, for instance, various antenna modifications, in changes to the firmware, or in replacing the enclosure. Practices of making and unmaking (preventing change) deeply affect how the contemporary experience of wirelessness takes place.

Isn't experience something that is just pragmatically given, that we perceive in some ways, that we ideate or remember in others? And in relation to wireless communication, doesn't the presence of the wireless networks in houses, cafés, airports, hotels, and city streets simply deliver connection to information networks in a way that we can quickly take for granted, or that we at least hope to take for granted? There are number of problems and obstacles in taking experience as just given. First, wirelessness has a texture that intensifies certain aspects of experience. Second, in

Figure 4.1
A Linksys WRT54G wireless router.
Credit: Jonathan Zander.

contrast to phenomenology and the many sociological approaches that draw on it to anchor experience in the living, speaking subject (Derrida 1973), the impersonal and material aspects of wirelessness fold in from the edges of experience. They are not given in experience, nor outside it. While pragmatic thought in general is often taken as a method for testing ideas, it harbors within it, and especially in James's version of it, a much more animated, effervescent account of experience. James's characterization of the weaving together of transitions in experience is symptomatic of this: He writes: "According to my view, experience as a whole is a process in time, whereby innumerable particular terms lapse and are superseded by others that follow upon them by transitions which, whether disjunctive or conjunctive in content, are themselves experiences, and must in general be accounted at least as real as the terms which they relate" (James 1996a, 62).

Here, the emphasis lies on the need to count transitions as real as any content of experience. James affirms the "reality of change" (Massumi 2002, 201). His radical empiricism makes a transition into a leitmotif of experience. If wirelessness is typical of contemporary experience, then it cannot be understood without reference to the vectors and gradients of change that it enfolds and compresses. We can also see radical empiricism, as this chapter does, as a name for any exploration of the boundaries, contours, neighborhoods, and limit points of making and remaking things in transition. The "innumerable particular terms" of wirelessness include many specific practices as well as pieces of hardware and software caught up in "transitions" that cut across and recombine things and feelings, gestures and processes.

Who Sets Boundaries on Devices?

Wireless spaces fluctuate readily, sometimes even with the weather, but particularly in the presence of others. Changes affect wireless devices, even just a single wireless device such as a wireless card (see figure 4.2), differently.

There is an uncertain spatiality to wirelessness that comes from the encounter between the conjunctive envelope described in the previous chapter and network topologies. In network topologies, connections and relations are often centrally managed. The uncertain limits of wirelessness have already been a matter of public concern in various forums. For instance, a "spectrum-commons" debate began in the late 1990s, particularly around the auctions for the mobile phone spectrum. This debate was

Figure 4.2
"AirStation" in the kitchen.

an adjunct to other wide-ranging debates about intellectual property and information networks that were occurring at that time. In 2003, a well-known technology analyst, Kevin Werbach, published a report titled *Radio Revolution* (Werbach 2003) arguing that existing regulation and allocation of the radio-frequency spectrum was based on a misunderstanding of wireless communication. The report entered into the wider spectrum-commons debate by arguing for changes in the way the U.S. Federal Communications Commission (FCC) allocates frequencies. It was structured around a series of analogies and explanations of how wireless technologies have changed. According to Werbach (2003, 2), "Our intuitions about wireless, by and large, are mistaken. They are based on outdated technologies and inaccurate analogies. If we hope to move forward in exploitation of the airwaves, we must take a step back. We must understand wireless communication for what it really is. And then we must re-evaluate our assumptions about what it could be."

Werbach argues that existing spectrum allocation and licensing regimes mistakenly focus on an abstract territorial concept of spectrum (as a

limited, even scarce resource that needs to be parceled out carefully in order to avoid conflict, competition, and interference that would render it useless to everyone). Instead, according to Werbach, in order to "move forward in exploitation of the airwaves" we need to embrace a "new dynamic paradigm" in which "more than one service can occupy the 'same' spectrum, in the same place, at the same time. The frequencies that now carry one signal could someday carry thousands . . . or billions" (p. 3). The new dynamic paradigm focuses on the behavior of devices: the "key question in a world of dynamic wireless systems is how to set the proper boundaries on how devices can operate" (p. 16). The ins and outs of the spectrum-commons debate need not greatly concern us here. That debate, and the attempts to develop new paradigms of wireless communication within it, suggest that wirelessness as a contemporary mode of experience concerns a topologically problematic space.

Werbach argues that rather than asking how to allocate radio spectrum, the key question should be "how to set the proper boundaries on how devices can operate." Although Werbach aims to reform U.S. regulatory practices, the question of the "proper boundaries" on wireless technology is much wider than a regulatory issue. There are many ways of setting the boundaries on how devices operate. And there are many different people or groups of people who could be involved in setting or changing boundaries. Many of these ways of setting boundaries are part of the devices themselves. Boundaries are not simply imposed from the outside. They can be altered by modifying hardware (antennae, enclosures, etc.), changing or upgrading software (the "firmware" that the devices use), configuring the many security and access settings on the devices, trying different locations for the devices (on roofs, on street poles, in cars, etc.), as well as by federating devices in new sets and groupings (as did the many community and wireless mesh networks), or by building wireless devices from standard components (as do the shānzhaìjī device makers in China). In a sense, wirelessness transpires as an experiment that explores different ways of altering the boundaries on how devices operate. This experiment also involves the experimenters. The question of who can alter the boundaries on devices is contested.

Wirelessness understood as an experiment in who today can alter what device boundaries diverges from a now more familiar interpretation of the relation between experience and modern infrastructure. It is widely accepted that mundane experiences of place, movement, and mobility rely on infrastructures that remain more or less invisible (but for a critique of this, see Edwards 2003). For instance, the social scientists Paul Dourish and

Genevieve Bell (2007, 417) argue, in the context of pervasive computing, that infrastructure shapes the fabric of experience:

> By "the infrastructure of experience," we want to draw attention to the ways in which, in turn, the embedding of a range of infrastructures into everyday space shapes our experience of that space and provides a framework through which our encounters with space take on meaning. The experiential reading of infrastructure, then, sees infrastructure and everyday life as coextensive; accordingly, it encompasses not just technological but also the social and the cultural structures of experience in pervasive-computing settings.

In this view, infrastructure has both technological and sociocultural aspects. As technology, infrastructure shapes experience and materially supports meaning, itself deposited in social and cultural structures. While this makes sense and would be hard to disagree with, it still departs from two separate realities—technology that is more or less physical and experience that is more or less social and cultural.

Rather than saying that infrastructures such as wireless networks shape an experience of space, we could say that through wireless devices certain tendencies or potentials in contemporary experience are explored and spatialized. These tendencies or potentials are not always consistent with each other. From a radical empiricist perspective, infrastructure can readily invert into experience. Thing and thought are not in principle separable in radical empiricist understandings of experience. Precisely because they weave through experience, wireless devices are sometimes infrastructures and sometimes highly intimate possessions. The same device can be both. For instance, a small device such as the Novatel MiFi acts as a "personal hotspot" (Pogue 2009), and is both infrastructural and personal. Via wireless devices, what Dourish and Bell call the "embedding" of infrastructure into everyday space, I would argue, enters an unstable trajectory. Wireless equipment lies somewhere on the boundary between the proper infrastructures of modernity (roads, airports and railways, telephone exchanges, lines, transmissions towers and satellites, electricity pylons, water mains and gas pipes, etc.) and consumer electronics. Today, many wireless devices, especially relatively bland products such as access points like the Linksys WRT54G or the many gadgets with Wi-Fi built in, take the shape of small boxes with short antennae (although as the following chapters will argue, the shape of wirelessness is constantly reimagined in different forms—maps, networks, gadgets, etc.). These boxes look somewhat different from most other consumer electronics. Their relatively simple controls and small size mean that they can quickly fade into the background in most settings. In commercial and institutional settings, they can be found mounted high

on the wall, or inside another enclosure (for instance, in the United Kingdom, the commercial wireless access points in thousands of bars and pubs lodge inside a gambling machine called "Who Wants to be a Millionaire" based on a popular TV show). There are many built spaces now populated by such devices in ways that we are scarcely aware of (Thrift 2004), and this trend shows no signs of abating as femtocells and picocells promoted by telephone companies arrive on the doorstep to compete with Wi-Fi-based broadband. A phenomenology of wireless boxes mounted via wall brackets might conclude that wirelessness has a quotidian invisibility. It is practically bracketed out (although this bracketing out is constantly interrupted, as will be discussed in a later chapter). Sometimes, one way or another, we are compelled to perceive these boxes and make use of them in ways that shift quite dynamically. There is a truism in the phenomenology of technology and probably in the cultural and social studies of technology more generally that we become aware of technology only when it breaks down.[4] In fact, in relation to wirelessness and many other technical situations, a flickering oscillation between breaking-down, becoming-aware, and background-forgetting is more common. Organized forms of breakdown—hacking, copying, modification—attract energy, investment, and attention.

