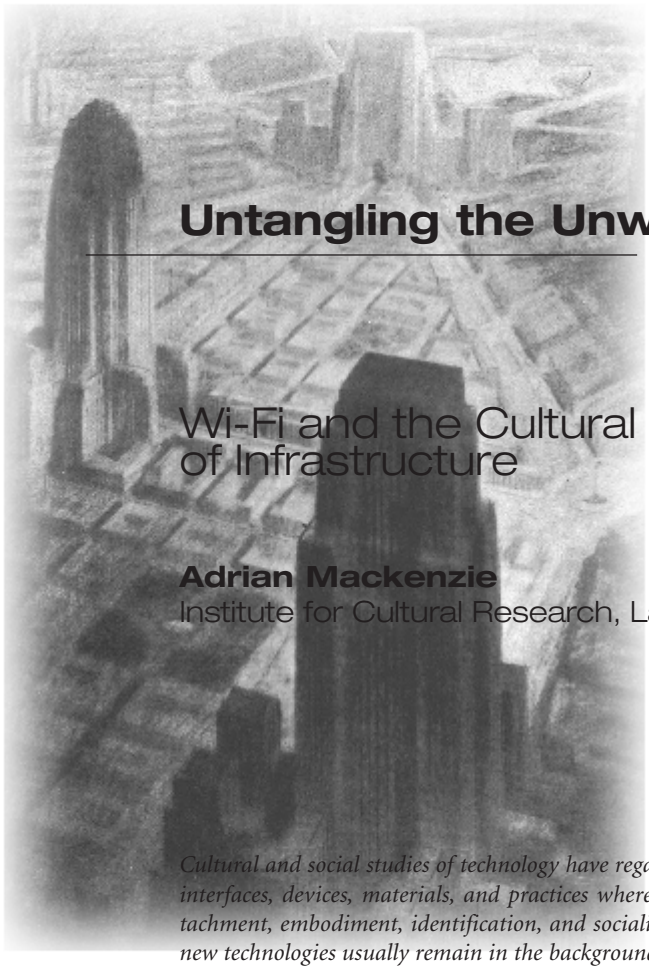

Untangling the Unwired

Wi-Fi and the Cultural Inversion of Infrastructure

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Cultural and social studies of technology have regarded infrastructure *as less significant than the interfaces, devices, materials, and practices where processes of consumption, representation, attachment, embodiment, identification, and sociality are most visible. Infrastructural elements of new technologies usually remain in the background of analysis. What would it mean to invert the figure-ground relation between technology and "infrastructure"? Via a case study of an increasingly popular, everyday contemporary wireless networking technology, Wi-Fi, the author suggests that infrastructures have begun to figure as sites of cultural contestation. Infrastructures work as highly potentialized fields, triggering a multiplicity of interpretations. Using textual and ethnographic materials, the author suggests that rather than being the immobile grounds of technological cultures, different imaginings and practices of connectivity run through the many Wi-Fi projects, enterprises, and visions of the past 2 years. In seeking to understand these different imaginings of connectivity, the author suggests that contemporary infrastructures embody cultural logics at odds with each other.*

Keywords: *mobility; infrastructure; Internet; communications technology*

A somewhat banal component of contemporary computing technology, Wi-Fi, or 802.11b wireless local area networking, has begun to "naturalize" itself in buildings, cities, parks, transport systems, and towns throughout Europe, North America, Southeast Asia, Australia, and the Middle East. This technology connects computers to one another or to the Internet using radio links in an unlicensed part of the radio spectrum, 2.4 GHz. It replaces the cable that runs from a computer to a network socket in

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the wall with an invisible radio link. Unlike the dazzle of Hollywood cinema's digital effects, the startling mobility of images in recent computer games, or the efflorescent sociality of mobile phones, Wi-Fi is hardly spectacular in any way, shape, or form. If it appears in images at all, it is toward the back of the catalogues of computer and electronics retailers. There, Wi-Fi has more affinity with piles of sandals on sale in a suburban supermarket than a site of political contestation over space, the city, mobility, and individuation. More often than not, it features as just one more line on the specifications of a new laptop computer.

Wireless computer networking is perhaps not a crucially important innovation in itself, just another ordinary ingredient in the mixture of digital communication networks rapidly extending through cities, towns, and sometimes the countryside in Europe, North America, and parts of the Asian Pacific. Wi-Fi, suggests a recent supplement on the state of telecommunications in the *Economist*, "is certainly useful…but it does not amount to an epochal shift" (Standage, 2003, p. 11), and yet a merely "useful" technology has attracted and continues to receive much media attention and commercial investment. It has set off a tremendous number of cultural-technological projects in which the "naturalness" of wireless networking is contested in diverse ways. The persistent media interest; the burgeoning commercial projects; the scattered, diverse popular and artistic projects; and the persistent hopes for wireless networks are enmeshed in complex ways. Wi-Fi appeared in 2002 in the aftermath of the "dot-com" crash or "techwreck" of early 2001.[1] Hopes were quickly pinned on Wi-Fi as a potential stimulant to the post–dot-com/techwreck entrepreneurial doldrums of Silicon Valley and dashed expectations of ongoing computer-driven information revolution. Because it appeared as a "next big thing" phenomenon, and because many companies investing heavily in it were also involved in the dot-com crash, Wi-Fi was almost instantly termed a "bubble" (Karif, 2003). As a cultural-technical phenomenon, it is haunted by the dwindling utopian social promise of the Internet as rejuvenated public sphere. Corporate ownership of network infrastructure looms large in current utopian-social interest in Wi-Fi. As new media and the Internet were quickly absorbed into diverse everyday performances over the past decade (Miller & Slater, 2000), the corporate assimilation of the Internet, hardly surprisingly, was effectively completed in the form of private and "public" network infrastructures (Sassen, 2000).

