Wireless Networking and Human-Building Interaction: Designing for Connectivity

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Abstract

Wireless connectivity is essential to interaction with computational systems, which are increasingly embedded in the built environment. Perceived by the majority of people as a resource, or a given, connectivity itself has not received much attention from designers and architects. Because it is critical to functioning communication between embedded and portable computing devices, interaction with wireless connectivity needs to be taken more seriously. This can only be achieved if we adopt a more tangible approach to interaction design, reflected in early HCI proposals for *seamful* design. This paper will conceptualize the role and potentials of wireless communication systems in human-building interactions. Two concrete proposals are made in order to illustrate designing for connectivity.

Author Keywords

Wireless connectivity; *seamful* design; tangible interaction; networked space; responsive building;

ACM Classification Keywords

H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Wireless communication as *material*

The use of the notion material for an imperceptible phenomenon here relies on Jean-François Lyotards interpretation of communication for the 1985 exhibition *Les Immateriaux* he co-curated with Thierry Chaput Using the communication model they worked towards extending the meaning of the word material (matériau) which encompasses *matières* (referents), *matériels* (hardware), matrices (*matrices*), and even *maternité* (maternity). They tried to include the immaterial in their definition of the "given" matter.

Internet of Things (IoT)

IoT is a name used for a vision of networked objects which are connected and structured in a similar way to the information on the Internet. Coined in 1999 by British entrepreneur Kevin Ashton, the name referred at first to networking of physical objects using RFID tags and readers in shops and supermarkets. The second wave of interest in IoT works towards more general connectivity across objects and devices using Bluetooth or Wi-Fi connections.

Introduction

Early human-building interaction research largely focused on problems inherited from the human-computer interaction (HCI) field and building performance research. Researchers envisioned creative and contextual uses of available technology to study energy efficiency and different post-occupancy evaluation scenarios [8, 10]. With the Internet of Things (IoT) entering the scene and the increasing interest from companies and academia in Smart Homes and Smart Cities, it became even more compelling to envision the built environment as an overall-connected, sensitive and responsive system. Connectivity gradually became a central requirement in these systems, networking tangible and intangible components with interfaces and people. Yet, designers and architects rarely observed connectivity outside its functional paradigm. Offsetting these trends, connectivity is analysed here both as a resource and a *material* to be designed and to interact with. The role and potential of wireless communication systems in human-building interaction are conceptualised. An approach to design of space is discussed then, which internalises awareness of wireless. This internalisation happens through permanent observation and careful design of seams in wireless connectivity. Building on earlier efforts in the HCI community to promote a *seamful* approach to design [2, 13], some concrete proposals are made at the end of this paper.

Buildings are increasingly integrated with computing systems that regulate temperature, shades, permission to open doors. This should not imply that buildings are becoming computers for living in. Buildings and computers have a different purpose. Computers are machines that can be used for a large number of unrelated purposes. In the most general case, they produce output based on an algorithm that processes some kind of input. Buildings, on the other hand, are something we have been constructing and using for centuries, whose technological paradigm is based on producing a fixed, immutable artefact. This artefact is usually meant for a specific purpose (such as living, learning or producing consumer technology) and needs to be reshaped each time its purpose changes. While output of interaction with computers is mostly intangible (something is computed), interaction with buildings is mostly tangible and irreversible.

The development in the HCI has mostly followed the direction from intangible to tangible – bringing interfaces and manipulation closer to natural interaction. Interaction with buildings follows the opposite trend, from tangible – opening a door using a door knob – towards intangible – movement triggered door sensors, shades that respond to daylight conditions, programmable thermostats, etc. The unavoidable proliferation of sensors and chips requires different kinds of interaction than our normal door knob. This is why it is important more than ever to think of human-building interaction in all stages and areas of design.

Wireless Connectivity

Wireless communication signals propagate through the environment, distributing information as far as possible. They are met with resistance in the form of built structures and other obstacles, movement of bodies and people's communication activity.

Wireless communication engineering is mostly concerned with increasing speed and network coverage,

Figure 1: *Seamful game* play at Ubicomp 2004 in Nottingham, England. *Seamful game* is a GPS and WiFi based game exploring the concept of *seamfulness*, created by Matthew Chalmers, Marek Bell, Barry Brown, Malcolm Hall, Scott Sherwood and Paul Tennent

Figure 2: The Bryant Park Wireless Network one of the first wireless networks covering a large public space. People's spatial preference is a combination of social and technical connectivity. Bryant Park, May 2012

in response to the growing demands set by service providers and network users. The decisions made in this scope are mostly driven by optimisation of resources and infrastructures. Awareness of the act and the affordance of connectivity were mostly overlooked in instrumental design of these systems. The public primarily regards wireless networking technology as a technical infrastructure which should provide seamless flow of information across a network of base stations, access points and mobile devices. We only pay attention to the performance of wireless networks when they fail.