The devices that comprise the infrastructure keep changing, and this process of change is difficult to control. New components are constantly being added, and sometimes old ones are taken away by the manufacturers of consumer electronics. While some of this dynamism is due to the market conditions in which wireless equipment is built using standard mass-produced components, other parts of it are due to processes that overflow the market competition, and in fact subvert markets and branding. Here the Linksys routers are typical. They, like most consumer electronic devices today, are effectively scaled down computers, with their own memory, CPU, interfaces, and software. These components come together in the router from different sources. Sometimes the substitution of components flows in the wake of relatively small changes in the internal design of the object as engineers find new ways to cut costs, simplify fabrication, or enhance the behavior of the object. For instance, after the networking equipment corporation Cisco Systems, Inc. purchased Linksys in 2003, models of the WRT54G have fewer lights on the front but an extra button for "Secure Easy Setup." Viewed from the outside as a box, the router looks generic and static, and indeed has been mass-produced. Seen over time, however, the router has undergone a surprising degree of modulation, activity, and expression related to software cultures more generally. Some-

times new components come and open the device to whole worlds or realities that were previously not part of the object. (For instance, as discussed below, a larger flash memory might change the kind of software that can be installed in the router.) These changes alter the boundaries within which the devices operate.

If it seems that infrastructures exist relatively inertly in comparison to experience, we need only think of the work of maintenance and repair that goes on in contemporary cities around communication and transport. Stephen Graham and Nigel Thrift (2007, 8) argue that maintenance and repair form an increasingly important component of the life of "cities of repair" today. Frequent cycles of replacement and disposal of electronic equipment such as computers and telephones bring severe problems of configuration, maintenance, and upgrading, as well as geopolitical problems of waste management, energy supply, and pollution into play. This means that an experience of infrastructure includes transitions between working and not-working, between emerging and the taken-for-granted, between old and new: "The inherent and continuous unreliabilities within all infrastructure systems, which necessitate continuous efforts of repair and maintenance to actually allow them to sustain the distantiated connections and flows that they are designed to deliver, still tend to be rendered invisible both culturally and analytically" (Graham and Thrift 2007, 10).

While Graham and Thrift see the inherent unreliabilities of infrastructure as something largely negative, and as therefore tending to be "invisible both culturally and analytically," I would argue that in the certain respects wireless networks overflow this observation. Their unreliable transitioning has been heavily mediatized (see the following chapters), partly because their value and status as infrastructures have not been able to stabilize. For instance, in the case of municipal or metropolitan wireless networks, their outlines or boundaries as public, private, or commercial infrastructures cannot be readily fixed and have repeatedly shifted.

Occasionally devices affect infrastructure itself, especially if that infrastructure is "interwoven with the existing physical structure of space." We need not assume the possibility of concretely separating technology and experience at the outset. Experience, following James's account of it at least, cannot be easily corralled or concretized as either social or physical. Importantly, as discussed previously, experience has many impersonal aspects that do not feed directly into meaning, that hover on the edge of intelligibility as sensations or feelings. No doubt, social and cultural structures identify, fix, isolate, and abstract certain aspects of experience. But

in terms of James's radical empiricist account of experience, the flow of experience relies on relations that themselves do not always appear as images, statements, or signs. These relations have vital importance in constituting the flow of experience. James (1996a, 48) writes that "continuous transition is one sort of a conjunctive relation; and to be a radical empiricist means to hold fast to this conjunctive relation of all others." The key argument here, then, is that in work done on wireless devices, experience, and the infrastructural conditions of experience intermittently and provisionally coalesce. The assumption that an infrastructure frames a single space comes into question around wireless devices, some of which intersect with multiple infrastructures on different scales (Bluetooth, Wi-Fi, GSM, etc.), and some link multiple infrastructures together.

Internal Breakdown: The Kludge

Wireless devices display equivocal status as infrastructure. They subject various infrastructures to variation. Network infrastructure in particular goes into transition in wirelessness. There are several dimensions to this transition at work in IEEE 802.x networks such as Wi-Fi and WiMax. This is not only because the repair, improvement, upgrade, and maintenance work constantly alters things. It is because the thing itself, the wireless device, was always an unstable composite charged by different, even contrary, tendencies. In 2003, a participant in the *Consume* project based in Greenwich, London, touched on this when he exclaimed during an interview: "802.11b is a kludge!" A "kludge," according to the *New Hackers Dictionary,* is a hacker term for "an ill-assorted collection of poorly matching parts, forming a distressing whole" (Raymond 1996, 221). At that time, there was so much to be seen and heard about the promise of Wi-Fi, and about how adaptable, powerful, and effective it is, that it was striking to hear Wi-Fi—a very highly promoted and arguably successful networking technology built into millions of systems—derided as a "distressing whole." Given that the interviewee was heavily involved in a relatively prominent, well-known community wireless project that had many operational nodes deployed and working, why should he call Wi-Fi a kludge?

Kludges do not always arise from a technical design defect. A long history of kludges constitutes the material culture of media. The quasi-geometrico-optical metaphor of "convergence" that is often used to describe contemporary media neatens up the unstable mixtures of audio-visual, communications, and computing techniques occurring for the past few decades as various sound, visual, televisual, textual, graphic, tele-

phonic, and now radio media are folded into computing, and hence into other mobile and consumer electronics devices. They sometimes attest to the divergent realities, needs, and desires articulated together in technical objects. Whereas the notion of convergence emphasizes reduction to a well-defined context or state of affairs, "kludge" gestures toward *relationality*, to ongoing changes in nature stemming from juxtapositions. Massumi's (2000, 191) concept of relationality captures certain aspects of a kludge well: "Call the openness of an interaction to being affected by something new in a way that qualitatively changes its dynamic nature *relationality*. Relationality is a global excess of belonging-together enabled by but not reducible to the bare fact of having objectively come-together."

Relationality in this sense of transcontextual anomaly or excessive belonging-together occurs whenever differences come into play. In the case of wireless networks, the "complaint" about the Wi-Fi kludge is quite specific: it is directed at the Wi-Fi standards, 802.11b (IEEE 1999) (and presumably would also apply to more recent versions (IEEE 2003)). One way of understanding what might be excessive in a standard is to look at how its limits are defined. Without delving too deeply into technicalities here, IEEE Standard 802.11b or Wi-Fi is defined as part of a larger suite of standards dealing with digital communications in networks that use packets to transmit data, the IEEE 802 family. Other members of the 802 family include WiMax, Bluetooth, and Ethernet. These interlocking standards, usually implemented in computer code, sometimes built directly into semiconductor hardware, form the fabric of the Internet. The standards document for 802.11b published by the IEEE is titled "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Higher Speed Physical Layer Extension in the 2.4GHz Band" (IEEE 1999).