According to cultural theory, corporate assimilation of the new communications technologies tends to reject the relevance of places or practices that it does not create or manage (de Certeau, 1984, p. 201). As we will see, commercial promotion seeks to commodify and brand Wi-Fi using the discursive operators of "freedom" and "mobility." Yet this assimilation of Wi-Fi does not go uncontested. The constant appearance of new gadgets, devices, and practices that modify, alter, or hybridize Wi-Fi suggests that hopes for other forms of sociality and openness associated with communication technology still persist. That hopefulness is conditioned by the recent history of new media, particularly by a consciousness of the almost total commercial ownership and control of Internet and communications infrastructure (Galloway, 2004). The different practices, motifs, and performances of space, sociality, embodiment, and control entwining in Wi-Fi need then to be situated in the context of the ongoing development of new media and computer networks as sites of cultural construction of identity, value, mobility, work, space, and time.

The Cultural Relevance of Wi-Fi: Visible Infrastructure

In the years 2002 to 2004, a day rarely passed in which some new Wi-Fi-related product, protocol, standard, project, or event was not announced. In addressing the practical imaginings of freedom, mobility, sociality, and connectivity associated with Wi-Fi, I draw on a variety of sources and research approaches to Wi-Fi's mutable nature, including interviews, ethnographic observation, and textual analysis. The broad variety of problems and contests associated with Wi-Fi cannot be analyzed here. Rather, particular attention is given to the infrastructural dimensions of Wi-Fi, to how it becomes visible as infrastructure and yet resists reduction to infrastructure. The "naturalization" of Wi-Fi as infrastructure is contentious for reasons that can be analyzed in terms of competing organizations of social-technical spaces of communication.

Communications infrastructure falls outside the frame of most accounts of new media and communications (contra this, see Graham, 2004). Very often, communication infrastructure seems just another component of the "technostructure," the general planning and ordering of places according to strategies governed by an abstract model of the production of information. It is regulated by government policy and owned by transnational telecommunication corporations. Infrastructure is "strategy" (de Certeau, 1984, p. xix) because it has a proper place from which relations to an exterior environment (the city, the country, the state, customers, competition) run in and out. Infrastructure is literally rendered invisible as ground: buried, walled off, above the ceiling, beneath the pavement. This invisibility parallels a certain analytical invisibility and immobility.

From the first, Wi-Fi explicitly contested the status of communication infrastructure as invisible background or foundation. Numerous statements and projects attested to the increasing interest in infrastructure as site of cultural and political contestation. Much mass media commentary on Wi-Fi focused on its potential as a popular or even democratic network infrastructure. For instance, writing in San Francisco–based *Wired* magazine in 2002, the well-known technological futurist Nicholas Negroponte (2002) described Wi-Fi as a way to overcome the problem of the corporate domination of the Internet, writing, "You have broadband telecommunications systems built by the people for the people." This interest in Wi-Fi as infrastructural element was quickly taken up by newspaper journalists and editors. The northern editor of the *Guardian*, a major daily U.K. newspaper, asked, "When you live in a deep, dark wood at the bottom of a bumpy lane, you get used to doing without services even in the booming city of Leeds.…Can FirstNet [a Wi-Fi Internet service provider] hook up this particle of the Guardian to the main office [in London]?" (Wainwright, 2003, p. 21). (The answer was "no": too many trees in the way in the "deep dark wood.") Articles on Internet connectivity in new places afforded by Wi-Fi abounded during 2002 and 2003. Many noncommercial projects to build broadband communications infrastructures independent of existing cable and telephone networks appeared in print media and on innumerable Web sites. These ranged across the hundreds of "wireless community" groups (Wireless Commons, 2003) wanting to "unwire" their local neighborhoods (Cohen, 2003), collective attempts to federate Wi-Fi networks nationally and internationally through "pico peering" agreements (*Pico Peering Agreement*,

2003) or through manifestoes and political platforms such as the *Wireless Commons Manifesto* (Wireless Commons, 2003).

Extravagant claims for information are nothing new. A decade ago, at a time when the information mythology of cyberspace as a place apart from everyday life was at high tide, Geoff Bowker (1994) wrote about the method of "infrastructural inversion" as a way of investigating how claims about technology emerge and circulate:

> Take a claim that has been made by advocates of a particular piece of science/technology, then look at the infrastructural changes that preceded or accompanied the effects claimed and see if they are sufficient to explain those effects—then ask how the initial claim came a posteriori to be seen as reasonable. (p. 235)

What Bowker termed the "infrastructural inversion" was a way of making sense of extravagant claims by resituating them amid "the economic process of ordering social and natural space and time so that 'subjective' information can circulate freely" (p. 245). Infrastructural inversion is an analytical technique to render the unattended, invisible work that affords the mobility of information (e.g., on the Internet or on the financial networks) visible. This article both follows that suggestion in relation to Wi-Fi and reassesses it as a critical strategy. If some aspect of infrastructure attains a heightened visibility as site of desire, sociality, memory, and commodification, then the technique of "infrastructural inversion" may lack some of the traction it previously offered. Stated differently, in Wi-Fi and associated technologies, the infrastructure of information and mobile communication undergoes a cultural inversion into visibility.

How Do We Know What Wi-Fi Is?

Wi-Fi is defined as a technology that transfers information over short distances without physical connection (several hundred meters usually, although Wi-Fi enthusiasts and communications researchers have managed to extract transmissions over hundreds of kilometers using modified antennas). From the sheer variety of objects and projects associated with Wi-Fi, one thing that stands out is that the outline of the technology itself is not stable. Important aspects of it deform as different vectors of mobility and work, urban, and home life come to bear on it. Despite the publicity and the predictions of another dot-com–style bubble, Wi-Fi is not reducible to the setting up of commercial hotspots for wireless Internet access in offices, hotels, bars, cafés, and airports, nor to the "wireless community networks" in rural or urban areas.

Wi-Fi has given rise to an astonishing variety of projects, tactics, and artifacts over the past 2 years. Much early media attention in 2002 focused on the practices of "warchalking" and "wardriving." Roaming city streets with wireless-equipped laptop computers, warchalkers marked the presence of Wi-Fi networks in city streets and buildings using a lexicon of symbols drawn on sidewalks. These practices disappeared as quickly as they appeared (Hammersley, 2002). In their wake, wireless local area networking diversified into many projects, imaginings, and projections of movements of information. One symptom of diversity is the very rapid commodification and circulation of wireless hardware itself, which is now sold cheaply and often built directly into new computers as a standard feature (Intel's Centrino brand) to be used in the

home, the office, or hotspots. Another is the hybridizations of Wi-Fi technology with consumer electronic devices, such as ghetto blasters (BassStation, 2003) televisions (Sharp), audiovisual systems, digital cameras (Nikon, Kodak), and toy robots (Sony). The 802.11b communication protocols underpinning Wi-Fi have been constantly commodified in new forms and new contexts ranging from chips to cards to stand-alone devices (routers, switches, mesh-network boxes for commercial and domestic applications). Very much an entity in formation, Wi-Fi cannot be clearly delineated, rendered visible or invisible. Its "form factor" or physical shape changes rapidly through miniaturization. Its association with other technologies and infrastructures is multiple and shifting (e.g., it is being coupled with "3G" [third-generation] cellular telephone technologies).

Wi-Fi also continually surfaces in different geographical, institutional, and economic constellations. The technology was modified to allow large-scale or long-distance infrastructures (a remote village in Laos, Jhai Foundation, 2003; base camp at Mount Everest; a long-distance link in the north of Sweden; connections between the Solomon Islands in the South Pacific, Pareti, 2002). Many different urban and rural Wi-Fi projects and organizations burgeoned in neighborhoods (the countless "community Wi-Fi networks") and artist-activist groups such as Consume (2003). Widely reported in the print media, such projects were useful to hardware producers as a way of heightening visibility or "accelerating deployment" of Wi-Fi, as one of the Intel Corporation's (2003) press releases puts it. At the same time, wireless local area networks (WLANs; information networks based on Wi-Fi) percolated quickly through the arms of the state (military, education, justice, health, law enforcement) and through commercial sites (offices, shops, airports, hotels, train stations, trains, airplanes, cars, ferries, cafés, vineyards, courtrooms, conference centers, educational institutions, etc.).

Against a burgeoning background of wireless data networks (3G, ultra-wideband, WiMAX), one could say that Wi-Fi presents a matrix of technospatial potentials whose combinations and permutations are enumerated, tested, and adjusted in different spaces and movements. These potentials induce people's movements in different bounded spaces (kitchens, lobbies, cabins, streets, offices, plazas, alleys, floors, gardens, parks, filling station forecourts) connected to various movements of information (e-mailing, Webcam viewing, online chat, streaming audiovisual content such as music and TV, Internet telephony, blogging, photoblogging, online news, etc.). Wi-Fi mobility, then, articulates two movements together. (For instance, Wi-Fi enables first-class airline passengers to surf the Web as they cross the Atlantic.) Different manipulations of spatial movements in offices, homes, and public places result from this articulation. Only a few years ago, for instance, a router or switch was a piece of technical infrastructure that houses or apartments didn't need or have. With Wi-Fi and broadband Internet, it has suddenly become desirable for every home, let alone office, to have a miniature communications infrastructure—a router or a switch and perhaps a firewall for security—that coordinates movements of information in the home and connects the domestic communications infrastructure to the Internet. If, "thanks to the BT Voyager 2000 [a typical domestic Wi-Fi setup]…you can roam your home and garden at will" (BT, 2003, p. 104) with a laptop and still be connected to the Internet, it is because home occupants have been endowed with "freedom of movement to go with that freedom of information" (p. 104). An almost ironic reference to the Internet