Although specifications are intended to reduce ambiguity and eliminate openness to unexpected interactions, sometimes they have the opposite effect. As the title of the IEEE document states, the 802.11b standard describes a way for computers to be networked together using an unregulated portion of the electromagnetic spectrum, 2.4GHz. This is described as a "Physical Layer Extension." Like most contemporary standards and protocols, the 802.11b standard is enmeshed in a web of other standards and protocols. In its very title, Wi-Fi standard refers to and relies on a broader model for communications known as OSI, the Open Systems Interconnection model (on the significance of OSI in the history of the Internet, see Abbate 2000, 167–177). In this model (as well as in the main model for the architecture of the Internet, TCP/IP), the phrase "Physical

Layer" designates the physical and electrical components of the computer network. The physical layer is typically understood as the most stable, inert layer of the Internet. It includes all the wires, cables, optical fiber, microwave links, network sockets, and telephone lines out of which contemporary computer (and increasingly telecommunication) networks are cobbled together. Everything else in the network architecture contrives to hide the physical layer, to push it "down" to the bottom of the so-called protocol stack and to literally put it behind walls, in server rooms and/or inside manufactured hardware such as semiconductor circuitry (Smith 2004). Often it remains visible only in the form of the 10BT plug office PCs are connected into.

From the standpoint of the kludge, it is significant that Wi-Fi, as well as several other wireless members of the 802 standard family, straddles two of the seven layers of communication—the physical layer and medium access control layer—defined by the OSI model. The kludge of IEEE 802.11b, we might say, stems from the differences between the amorphous outline of the physical layer, which no longer resides in cables but occupies airwaves, and the organizational topology of the network implicit in a specific medium access control protocol, the Ethernet, which limits the number of networks nodes (or attached computers) and organizes them in a treelike hierarchy suitable for local area networks (such as those found in office buildings). In 802.11b (and its companion versions 802.11a, 802.11g, 802.11n), the physical layer has spread out of cable into the electromagnetic spectrum. Once it moves out of wires into the electromagnetic spectrum, the physical layer crosses some of the social, political, and cultural boundaries aligned with built space (for instance, the line between public and private) that the medium access control layer takes for granted and seeks to hold in place in the form of a network.

In contrast to some electronic products, wireless devices lie at the boundary between network topologies and physical space. Dourish and Bell (2007, 428) observe that there is something "physical" about wireless networks that renders their relation to space more complicated: "One fascinating aspect of the move from the systems we built on the wired Internet to those that we experience through wireless and mobile networks is that we are creating not a virtual but a thoroughly physical infrastructure, and we need to think about it as one that is interwoven with the existing physical structure of space."

The awkwardness of Wi-Fi mobility, and the reason that it generates so many forms, incarnations, experiments, and hacks, comes from juxtaposition of a medium access control protocol meant for well-defined, centrally administered, and self-contained local area networks such as offices with

a proliferating physical layer, propagating signals across once impermeable boundaries and between once divided spaces (home office and kitchen). Importantly, the "kludge" that the software developer refers to is deeply entrenched in the standard. It is not an accident that has befallen wireless devices due to bad technical work. The coalescence of divergent organizations of space and movement at the interface between the physical and medium access control layers produces interesting instabilities.

The kludge both suggests why Wi-Fi will undergo constant transitions and why it will generate a variety of mutations, performances, implementations, and instantiations. The abundance of Wi-Fi-related phenomena can be read as animated by an instability arising from competing logics of space, communication, and movement already visible in the architecture of the Wi-Fi standard. At this moment in the supersaturated medium of communication networks, many different imaginings of mobility and connectivity are in contention. They project different network topologies, different patterns of movement, ownership, regulation, sociality, and embodiment. In differentiating the parameters of these spaces, movements, and controls, communication infrastructures become a locus of social-cultural-material struggle. Wireless networks, as material-social-cultural process that changes communication infrastructures on a variety of scales, precipitate a diversity of movements that shift thresholds between public and private, between individual and collective. At the moment, two principal topologies inhere in IEEE 802.11b. The first presents Wi-Fi as a way of combining access to a medium, the Internet, in many more locations. We could call this the "medium access control" idiom. The second regards wireless LANs as a way of making visible, experimenting with, or engaging with certain physical, economic, and even political obstacles at the edge or in the infrastructure of information networks. The later topological interaction might be called the "physical layer."

The broader point is that wirelessness as a mode of contemporary experience harbors discontinuities between different kinds of relations. James writes that "there is vastly more discontinuity in the sum total of experiences that we commonly suppose" (p. 65). Although experience is really nothing but a series of transitions, and one experience can do nothing but lead to another, the transitions and tendencies that constitute experience do not necessarily fit together. James's striking image of living "upon the front edge of an advancing wave-crest, . . . falling forward" (p. 69) does not guarantee smooth travel. The front edge of the wave crest could just as well be the roughest, frothiest, noisiest place to be, the place where many different things jostle each other. Different tendencies or paths of transition vie with each other in wirelessness.

Individualizing Network Access

A medium access control or MAC address is in principle unique to a given piece of networking hardware. Every networked device, including every Wi-Fi card, has a unique MAC address. There is a dream of global and permanent uniqueness associated with the notion that each and every piece of networking hardware in use today has an individual numerical address assigned to it. Why should that uniqueness be desirable? While the figure of the network as a flat, nonhierarchical, lateral flow has become a quasi-ontological norm in the makeup of business, organizations, groups, and structures of many different kinds, the practical management of networks has a fine-grained governmentality associated with it.[5] An individualism of the network device closely complements the flat topology of the network. The term *Wi-Fi*—coined in 1999 by the Wi-Fi Alliance, an industry association (Wi-Fi Alliance 2003)—is sometimes said to abbreviate "wireless fidelity." The term resonates with *hi-fi*, a term for up-market home audio reproduction technology dating from the 1950s, and tacitly links Wi-Fi to domestic architecture and consumer electronics, to living rooms, televisions, and sofas rather than to cyberspace or office space. This resonance of "high quality but for domestic use" pervades a predominant idiom in which 802.11b equipment and software is visualized, installed, and configured as progress from bad networks to good networks. The transition from bad to good network centers on an individual who would enjoy access to a medium, the Internet, through a device. A powerful vector of the wave front of wirelessness heads toward the promissory horizon of constant, ubiquitous individualized or personalized access to a network medium.

By naming IEEE 802.11-compliant devices Wi-Fi, the industry alliance tackled the representational problem of rendering something visible—a new mode of access to network infrastructure—while stressing its invisibility and its ease of use. However, this implicitly personalized or individualized wireless devices. Network access, or access to the medium, becomes an individual possibility. For instance, around 2002 or 2003, Intel promotions of Centrino™ computing products heavily featured Wi-Fi. Intel is just one salient example among the real plethora of enterprises, schemes, and strategies centering on Wi-Fi as the basis of connected mobile computing. Mobility is understood here as allowing people to more easily use computers in different places by disconnecting computers from walls, wires, and sockets. The Centrino chipsets have been promoted through the slogan "the unwired office starts inside" (Intel Corporation 2003). Integration of wireless capability into the "inside" was represented in magazine

advertisements by an "X-ray" image of the motherboard of laptop computers (Intel Corporation 2003) shown above hotels, golf courses, beaches, and shopping malls. While "convergence" between communications hardware and computing hardware has been occurring for several decades (so-called Ethernet NICs—Network Interface Cards—have been standard computer components for a decade), in producing and promoting the coalescence of laptops and Wi-Fi, Intel was successful in the ubiquitous personalization of wireless devices.