as utopian social-political project ("that freedom of information") now underpins a vastly diminished promise of escape from a desk and of freedom to move in and around the domestic environment.

Wi-Fi as "Kludge"

How can the abundance of Wi-Fi examples be analyzed? As implied above, Wi-Fi, including the circulation of the capitalized term *Wi-Fi* itself, a registered trademark of the Wi-Fi Alliance (2003a) industry group, is more like an event than a thing. The abundance of Wi-Fi examples, applications, initiatives, and projects attests to the generativity of this event. However, the abundance of examples hides some complications and anomalies associated with Wi-Fi. The 802.11b protocols that underlie Wi-Fi are somewhat singular. A participant in the Consume project, based in Greenwich, London, touched on this when he exclaimed during an interview, "802.11b is a kludge" (J. Stevens, interview, March 14, 2003, London). *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, p. 221). After hearing and seeing so much about the promise of Wi-Fi, and about how adaptable, powerful, and effective it is, it is striking to hear Wi-Fi, a very highly promoted and arguably successful networking technology built into millions of systems today, called a "distressing whole." Given that the interviewee was heavily involved in a successful wireless project that had many operational nodes deployed and working, why should he call the protocol itself a kludge?

A long history of kludges constitutes the material culture of media. The quasi-geometrico-optical metaphor of "convergence" neatens up the unstable mixtures of audiovisual, communications, and computing technologies that have been occurring for the past few decades as various sound, visual, televisual, textual, graphical, telephonic, and now radio media were crammed inside personal computers and into many other mobile and consumer electronics forms. Kludges do not always arise from technical deficiency in design. They sometimes attest to the divergent realities 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. The cultural theorist Brian Massumi's (2000) concept of relationality captures certain aspects of a kludge well:

> Call the openness of an interaction to being affected by something new in away 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. (p. 191)

Relationality in this sense of transcontextual anomaly or excess belonging-together connects closely to the articulation of movements together in Wi-Fi. The "complaint" about the Wi-Fi kludge was quite specific: It was directed at the Wi-Fi protocol, 802.11b (Institute of Electrical and Electronics Engineers, 1999), but would also apply to more recent versions (802.11a and 802.11g). A *protocol* proposes a set of rules that allow machines or devices to communicate with each other without ambiguity (Galloway, 2004). Computer science defines a protocol as

> an agreement that governs the procedures used to exchange information between cooperating entities. More specifically, a protocol is such an agreement operating between entities that have no direct means of exchanging information, but that do so by passing information across a local interface to so-called lower-level protocols, until the lowest, physical, level is reached. The information is transferred to the remote location using the lowest-level protocol, and then passes upward via the interfaces until it reaches the corresponding level at the destination.…See also seven-layer reference model. (*A Dictionary of Computing*, 2004)

Without delving too deeply into technicalities here, Institute of Electrical and Electronic Engineers (IEEE) Standard 802.11b, or Wi-Fi, is a protocol defined as part of a larger suite of standards dealing with digital communications, the 802 family. 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 (1999) is titled *IEEE Std 802.11b-1999 Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Higher-Speed Physical Layer Extension in the 2.4 GHz Band*.

Although protocols are intended to reduce ambiguity and eliminate openness to unexpected interactions, they sometimes have the opposite effect. As the title of the IEEE's (1999) document states, the 802.11b protocol describes a way for computers to be networked together using an unregulated portion of the electromagnetic spectrum, 2.4 GHz. This is described as a physical layer (PHY) extension. Like most contemporary standards and protocols, the 802.11b protocol is enmeshed in a web of other standards and protocols. The protocol refers to and relies on a broader standard for communications known as the Open Systems Interconnection (OSI) model (on the significance of OSI in the history of the Internet, see Abbate, 2000, pp. 167-177). In this model, the term *physical layer* designates the physical and electrical components of a computer network. The PHY typically constitutes the most stable and inert, least mobile components of the Internet. It includes all the wires, cables, optical fibers, 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 PHY, 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 10 base-T sockets into which PCs are connected.

From the standpoint of the kludge, it is significant that Wi-Fi straddles *two* of the seven layers of communication—medium access control (MAC) and the PHY—defined by the OSI model. The kludge of the 802.11 protocols lies in the contradictions between the lability of the PHY, which no longer resides in cables but occupies radio signals, and the organizational topology of the network implicit to a specific MAC protocol, Ethernet, which limits the number of networks nodes (or attached computers) and organizes them in a treelike hierarchy suitable for local area networks (LANs; such as those found in office buildings). In protocol 802.11b (and its companion versions 802.11a and 802.11g), the PHY layer has spread out of cable into the electromagnetic spectrum. Once it moves out of wires into the electromagnetic spectrum, the PHY layer crosses some social, political, and cultural boundaries aligned with built space (e.g., the line between public and private) that the MAC layer seeks to hold in place. The awkwardness of Wi-Fi mobility, and the reason that it generates so many

forms, incarnations, experiments, and hacks, comes from the juxtaposition of a MAC protocol meant for well-defined, centrally administered, and self-contained LANs such as offices with a proliferating PHY, propagating signals across once impermeable boundaries and between once divided spaces (home office and kitchen). The "kludge" to which the software developer referred is deeply implicated in the protocol. It is not an accident that has befallen it because of bad technical work. The coalescence of divergent organizations of space and movement at the interface between the physical and MAC layers produces interesting instabilities.

Two Spatial Idioms Arising From the Wi-Fi Kludge

The kludge suggests both why Wi-Fi will be superseded 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 implicit to Wi-Fi itself. 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 idioms of movement, ownership, and regulation. In differentiating the idioms of these spaces, movements, and controls, communications infrastructures become a locus of social-cultural-material struggle. Wi-Fi, as a material-social-cultural process that changes communication infrastructures in a variety of locations, precipitates a diversity of movements that shift thresholds between public and private, between individual and collective. At the moment, two principal topological idioms circulate through 802.11b. The first presents Wi-Fi as a way of combining access to information networks with mobility. One could call this the MAC idiom. The second regards WLANs as a way of making visible or engaging with certain social, economic, and even political obstacles affecting information networks. That idiom might be called the PHY idiom.

MEDIUM ACCESS CONTROL

The term *Wi-Fi*, coined in 1999 (Wi-Fi Alliance, 2003a), abbreviates "wireless fidelity" and resonates with relatively expensive home sound reproduction technology dating from the 1950s, "hi-fi." It tacitly links Wi-Fi to domestic architecture and consumer electronics rather than to cyberspace or corporate infrastructure. This resonance of "high quality but for domestic use" pervades the dominant idiom in which 802.11b equipment and software is represented, installed, and used. Yet there are some evident tensions here. The MAC idiom grapples with the representational problem of rendering something visible—a new modality of communication infrastructure—while stressing its invisibility and its ease of use. Recent Intel Corporation promotions of Centrino computing products have 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). The integration of wireless capability into the "inside" is represented in the current adver-

tisements by an "x-ray" image of the motherboard of a laptop computer (Intel Corporation, 2003). Although "convergence" between communications hardware and computing hardware has been occurring for several decades (Ethernet network interface cards have been standard computer components for a decade), in producing and promoting the coalescence of hardware and Wi-Fi, Intel is banking on the ubiquitous naturalization of wireless networking. By embedding nonproprietary conventional objects such as the 802.11b protocols into the lowest level of commodity computer platforms, they become quasi-invisible, naturalized components of the ongoing "convergence" of computing and communication.

Intel's advertising slogan, "The unwired office starts inside," can be read in another way. The "inside" might also be that of the "Wi-Fi user," the person has begun to internalize network infrastructure connectivity as given throughout public, private, work, home, leisure, travel, and war zones. The human figures, usually men, seen in many promotional images associated with Wi-Fi characterize that "inside" in genesis in two ways. Recent Toshiba Corporation (2003) laptop computer advertisements situate a man usually alone, although occasionally at work in a casually stylish office meeting, in remote locations and relative isolation. He stands on a rocky promontory beside a storm-tossed sea, he sits in a tree house looking down on children playing in a sun-filled backyard, he looks out from a platform high above a sports stadium, or he lies on the grass in the middle of a park on a summer day. The laptop screen adjacent to these figures shows an office, a library, a scene from a film—in any case, something incongruous with where they are geographically located. In the images, it is hard to tell who is working and who is not. These men are not obviously dressed for work. The freedom to connect "in new places" to which Intel's promotions refer recurs across many different corporate promotions of Wi-Fi. An affirmation of "freedom"—"enter the world of freedom computing" (Toshiba Corporation, 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 send and receive 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 others become somewhat invisible.

This seamless incorporation is balanced by attempts to make certain places more salient: *hotspots*. Rather than just including hardware to handle 802.11b communications in its core chipsets, 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 wants 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 has staged "wireless days," with free national access in the United Kingdom and the United States, and also awarded cities for being the "most unwired."