Hence, Intel's advertising slogan, "the unwired office starts inside," can be read as referring to a subjective interiority. The "inside" might also be that of the "Wi-Fi user," a human subject who has begun to internalize network connectivity as potentially available anywhere—in public and private, at work, at home, during leisure, travel, or war. The human figures—usually men—who populate promotional images associated with Wi-Fi suggest an "inside" in genesis in two ways. In 2003, Toshiba laptop computer advertisements showed a man usually alone in remote locations, although he was occasionally at work in a casually stylish office meeting (Toshiba Corporation 2003). He stood on a rocky promontory beside a storm-tossed sea, he sat in a treehouse looking down on the children playing in a sun-filled backyard, he looked out from a platform high above a sports stadium, or he lay on the grass in the middle of a park on a fine day. It was hard to tell who was working and who was not since these men were not obviously dressed for work. Each time, he looked at a laptop screen on which some other photographic image had been graphically superimposed: an office full of people, a library stocked with books, a scene from an action film. In each case, the superimposed image was somewhat incongruous with the geographic location. The freedom to connect "in new places" that Intel's promotions refer to recurs across many different corporate promotions of Wi-Fi. An affirmation of "freedom"—"enter the world of freedom computing" (Toshiba 2003), "lose the wires, be free" (MyZones 2003)—is attached to an absence of wires. Not having to plug a computer into a socket in the wall to do e-mail, download files, or surf the Web, means that the screen loses its moorings and begins to float around. The socket in the wall to which screens are tethered dissolves. In other words, for the unwired user, the relation between screen and fixed infrastructure changes. Communication is no longer incarcerated, connectivity becomes quasi-independent of location, and in this liberated space, others become somewhat invisible.

Yet any attempt to individualize wirelessness as the experience of a subject accessing a network encounters problems. The commercial promise

of ad hoc wireless attachment to the Internet always had to be accompanied by an effort to make visible places where the networks could be accessed: *hotspots*. Wireless networks were not, and are still not, everywhere. They tend to be unevenly concentrated in city centers and transport hubs. The need to make wireless access points visible was recognized in the corporate strategy of hardware producers such as Intel. Rather than just including hardware to handle 802.11b communications in its core chipsets for laptops, Intel "has been working with leading wireless network service providers, hotels, airports, retail and restaurant chains worldwide to accelerate deployment and increase awareness of wireless public hotspots" (Intel Corporation 2003). The chip manufacturer wanted to "accelerate deployment" of the technology by negotiating with other businesses such as hotels, cafés, bars, and airports, and offering a "verification program": "Intel has developed the Wireless Verification Program, which includes engineering and testing of Intel Centrino mobile technology with various access point devices, software combinations, hotspot locations and wireless service providers to verify they are compatible. . . . The company expects to verify more than 10,000 by the end of the year" (Intel Corporation 2003). Intel staged "Wireless Days" with free national access in the United Kingdom and the United States, and also gave awards to cities for being the "most unwired." Outside the wireless devices themselves, the hotspot had to become a visible feature in cities, terminals, hotels, and other facilities. Hotspots were quickly and widely scattered through North America, Europe, and Southeast Asia (see Wi-Fi Alliance 2003 for a geographic-location database). As we have seen in previous chapters, they rapidly multiplied in affluent urban zones such as central London, Manhattan, Seattle, and Singapore, but were also to be found in almost any town bigger than a village in Europe or North America. Starbucks ("We Serve More Than Coffee"), McDonald's ("Bites or Bytes, We Do Both"), airports, hotel lobbies, and bars made themselves into Wi-Fi access points for the Internet so that drinking coffee, eating burgers, or waiting for a flight become associated with network access. Flows of food, drink, and passengers merged with flows of data.[6]

Against Individual Access

In principle, at the wireless hotspot, flows of customers, clients, residents, and travelers register to access the Internet for work and recreation. In the home, wireless access points connect the entire domestic domain to the Internet. But networked mobility in streets and buildings also creates

the potential for increased opacity and anonymity. From the standpoint of medium access control or network management, the proliferation of wireless access points has been viewed as a security problem. At industry trade shows such as the "WLAN Event" staged at the Olympia Exhibition Centre in London each year (WLAN 2003), many of the best-attended seminars on the schedule have addressed Wi-Fi *security*. Network administrators and technical information technology directors have regarded Wi-Fi warily because Wi-Fi spreads network topology from the controlled spaces of cables, conduits, and switching rooms. Only after major changes in how users gained access through more secure encryption schemes (from Wired Equivalent Privacy (WEP) to Wireless Protected Access (WPA)) could network administrators in corporations and organizations begin to accept and invest in wireless networks for commercial and institutional settings. From the perspective of the MAC idiom, the world of freedom also means excluding unwanted participants from the networks. Freedom of access comes with freedom from the presence of unwanted others.

The prominence of security as problematic highlights the difficulty in saying who the subject of wirelessness is. Technicians and administrators from corporate IT departments regard Wi-Fi as putting the boundaries of their organization's networks, and in particular, the question of who is inside and outside those boundaries in question. While connections to wires and cable can be visually traced like railway lines, wireless networks spread out diffusely and invisibly, even if they do not go very far. (How far a wireless network can reach depends on the sensitivity of the antennae in use and the local terrain.) The seminars on security, handbooks, and many articles usually figure the "threat" in terms of different possible vulnerabilities and attacks on the integrity of the corporate body. The arrest by the FBI of Wi-Fi hackers in a shopping mall carpark in Detroit (Poulsen 2003), the trial of a hacker who accessed a county court Wi-Fi network in Texas, the largest security breach involving credit card numbers to date (Espiner 2007), or the sentencing of a teenager in Singapore who played online games using a wireless access point in the apartment next door (Chua Hian 2007), all highlight sensitivities about unauthorized access to wireless networks. Unauthorized outside access to the networks is only part of the worry. Danger arises from inside organizations. The software and hardware tools on display at trade shows, and written about extensively in the myriad how-to computer books (Edney and Arbaugh 2004; Barken 2004; Miller 2003), trade publications, and websites, also concern themselves with controlling access *within* the organization. For instance, myriad network analysis tools such as *AiroPeek* allow Wi-Fi

network administrators to identify "rogue nodes" attached to their networks by someone *in* the organization as well as blocking attempts to connect to the networks from outside (Wild Packets Solutions 2005)).

Making a Physical Layer from "Virtually Nothing"

In individualizing access to networks through addresses and encryption protocols and pathologizing anonymous, unmanaged access, the medium access control idiom configures wirelessness as individual mobile human users connecting to the Internet. The most important device in network connectivity is the access point that forms the core of hotspots and domestic wireless networks. Quasi-public venues are complemented by a population of wireless devices inhabiting homes and offices. The wireless devices (telephones, laptops, radios, music players, cameras, etc.) found within range of a hotspot/office/home wireless access point offer some release from the postural, gestural stasis of wires, walls, and desks. Yet they are also shadowed by the potential for devices whose operating boundaries are not fully set by medium access control regimes.

Any move away from fixed locations exposes new surfaces where others can begin to appear in modes that are not configured by the medium, the Internet and its dominant access control mechanisms (authentication, encryption, logins, etc.). The physical layer, ostensibly the least social and least tractable aspect of a network, actually can impinge on networks in ways inconsistent with medium access control. Andrew Ross (1991, 98) argued two decades ago in fairly general terms that certain aspects of technology rely on popular participation: "No frame of technological inevitability has not already interacted with popular needs and desires; no introduction of machineries of control has not already been negotiated to some degree in the arena of popular consent." The frame of technological inevitability associated with wirelessness centers on the spread of networks through proliferation of devices: there will be many wireless devices and they will connect everywhere to the Internet (or some version of the Internet). However, this wave of devices advances through "interaction with popular needs and desires" that crisscross between physical spaces and network topologies, between physical layer and medium access control.