The hotspot is a significant topological component of the MAC idiom. Hotspots are widely scattered throughout North America, Europe, and Southeast Asia (see Wi-Fi Alliance, 2003b, for a geographical location database). Driven somewhat belatedly by telecommunications corporation investment, hotspots have rapidly multiplied in affluent urban zones, such as inner-city London, Manhattan, Seattle, and Singapore, but they can also be found in almost any town bigger than a village in the United Kingdom. In principle, a hotspot is a point of intersecting flows, a place where heavy traffic or concentrated activity occurs. Starbucks ("We serve more than coffee"), McDonald's ("Bites or bytes, we do both"), airports, hotel lobbies, and bars are making themselves into Wi-Fi access points for the Internet so that drinking coffee, eating burgers, and waiting for a flight become associated with network access. The flow of food, drink, and passengers merges with flows of data.[2]

A final element of the MAC idiom suggests that the interaction between freedom, mobility, and invisibility is more complicated. Invisible networks seem to invite deviance and illicit intrusion. In the computer industry, systems administrators and technical directors regard Wi-Fi warily because Wi-Fi disconnects network topology from the controlled spaces of cables, conduits, and switching rooms. At the Wireless LAN Event, staged at the Olympia Exhibition Centre in London in late May 2003 (Wireless LAN Event, 2003), many of the most well attended seminars on the schedule addressed Wi-Fi *security*. From the perspective of the MAC idiom, an important component of the world of freedom means practically excluding unwanted participants from the networks. The freedom of attachment correlates with freedom from the presence of unwanted others.

There are several aspects to the prominence of security as a problematic. Technicians and administrators from corporate information technology departments regard Wi-Fi as threatening the boundaries of their organizations' networks. Whereas connections to wires and cable can be visually traced like railway lines, wireless networks spread out diffusely and invisibly, even if they don't go very far. (How far a wireless network can reach depends on the sensitivity of the antennas in use and the local terrain.) The seminars on security figured the "threat" in terms of different possible vulnerabilities and attacks on the integrity of the corporate body. The recent arrest by the Federal Bureau of Investigation of Wi-Fi hackers in a shopping mall parking lot in Detroit (Poulsen, 2003), the trial of a hacker who accessed a county court's Wi-Fi network in Texas, and the arrest of a man downloading child pornography using a laptop in his car in Toronto (CTV.ca News Staff, 2003) have all heightened sensitivities about unauthorized access to Wi-Fi networks. But unauthorized access to networks from outside is only part of the worry. The danger comes from people within organizations. The software and hardware tools on display at the Wireless LAN Event, and written about extensively in myriad how-to computer books, in trade publications, and on Web sites, are also concerned with controlling access *within* an organization. For instance, network analysis tools on sale at the exhibition allow Wi-Fi network administrators to identify "rogue nodes" attached to their networks by someone *in* their organizations as well as to block attempts to connect to the networks from outside (e.g., AiroPeek NX, an "expert 802.11 wireless LAN network analyzer"). As yet, procedures and mechanisms for controlling access to Wi-Fi networks are still in a state of flux. These security seminars are one important way in which the MAC idiom practically negotiates th redrawing of the boundaries between public and private space, between corporate and noncorporate, between individual and collective spaces.

In sum, the MAC idiom, as a practical imagining of mobile communication, highlights several different topological features of wireless networks. The 802.11 protocols are compressed into increasingly invisible commodity hardware merged with the silicon substrate. At the same time, the spatial distribution of network connectivity often takes the form of commercial hotspots that need to make, for the moment at least, the existence of quasi-invisible wireless networks infrastructures visible. The unwiring of homes and offices parallels these quasi-public venues. Human figures carrying their computers within range of a hotspot/office/home wireless access points are promised a freedom from network cables, fixed wall sockets, and desks. But they are also uncoupled from the presence of others. This latter uncoupling is not decisive or certain, for the move away from desks also exposes new interfaces for others. This uncertainty features prominently in the concern with security, the practical tactics for regulating access to networks and for preventing networks from growing unexpectedly ("rogue nodes").

UNEARTHING THE PHY

Andrew Ross (1991) astutely argued over a decade ago that technologies 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" (p. 98).

Consistently, media attention to Wi-Fi has been attracted by the possibility that Wi-Fi networks might be something more than another event staged for the benefit of computer hardware manufacturers, whose main product, the computer, has become a sluggish sales performer and who are now retooling themselves as home entertainment electronics producers. Similarly, the many "community wireless networking" projects that began to spring up in many different parts of the world in 2002 have been publicized, sometimes very enthusiastically in the mainstream press, as an alternative to the commercial infrastructures of the Internet and as a release from the offices and desks that hamper the Internet. In the aftermath of the dot-com crash, anything in the domain of digital technology that carries countercultural, noncorporate cache tends to attract mainstream media interest.

The second topological-signifying idiom, the PHY mentioned above, surfaces intermittently in media stories about wireless projects. The projects span a disparate set of interests, including a geek commitment to exploring the technical limits of connectivity (e.g., the Hurghada project in Egypt; Adly, 2003), the development of a "wireless commons" (Wireless Commons, 2003), and United Nations–sponsored efforts to leapfrog infrastructural hurdles in developing countries (BBC News, 2003; United Nations, 2003). They lack the co-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 them 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 PHY idiom is distinguished from MAC in several ways: by a nonexclusive relation to others, by some different practices of

space and distance, by varying degrees of politically explicit challenge to commercial ownership of infrastructure, and by an interventionist stance in relation to commodity computer hardware. Potentially at least, this idiom constitutes a more metastable, heterogeneous mixture of practices, feelings, and imaginings of communication than the MAC idiom. A transformation of media technology habitus, the embodied social knowledge of communication, infrastructure, and urban mobility, could be at stake here.

Consume, a project active in East London during 2002 and 2003, encapsulated several dimensions of the PHY idiom. Consume's components include wireless network nodes transmitting from the roof of the former Greenwich Town Hall, a Web site that represents the current state of wireless connections in a geographical area centered on London, public events, and booths that deploy wireless networks. The project has received a substantial amount of media attention over the past few years. A key figure in Consume, James Stevens, is regularly interviewed by newspapers (and academic researchers). Consume's Web site (http://www.consume.net) shows a map of London with each wireless access node marked. It provides technical information about how to connect to each node and an e-mail address for each node's owner. These wireless access points are scattered across London. In some places, their coverage overlaps; in others, there are wide gaps with no coverage (although again, this depends on the sensitivity of the antennas in use). These nodes are marked as having different operational status: Some are active, some are still being set up, some have been taken off the air for various reasons. The information is neither reliable nor accurate, because the people who operate nodes can take them off the air without notifying Consume. Until someone reports a problem, its Web site will not reflect any change. The primary function of the Web site consists not so much of providing access to wireless networks. Rather, as one person involved in another London wireless project put it,

> Yeah…it's not intended to be a definitive database. What it's meant to be is, in a certain sense, a social tool. You put in your postcode, or somehow you locate yourself on it, and then you seen who's around you based on whatever details they've provided—whether that's a URL, what kind of equipment they have. And in a way, you personally make contact with them and see if it's real or not. So it serves some purpose. (Simon Worthington, interview, May 2003)

The results of the Consume project were quite localized connections between people living in the same neighborhoods of London and relatively short-lived augmentations in networked connectivity. (Further research would be needed to establish just how many people use the several hundred nodes shown in Consume's database.) A different relation to space typically emerges in these projects. Space is not necessarily seen as something that individuals traverse, picking up and shedding networks connections as they move in and out of hotspots. Just the opposite: Most of these projects aim to enroll people who are less mobile and who lack cutting-edge infrastructural connectivity.

The "wireless clinics" that Consume ran from February 2002 to July 2003 made temporary, local alterations in the topology of networked communications. They assembled people together by drawing on an interest in the intersection of culture and technology rather than simply installing wireless networks in parallel with the commercial projects. Of these events, one observer noted,

> Other things that Consume does that have been really useful and that our project [YouAreHere] takes part in is the events. Sometimes they're more social, fun events where people in a big old town hall use Wi-Fi to download a whole lot of music, and dj. (Simon Worthington, interview, May 2003)

Attention seems to move away from wireless technology itself toward the technology as a way to bring people into association with each other without the intermediaries of commercial internet service providers or network infrastructures.

Projects such as Consume are not totally disconnected from or opposed to the MAC idiom and its milieu. At some point, a wireless network usually connects back into commercial infrastructures. On the roof of Consume's workshop in Greenwich, one antenna points across the river toward the office buildings of Canary Wharf. For over a year, Consume had a 1 Mb/s Wi-Fi link to a data center there. When the link began to fail (perhaps because of the rampant growth of other 802.11b networks in the vicinity), Consume had to have a commercial broadband connection installed. Second, at one corner of the annual industry Wireless LAN Event in London, Consume shared a stand with the Access to Broadband Campaign (2005). The title of the project, Consume, reflects this somewhat complicated relation to commercial network infrastructures: "So that in calling it Consume, the idea is that it consumes the net, that it should be a replacement for the commercial networks, not just locally but internationally" (Simon Worthington, interview, May 2003).

Consume plays on two different senses of the word at once. On one hand, it issues an injunction to consume. People might be able to consume bandwidth almost free of charge if they have wireless equipment. They can consume bandwidth, for whatever purpose they can think of: downloading episodes of *The Simpsons*, perhaps. On the other hand, the Internet as an increasingly commercial entity to which access is controlled by different thresholds involving payment, will be consumed or eaten up.

Other organizations and groups associated with the PHY idiom take a more oppositional stance to the commercial networks. Some formulate ambitious plans to set up alternative national or international infrastructures based on Wi-Fi. Others have a much more local scope. Although Consume is not building international or even national wireless networks, it is a signatory to the *Pico Peering Agreement* (2003) and the *Wireless Commons Manifesto* (Wireless Commons, 2003). These documents represent attempts to engineer the 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., *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 conference held in Copenhagen that focused on developing and promulgating the *Pico Peering Agreement*, one participant suggested 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 inter-

> net, but one where the system of ownership is decentralised enough for it to remain a "common." (Albert, 2003, p. 7)

These initiatives are directly influenced by open-source and free-software movements, and the licensing schemes of the Creative Commons, but take up a political stance in relation to infrastructure on the basis of the proposition that access to communication infrastructure should be free or a public utility.