It would be difficult to convey the full spectrum of needs and desires around physical space associated with wireless devices. The physical layer has already been discussed in the previous chapter as the air interface. Here the physical layer resurfaces in the many facets of wireless devices that undergo replanning, reshaping, extension, or substitution. These projects

span a disparate set of interests, ranging from a geek commitment to exploring the technical limits of connectivity as in the Hurghada project in Egypt (Adly 2003) or the development of a "wireless commons" (WCM, 2003), to UN-sponsored efforts to leapfrog infrastructural hurdles in developing countries (BBC 2003; United Nations 2003). They lack the coordinated global advertising and publicity of corporate promotions. In contrast to the effort to attract individuals to hotspots where controlled individual access to computer networks is available, the common thread in all these projects concerns unearthing communications infrastructures, making infrastructures visible, and transforming them into sites of collective interaction and work. Rather than connecting to the Internet or to the workplace from new places and in new ways, this idiom treats connectivity to network infrastructure in urban and nonurban spaces as holding social potential that goes beyond individuals roaming their own homes, cafés, and hotel lobbies. The physical layer idiom is distinguished from medium access control in several ways: by a nonexclusive relation to others, by some different practices of space and distance, by varying degrees of contestation of commercial ownership of infrastructure, and by an interventionist stance in relation to commodity computer hardware. Potentially at least, this idiom constitutes a metastable, heterogeneous mixture of practices, feelings, and imaginings of communication. A transformation of media-technology habitus, the embodied social knowledge of communication, infrastructure, and urban mobility, could be at stake here.

Let us return a Linksys WRT54G wireless router. Once out of the manufacturer's box, there are no guarantees about what will be done with such a device. Because the Linksys WRT54G architecture is generic and comprises generic components, the software and certain elements of the hardware provided by Linksys can be readily altered or replaced. Two main sites of experimentation can be found in the WRT54G series: the antenna hardware and the firmware.

The device's antenna can be replaced. Antenna modifications probably deserve a chapter in their own right since they embody the infrastructural imaginings deeply associated with Wi-Fi networks. Nearly every website or book on wireless hacking has a section on antennae. Why are antennae so interesting? In the opening paragraphs of the "Do-It-Yourself Antennas" chapter of the book *Wireless Hacks* (Flickenger 2003), Rob Flickenger states:

> As you sit at a cafe eating your lunch, you may be completely unaware of the dozens of people simultaneously using the environment around you to communicate with people around the world. I believe that is largely this mysterious, intangible aspect of unseen global communications that draws people to embark on their own

antenna projects. The deeply rewarding feeling of making something useful out of virtually nothing is worth much more than saving a few dollars on a network component. (p. 172)

The "making something useful out of virtually nothing" here refers mainly to antennae. In a time when most digital or electronic technology is fabricated in plants in Southeast Asia, the possibility of altering a device using cans, old satellite TV dishes, various pieces of wire, cable aluminum foil, and wire mesh seems for some people "deeply rewarding." It almost seems a privilege to make something. Although many interventions and engagements with wireless networking and digital media more generally focus on making things in software, hardware modifications of antennae in particular provide a stronger sense of agency, a more pronounced sense of making something.

Indeed, antennae become key elements in making wireless devices into wireless networks. *Linksys WRT54 Ultimate Hacking* argues that altering the antenna "can be one of the make-or-break activities that will determine the success of your network. . . . By changing our antennas, we can achieve some very impressive results" (Asadoorian and Pesce 2007, 268). Probably the most iconic modification of wireless routers is the "Pringles Can Waveguide." Although it does not change the power of the signal transmitted, it points it in a narrower beam in a chosen direction, so that widely separated points can be wirelessly linked. By changing the antenna on a wireless access point, the range of the networks can be readily extended to several kilometers, in some special cases up to several hundred kilometers. The upsurge of community wireless networks, municipal or metropolitan wireless networks (discussed in later chapters), and commercial federations of wireless networks such as Meraki (see also chapter 7) and FON (FON 2006) largely depends on substituting different antennae.

Connecting a "home-brew" or separately purchased antenna to a wireless router seems fairly mundane, if not slightly fiddly DIY, work. It hardly seems to invert relations between devices and infrastructure, between experience and the conditions of experience. However, these mundane modifications explore the intersection between the DSP-defined topology of signal envelopes and the Internet protocol–defined topology of the network. Antenna modifications alter signal propagation (longer links, connection through walls, etc.) in the interests of extending a network topology. Changing the antenna changes the range or speed at which information moves. In this sense, it alters the boundaries influencing how the device operates. It affects the kinds of networks of relations that can

be imagined between devices. Hence, new forms and distribution of infrastructure can take shape.[7]

"Bricking" the Physical Layer

brick: n. 1. A piece of equipment that has been programmed or configured into a hung, wedged, unusable state. Especially used to describe what happens to devices like routers or PDAs that run from firmware when the firmware image is damaged or its settings are somehow patched to impossible values. This term usually implies irreversibility, but equipment can sometimes be unbricked by performing a hard reset or some other drastic operation. Sometimes verbed: "Yeah, I bricked the router because I forgot about adding in the new access-list." (Raymond, 2003)

Like many consumer electronics gadgets today, a wireless router is actually a computer. As a result, it uses generic chips and electronic components for various purposes. The main onboard CPU, in particular, is nearly always a generic chip since not many wireless router manufacturers can afford to design and fabricate their own CPU. What then of other limits on how the devices operate? Is the physical layer subject to transformation through other changes in the boundaries of the devices apart from the antenna? As we saw earlier, even if we take a single model or submodel of the Linksys WRT54G series, it is hard to even find a single, stable manufactured object. Most of the WRT54G models contain processors made by Broadcom, a well-known designer and supplier of integrated circuits for communications equipment whose corporate motto is "Broadcom in your life: connecting everything®" (Broadcom 2008). This processor can be reprogrammed, and needs in fact to be programmed so that wireless networks can come into existence. In fact, Linksys itself regularly modifies the "firmware" that runs on the processors in its wireless routers. Different versions of the same model may have different firmware on them and therefore behave slightly differently.

In a sense, the wireless router manufacturer wants their product to be as solid and reliable as a brick. It should just sit there and help hold something in place, like a brick holds a roof. At the same time, a wireless device cannot afford to behave like a brick because the abstract reality it shares in calls for a degree of dynamism that a brick is not normally allowed to display. So, the firmware on wireless devices always has settings that can be altered or reconfigured to take into account the different situations the wireless device might find itself in. Despite their relatively inert appearance as black, blue or silver boxes, wireless routers have hundreds of settings ranging from highly technical details of transmission power and error

correction to security settings, access details for users, and administrative procedures for logging network traffic. The firmware usually supports a miniaturized organized network management infrastructure and puts it at the disposal of the power-wireless user. Typically, these settings can be accessed through a Web interface run from a small Web server on the device itself (see figure 4.3).

In many forms of consumer electronics (set-top boxes, digital music players, game consoles), firmware is hard to alter. Manufacturers regard it as part of their product. Unlike application software on personal computers or mobile phones, changing the firmware, by for instance, replacing it with some "third-party" firmware, voids the warranty. However, like the hardware components themselves, firmware can be generic. For several years, Linksys WRT54G series used a version of Linux, the free-open source operating system kernel, as firmware. Effectively, all Linksys routers were Linux-based computers. Using Linux-based firmware saved Linksys the costs of developing their own firmware, or paying license fees for some other firmware. But generic firmware renders devices alterable. Many people understand how Linux works and many software tools have been developed for tinkering with and adding to it. Subject to software development techniques, the boundaries of the device become much more fluid. Hardly surprisingly, Linksys engineers became aware that its wireless routers were the target of many hacks and modifications going beyond the settings provided in the control interface. In 2005, Linksys released specific versions of the WRT54G such as the WRT54GL that are more open to modification. (The L in this model refers to Linux.) The WRT54GL is specifically intended for wireless hackers. But offering a model specifically intended for hackers only makes sense in the wake of the many modifications that hackers had already performed on earlier WRT54G models. These went well beyond simple changes in the firmware settings that alter the parameters of a device (for instance, increasing the transmission power or changing the clock speed of the CPU can speed up traffic on the network in some cases).

Practices of modifying WRT54G routers are widely documented on the Web (Instructables 2009) and in print (Asadoorian and Pesce 2007). The limit case of modification, the most profound transformations of device boundaries, risk "bricking" the router. The worst-case scenario is that a wireless device—Linksys WRT54G, or the iPhone, PlayStationPortable, NintendoDS, for that matter—can be "bricked" if its firmware is altered injudiciously. Bricking brings us closer to the physical layer because it can collapse all boundaries of the device. Short of this point, substitute firmware such as *OpenWRT*—short for Open Wireless Real Time (OpenWRT

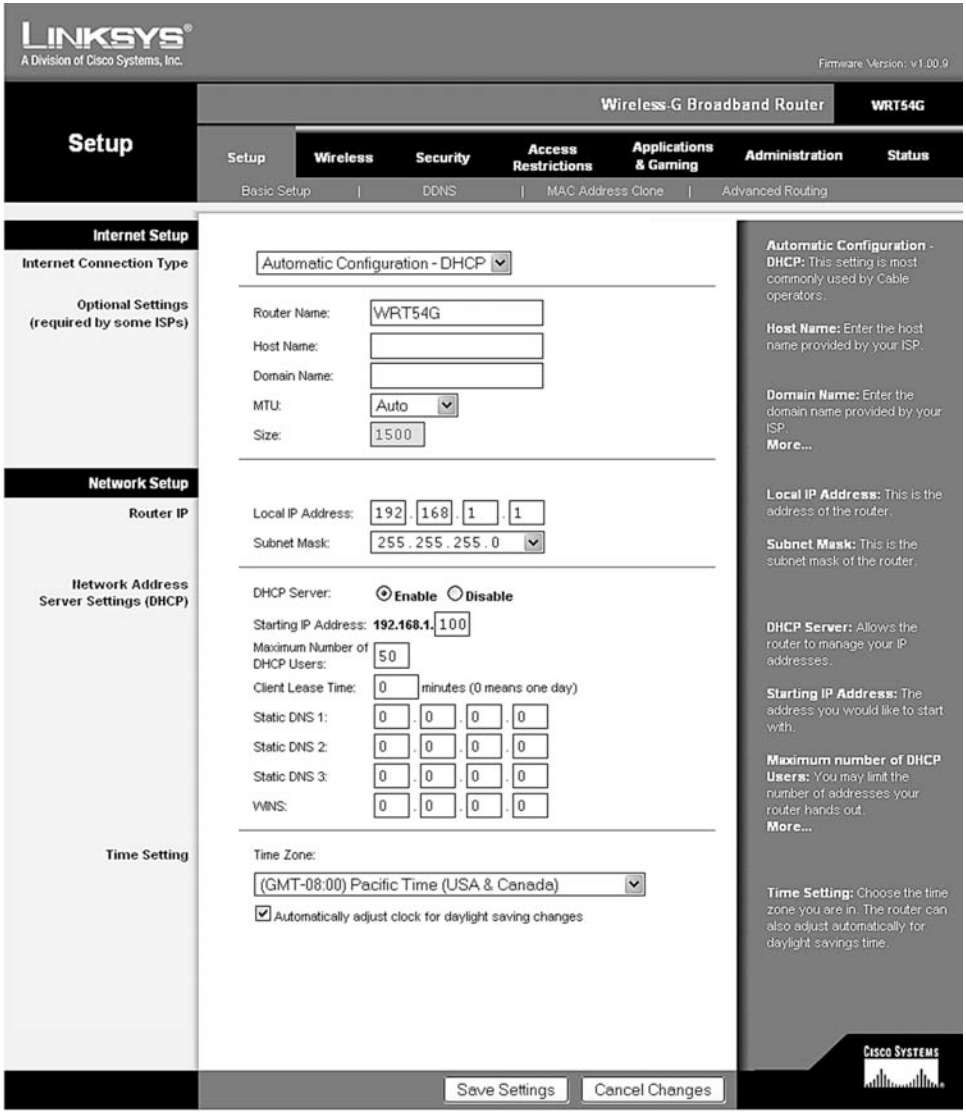

Figure 4.3
Linksys WRT54G Network Setup screen.

2008)—opens space for continuous experimentation with boundaries. As a wireless real-time embedded operating system based on the free open-source software Linux, OpenWRT is a complex piece of software in its own right, with several major versions of increasing technical complexity. OpenWRT offers a substitute for the firmware of several hundred different wireless devices, but for Wi-Fi routers in particular. The possibility of substitution relies on the fact that hardware manufacturers, as mentioned previously, resort to generic semiconductor components such as processors, memory chips, and wireless transmitters. Because the components are generic, the firmware can be substituted. However, this is always a fraught and somewhat experimental process, perhaps much more so than antenna modification, which can be done according to recipes. The possibility of bricking, however, is not the end of the world for OpenWRT. In fact, one of the reasons to install OpenWRT is precisely to "debrick" a device that has been subject to destructive or flawed firmware modifications. But aside from the extremely frustrating situation where some device has been bricked, why would someone bother to substitute different firmware for that supplied by the manufacturer? What explains the desire to reconfigure the boundaries of the device in ways that exceed the configured user already imagined by designers of the control interfaces and antenna?

The OpenWRT project description at openwrt.org claims that "instead of trying to create a single, static firmware, OpenWrt provides a fully writable filesystem with package management. This frees you from the application selection and configuration provided by the vendor and allows you to customize the device through the use of packages to suit any application" (OpenWRT 2008).

As so often happens in wireless technology projects, the OpenWRT project claims a certain kind of freedom, a freedom from the "selection and configuration provided by the vendor." This freedom comes from a substitution. OpenWRT replaces a "single, static firmware" with a "fully writeable filesystem." This means first of all that the device is no longer something that can only be changed at the edges. Once it becomes a "fully writeable filesystem," various points in the device open to intervention. Many of the modifications or hacks described in books such as *Linksys Wrt54g: Ultimate Hacking* (Asadoorian and Pesce 2007), *Wireless Hacks 100 Industrial-Strength Tips & Tools* (Flickenger 2003), or *Wi-Foo* (Vladimirov, Gavrilenko, and Mikhailovsky 2004) rely on OpenWRT to attach new devices (storage, others kinds of network connections), to change the way that the wireless router connects to the Internet, to allow routers to talk to each other, or to change the range of the wireless router by raising or

lowering the transmit power of the wireless radio. More exploratory possibilities come from installing software that completely changes the functionality of the device, effectively making it into a different device. For instance, hacks described in Asadoorian and Pesce 2007 can reconfigure Linksys WRT54G to no longer act solely as a wireless router, but also as a DNS server (which resolves hostnames to IP addresses) or as a wireless switch that connects different network segments together. In these kinds of configuration work, the physical layer begins to extensively modify medium access control. The tensions between these different kinds of space can be seen as generative of new relational topologies.