Rather than concentrating on *hotspots* where individuals will access the Internet "in new ways," these projects aim to modify the proprietary status of the infrastructure itself by introducing collectively organized detours, bypasses, and supplements to it. Sometimes, they modify hardware or produce software. Examples of this can be seen in Consume's Greenwich studio. In the equipment room, several gray boxes stand side by side on a bench. LocustWorld's (2003) MeshBoxes allow wireless nodes to be connected in a "mesh" that can cover an extended area in the same way that a cell phone network does. Antennas are also the objects of wide-ranging modification in the PHY idiom. Modified antennas extend the range of 802.11b well beyond the technical limits of a few hundred meters. Images of these antennas figure prominently in newspaper reports (Cohen, 2003; Wainwright, 2003). Commodity hardware, assembled and modified, becomes part of the practical rhetoric of the cultural inversion of infrastructure.

The PHY idiom exhibits a much more diverse "sociogeographical" range than those of the MAC idiom, with its investment in hotspots, homes, and offices. It ranges geographically across Southeast Asia (Jhai Foundation, 2003), the Pacific Islands (St. Clair, 2003), Africa (Adly, 2003), Europe, and the United States. Whereas the MAC idiom imagines individuals enjoying the freedom to move around major metropolitan centers in Europe, North America, Japan, Korea, or Taiwan with more or less constant Internet connectivity, the PHY idiom envisages a different mobility, a mobility in infrastructure itself, in its plasticity as a site of collective work.

The desire to construct infrastructure, to create a supplementary or alternate "PHY" for the Internet, is an intriguing and significant development in the post-dotcom cultural politics of communications. With its geographical dispersion, its efforts to modify or rebuild commodities (hardware and software) and communities, its slowing down of individual movement into clusters or "meshes," and its legal-technical efforts to develop alternative, large-scale digital infrastructure, the PHY idiom diverges significantly from the sociotopological idiom of the MAC idiom. It testifies to a growing "potentialization" of physical infrastructure that adds onto or in some cases replaces commercial infrastructure.

Implications for the Infrastructural Inversion

Wi-Fi in general increases the mobility of digital information in built environments, but this mobility is differentiated and unstable. It may not be the most important, "disruptive," or "emergent" technology of the digital epoch. Whether it is does not matter. Instead, Wi-Fi can be analyzed as an ongoing event that articulates different types of spatial and informatic movements together. The matrix of relations between

these movements generates a diversity of wireless networking phenomena. These appear as gadgets, business plans, community projects, government policies, everyday habits, and vision statements. The second major argument has been that Wi-Fi's ongoing development and proliferation can be analyzed in terms of two divergent idioms or articulations of network space. The MAC and PHY idioms continue discourses of communication infrastructure and the Internet that predate Wi-Fi and that reside within the constitution of the 802.11b protocols as a sociotechnical entity. The MAC idiom frames Wi-Fi as an extension of infrastructure that must be invisible for the sake of freedom, mobility, and security. The PHY idiom treats Wi-Fi as an opportunity to change the meaning, value, and properties of infrastructure itself as a cultural-political-practical project. The Wi-Fi kludge holds these two awkwardly and provisionally yet constitutively together.

For academic analysis of communication infrastructures, movement, and space, seeing Wi-Fi as a kludge yields a deeper understanding of how consumption, production, appropriation, and resistance mutually condition one another. The MAC idiom uses the PHY idiom to make Wi-Fi visible and significant. The PHY idiom needs the MAC idiom to drive expansion and normalization. Their mutual dependency means treating mobile technology as a site of contestation and contingency at every level rather than a neutral medium or instrument that can be appropriated to different ends. The Wi-Fi kludge also suggests a different analysis of infrastructural inversion. Cultural theory (de Certeau, 1984), sociology (Bowker, 1996), and geography (Graham & Marvin, 2001) have treated infrastructure as something that needs to be uncovered because of social and political struggles occurring there. The ethicopolitical injunction to make infrastructure visible was motivated by a sense of the possible transformations that might result. In wireless networking, infrastructure becomes partially and intermittently visible independent of sociological analysis. What is the task of the analyst in the face of spontaneous infrastructural inversion? The kludge suggests that submersion and inversion occur simultaneously, in constructive tension, and that the Wi-Fi matrix animates different movements and different spaces. From perspective of the kludge, sorting and naming these mobilizations, and explaining how they are generated by articulation between different movements, could contribute to widening, multiplying infrastructural inversions.

Notes

1. Geert Lovink (2003) asked,

> To what extent has the "tech wreck" and following scandals affected our understanding of new media? No doubt there will also be cultural fall-out. Critical new media practices have been slow to respond to both the rise and the fall of dot-commania.

2. "Actually, despite their proliferation, the hotspots have not, it seems, been very hot. The bar employees often don't 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).

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