Living between Physical Layer and Medium Access

Work done on the physical layer affects what counts as infrastructure. It experiments with what counts as a good or bad connection, and a good or bad network. It confers the power to speak in the name of a good connection or a good network on different devices or altered devices and hence on different people. From 2002 to 2007, organizations, individuals, and groups interacted with the physical layer in order to enforce or oppose the control and management of network access. They formulated ambitious plans for extending national or international commercial and noncommercial, private and public, local, regional, and occasionally transcontinental infrastructures based on Wi-Fi. Many had explicitly local scope (for example, the wireless community networks discussed in the next chapter, although many of these projects still had forms of global awareness attached). The *Pico Peering Agreement* (PPA 2003) and the *Wireless Commons Manifesto* (WCM 2003) were examples of infrastructure-oriented attempts to move from bad to good networks. These documents represent attempts to engineer connection of local networks into extensive ad hoc informal meshes of wireless nodes across local and national boundaries. The attempts range from manifestos (e.g., "We have formed the Wireless Commons because a global wireless network is within our grasp. We will work to define and achieve a wireless commons built using open spectrum, and able to connect people everywhere"; *Wireless Commons Manifesto*) to quasi-legal agreements that seek to formalize connections between networks (*Pico Peering Agreement*). What would motivate anyone to try to replace international communication infrastructures with infrastructure built and run by relatively ad hoc collectives? Their stance is not simply oppositional. Reporting on a 2003 conference held in Copenhagen to develop and promulgate the *Pico Peering Agreement*, one participant suggests that

> the consolidation of commercial operations in the 2.4GHz spectrum in the form of "hotspots" in hotels, airports and coffee chains, is not as threatening as it first seemed. These commercial networks continue to focus on wireless network access. The Free Network, as defined by documents such as the PPA (Pico Peering Agreement), has an entirely different and unique potential: to be a viable and competitive supplement to the internet, but one where the system of ownership is decentralised enough for it to remain a "common." (Albert 2003, 7)

These initiatives are directly influenced by free software movements, but take up a political stance in relation to infrastructure based on the proposition that access to communication infrastructure should be free.

Rather than concentrating on hotspots where individuals will access the Internet "in new ways," these projects aim to alter the proprietary status of the infrastructure itself by introducing collectively organized detours, bypasses, and supplements to it. Sometimes they modify hardware or produce software. Typical of the hardware and software modifications, LocustWorld MeshBoxes (LocustWorld 2003) allow wireless nodes to be connected in a "mesh" that can cover an extended area just as a cell phone network with its scattered masts does. As we have seen, antennae are objects of wide-ranging modifications in the physical layer idiom. Antenna modifications that extend the range of 802.11b well beyond the technical limits of a few hundred meters go hand in hand with reconfigured devices that no longer simply provide medium access, but aggregate in different connective formations. Commodity hardware, assembled and modified, becomes part of the practical rhetoric of the cultural inversion of infrastructure. Interactions with the physical layer exhibit a more diverse "sociogeographic" range than those of medium access idiom with its investment in hotspots, homes, and offices. They have a wider geographic range in South East Asia (Jhai Foundation 2003), the Pacific Islands (St. Clair 2003), Africa (Adly 2003), Europe, and the United States, and intersect extensively with development projects (see chapter 7). While the medium access control idiom configures individuals to enjoy a freedom to connect as they commute in and out of conurbations in Europe, North America, Japan, Korea, or Taiwan, collective work on physical layer interactions envisages a different mobility, a mutability in network infrastructure itself. The desire to construct infrastructure, to create a supplementary or alternate "physical layer" for the Internet, is an intriguing and significant development in the post-dot-com cultural politics of communications. It is also a key component in making wirelessness possible. If, as Andrew Ross argues, there is no frame of technological inevitability that has not interacted with popular desires and needs (Ross 1991, 98), then any inevitability

attaching to wireless technologies requires something like the physical layer interactions. With its geographic dispersion, its efforts to modify or rebuild commodities (hardware and software) and communities, its aggregation of monadic individual connection into associated clusters or "meshes," and its legal-technical efforts to entrench alternative, large-scale digital infrastructure, the physical layer idiom distends the smooth growth of a network topology in the idiom of medium access control.

Experiments in redefining the boundaries or limits of wireless devices "potentiate" devices as physical layer infrastructure that exists outside or in some respects independently of commercial network infrastructure. Such experiments address powerful enterprises and organizations that corral and tether wireless signals to service plans and network management systems. We could say that a radical empiricist vein of practice runs through these experiments. Radical empiricism supplies techniques for paying attention to the ways pure experience comprises an abundance of connections, tendencies, and differences. Modifications of a wireless device (as well as efforts to resist modification) speak in the name of different styles of connection to networks. Notions such as "autonomy" or "openness" attach alternative sequences or sets of connections to devices, developing their potential to construct alternative network infrastructures. Many of these experiments in resetting the boundaries of devices directly challenge commercial or product-oriented interpretations of wirelessness (as a service or product for personal freedom). The open-ended and sometimes almost practically pointless work done in these experiments is inextricably practical and symbolic, it blends meaning and practice. The work, as Nancy suggests, "remains without end," partly because these devices can only provisionally stabilize some aspects of wirelessness. Wireless connections and the idea of network run unevenly across the wave crests of contemporary experience. Sometimes wireless devices work as components in a stable, taken-for-granted background of expanding networks. Intermittently, they appear as elements of an ecology of excessive belonging-together, overflowing the bounds of sociotechnical network infrastructure.

Notes

Chapter 1

1. The "wireless sniffing and monitoring" software *Kismet* runs on a laptop (Kershaw 2008). For instance, a Kismet scan for wireless devices in a train car typically shows several active Wi-Fi devices.

2. In many respects, the figure and practice of the network distinguish wirelessness today from the telegraphic wirelessness of the early twentieth century. The sensations of wireless movement and relation that excited so much interest a hundred years ago (for instance, in futurist writings on radio analyzed by Timothy Campbell (2006)) recapitulate themselves today in the much more dispersed or extensively distributed network forms.

3. Literary, sociological, anthropological, historical, and other critical studies concerning contemporary science and technology pursue a common question: How does technology change what it is to be human? (For the term *human*, other words such as *social*, *cultural*, *political*, *economic*, or simply *who we are* can be used.) Here, I want to resist any such framing. Among the many problems facing that form of questioning is this: How do you counteract what we might term "overrelevance"? Many high-profile technological changes such as mobile phones, a new drug for breast cancer, or a stem-cell treatment for multiple sclerosis are all too portentously relevant. In the case of the mobile phones, for instance, this abundant relevance makes it hard to think past the obvious impacts on patterns of mobility, modes of habitation, social practices of media use, and urban everyday life. Work on these social impacts, especially in relation to mobile phones, is not scarce, it is constantly growing and will likely continue as the various wireless technologies (3G, Wi-Fi, Bluetooth, WiMax) intermingle and hybridize. The social impacts of mobile phones are too great to ignore. In many respects, the transit time between technology and social impact on human life is too fast. To slow down enough to enter into the processes of change, other ways of constructing an engagement with change need to be found. One reason why this book does not have much to say about mobile phones or "smartphones" such as Apple's iPhone is that they are so glossily obvious

and relevant. However, it does take quite a strong interest in the increasing overlap between techniques used to construct and manage mobile phone infrastructures and Internet networks.

4. At this point, many readers might be feeling uneasy. Surely concepts of experience are just too philosophically depleted for further use. Aren't they so engrained with the figure of the human that any actual encounter with change glances off them? Yes and no. If wirelessness is a form of experience, it is not one that leaves the subject of experience, the one who experiences, unchanged. It does not leave experience itself unchanged, and because of that, the one who experiences, also changes. (The subject, or subjectivity, is always one who experiences something, even if only themselves as a subject.) It is on this point that James's radical empiricism can make a crucial difference. One of the basic questions of this book is how we make sense of changes in the fabric or texture of experience, without understanding that change in terms of pregiven notions of experience and its subjects. I am very much in sympathy with those strands of critical work on media and technology that call for accounts of human subjects and technological objects co-constituting hand in hand (see Mackenzie 2002). However, one of the interests in promoting an account based on experience and experiments in rapid change is to see how that encounter can generate specific changes, or channel inmixing of both living and nonliving things in forms of unexpected otherness or alterity.

5. The problem of overconnectedness has already been a topic of network theory. From the perspective of connectivity and stability, this phenomenon had already by been pursued by network sociologies and social network theorists (Van Dijk 2006, 187–188). Such discussions often rely on the formal studies and modeling of network connectivity found in the work of Stuart Kauffman (1995) or Albert-László Barabási and Duncan Watts (Barabási 2002; Newman, Barabási, and Watts 2006). They often conclude that too many connections in a network leads to lack of adaptive capacity or reduced ability to change. One could argue that certain wireless projects, such as the municipal wireless network in Philadelphia or San Francisco, foundered on the problem of too many connections. However, this structural analysis of overconnection as an intrinsic property of the network form largely renders illegible the practices of networking. It glosses over the work of making or removing connections, and slides over the differences in intensity of connection. As we will see, the making and breaking of network connections is a highly invested process, and kindles potent competition between several different technical standards, architectures, topologies, configurations, and perhaps more importantly, cultures of wireless networking. Network connections multiply as wirelessness intensifies. Complications at various levels—at the level of the technical standards and protocols that define wireless networks, at the level of attempts to control, configure, and map wireless networks, and at the level of attempts to expand or even generalize wireless networks globally (as in wireless development projects)—produce kinks and torsions in wirelessness.

6. This phrase comes from one of the reviewers of the manuscript of this book.

7. "Tout y est pris sur un même plan: idées, propositions, impressions, choses, individus, sociétés. L'expérience, c'est cet ensemble diffus, enchevêtré, de choses, de mouvements, de devenirs, de relations, sans distinction première, sans principe fondateur" (Debaise 2005, 104).

8. The point of this variation on James's account of the rationale of radical empiricism lies along similar lines to that proposed by Elizabeth Grosz (2005, 143) when she suggests that Bergson helps us reapprehend the thing: "to orient technology not so much to knowing and mediating as to experience and the rich interdeterminacy of duration, to a making without definitive end or goal."

While I turn to Bergson at several points in the following chapters, and specifically in the conclusion, James's work also emphasizes a superabundance of the real and experience. Bergson's (1934, 240) highly affirmative regard for James centers on just this point: "Whereas our motto to us is *only what is needed,* that of nature is *More than is needed,* too much of this, too much of that, too much of everything. Reality, as James sees it, is redundant and superabundant."

However, if Bergson's work has facilitated diverse and wide-ranging interventions in debates around audiovisual media such as cinema, video, and interactive or digital art (Hansen 2004; Rodowick 2001), James's work, much less known in media and cultural studies, stresses a specific set of relations that I find conducive to the problem of wireless technologies. James's emphasis on *conjunctive* relations lends much greater weight to the wirelessness of wireless technologies. Even in simply pointing to conjunctive relations, and bringing them into the flow of experience, radical empiricism moves in the direction set out by Grosz.

9. The word *consciously* evokes *unconsciously*, and can thereby switch on the paradigm of subjectivity. The complementary term best substituted here would be *nonconscious*.

10. For a fully developed account of James's political philosophy, see Ferguson 2007.

11. How many different aspects of wirelessness will we need to examine? The treatment in the following chapters marks out space, action, belonging, awareness, and globality as key facets of wirelessness. In choosing different scales of analysis for this book, I have attempted to remain alert to the problem discussed by historian of information technology Paul Edwards (2003) in an essay on infrastructures and modernity. Because we live "within multiple, linked infrastructures," we also "inhabit and traverse multiple scales of force, time and social organization" (p. 222). Confining analysis to any one scale (typically the micro for media, cultural, and social studies of uses and practices; the meso for analyses of institutions, organizations, and systems; the macro for studies of capitalism, modernity, etc.) jeopardizes the possibility of following these traversals, and jettisons any chance of finding out what transformations and translations come of it. Edwards argues that multiscale (micro-, meso-, and macroscale) analyses of technology, society, and nature are

needed. In contrast to the microemphasis found in social constructivist accounts, and the sometimes weighty static structures of macroscale accounts, radical empiricism has no pregiven commitment to any particular scale of analysis. It is constitutionally open to multiscale analysis by virtue of its highly composite treatment of experience.

12. For an extended discussion of Nancy on capital and Being, see Ross 2007.

13. Nancy's work derives from a French deconstructionist reading of Heidegger. The match between his style of writing and James's is, to say the least, rather poor. However, while Nancy's elliptical style and heavy hyphenation pose certain reading challenges, his intensive development of the conjunction "with" in framing of Being-with offers, it seems to me, a highly useful expression of the most extreme forms of capture of conjunctive relations. This will be particularly useful in understanding "global wireless" or "wireless worlds."

Another way to go here would be to examine the contemporary appropriation of intersubjective relations in communicative processes. This has been analyzed extensively in Marxist and post-Marxist political economy, cultural, and media theory, particularly in the work of Paolo Virno and Maurizio Lazzaratto (Lazzaratto 1998; Terranova 2000; Virno 2004).

14. Given all possible permutations, the following seven chapters could be read in a thousand or so different orders. The order in which I have arranged the chapters moves from the city to chipset/algorithm, to device, to networks, to media and markets, and then to wirelessness writ large in global development projects. But the chapters could be read in a different order: from small to large, from chip (chapter 3) to globe (chapter 7), via devices (chapter 3), network actions (chapter 4), media markets (chapter 5), and (chapter 2) cities. That order would reflect a gradually broadening theoretical argument that begins with minute sensations and moves to global awareness of others.

Chapter 2

1. A wireless-city literature is gradually beginning to take shape. See Forlano 2008 as well as Hampton and Gupti 2008.

2. The urban grid reappears, as the next chapter discusses, in the architectural layout of digital signal-processing chips, as well as in the algorithms used to shape wireless signals.

3. In *The Meaning of Truth,* James (1909, 45) writes: "To call my present idea of my dog, for example, cognitive of the real dog means that, as the actual tissue of experience is constituted, the idea is capable of leading into a chain of other experiences on my part that go from next to next and terminate at last in vivid sense-perceptions of a jumping, barking, hairy body."

12. Every algorithm, apart from so-called brute-force algorithms, contains a twist or kink that affects the flow of the computational process. (The fast Fourier transform is fast because it applies a "divide-and-conquer" strategy to synthesize or analyze the components of a signal.) The hidden Markov model is one twist or kink at the heart of the Viterbi algorithm. It treats the received signal as a set of states that correspond to a Markov model that cannot be observed directly. Via the hidden Markov model, the Viterbi algorithm turns the communication situation inside out. The combination of a known and finite set of system states and probability is turned inside out by the algorithm because it treats the Markov model as hidden. The object of making a hidden Markov model is to deduce the most probable sequence of internal states that could have given rise to the observed sequence of signals.

Chapter 4

1. I understand experiment here along the lines suggested by Isabelle Stengers (2000, 89): "This is the very meaning of the event that constitutes the experimental invention: *the invention of the power to confer on things the power of conferring on the experimenter the power to speak in their name*."

This two-stage conferral of the power to speak in the name of something seems to me to succinctly express some of the essential tensions between different kinds of work done by wireless devices. Some of the techniques described in this chapter confer powers of speaking in the name of networks in the world; others resist conferring any such power.

2. Other symptoms would also include circuit bending for music and sound, dorkbot events (dorkbot 2008), hacklabs (London Hacklabs Collective 2008), and, indeed, the many art, activist, and community-based wireless network projects of 2001–2005.

3. "Progresser dan la connaissance . . . signifie passer d'un mauvais à un bon reseau" (Latour 2007, 28). (All translations from French are my own.) This statement appears in a discussion of James's radical empiricism in the context of science.

4. This can be traced back to Heidegger's (1967) distinction in *Being and Time* between two different modes of being: present-to-hand and ready-to-hand.

5. On this point, see Chun 2006 and Galloway 2004.

6. Actually, despite their proliferation, the hotspots have not, it seems, been very hot. The bar employees often do not know of the hotspot's existence. Many hotspots are rarely used due to their excessive cost and because they remain, ironically, relatively invisible and difficult to access (Frankston 2003).

7. The many attempts to federate or associate wireless devices with each other in networks or "wireless mesh" would be one main consequence. This will be discussed in the following chapter.