As a counterbalance to this, several research communities explored the social and spatial aspects of this technology. Their interests were driven by a combination of factors, which can be correlated to the availability, adoption rate and social relevance of wireless communication technology. Most notably, some researchers experimented with rendering the *seams* visible – be it the act of connecting [13], availability of networks [2] their embodiment [4] or interaction with them [1].

In the early 2000s, the number of papers in HCI research that dealt with wireless technologies and their alternative rose sharply [2, 13]. This trend was followed by computational spatial analysis which performed sophisticated measurements and mappings of signal availability and use [7, 16]. Tools for mapping were developed hand in hand with wireless technologies, at the time when Wi-Fi became ubiquitous across university campuses and cities. Ethnographic studies that explored the importance of these new technologies for the use and character of public space in everyday situations appeared parallel to the massive adoption of Wi-Fi standard and deployment of public wireless networks [5, 6]. Artistic and design engagement with the technology expanded significantly around that time as well [14].

To this day, architects do not consider it their job to design for wireless connectivity – a service provided by somebody else. It is about time that architectural and interaction design deals with wireless communication infrastructures more systematically.

Wireless Signals and Architecture

As the role of technology in creation and mediation of space shifted from a tool to represent the virtual environment towards computing that attempts to process the environment, architecture was increasingly compared to interaction design. McCullough observed this similarity in the fact that both architecture and interaction design "address how contexts shape action" [11]. Information technology becomes social infrastructure, says McCullough, a transformation architecture has long undergone.

The idea that wireless signals are "like" architecture is at the core of the questions addressed here. When comparing the *spatiality* of wireless communication to the *spatiality* of space, properties of space (static and tangible) are applied to communication (dynamic and intangible for most part). The connection here lays in the fact they are both relevant to our experience of space and present simultaneously.

In *Computers as Theatre*, Brenda Laurel did not mean to construct a consistent analogy but to trace a way to conceptualise human-computer interaction [9]. Similarly, this paper aims to conceptualise tangible and

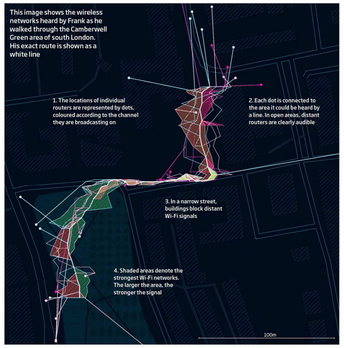

Figure 3: *Phantom Terrains* map of a walk in the city. The authors, Frank Swain and Daniel Jones modified assistive hearing technology as a prosthetic, extending its function to hearing the wireless network landscape http://www.phantomterrains.com

Figure 4: Sistine Chapel equipped with a Faraday cage on the occasion of the 2013 Papal Convention.

meaningful interaction between space, people and networks.

Seamful **Wireless Infrastructure**

From wireless networking to seamless integration of functions in a smartphone, invisibility is the key metaphor of the way technology operates or connects. Mainstream interaction design has largely adopted the *disappearing interface* as a principal design challenge, epitomized in the *Age of Context* [15]. The seamless paradigm embraces easy adoption of technology, reflected in intangible metaphors of the Cyberspace or the Cloud. As a critical reaction to this, a number of interaction designers and media scholars proposed *seamful* approach to structures, infrastructures and design in general. *Seamful* design is an approach that reveals underlying structures and relationships behind what appears as utilitarian infrastructure [2]. Advocating the intentional design of seams which appear at edges of connections and territories, such design encourages user engagement [3] and understanding of the resulting combined space [13].

Proposal 1: Permanent Awareness of Wireless Connectivity

A relatively standard procedure in rendering seamless infrastructures tangible is to take information on an aspect of wireless connectivity (signals availability, strength, encryption type) and assign it some aesthetic form [14]. This is an interesting experiment which contributes to the understanding of signal availability and traffic use in real time. But the image that is produced is short lived. In order to establish a language of interactions, such interventions would need to be more permanent. This would enable observation of patterns and regularities in the presence of wireless network signals.

One interesting example of long term observation is the listening experiment *Phantom Terrains* by Frank Swain and Daniel Jones. Swain, a journalist and Jones, an artist and software engineer augmented Swain's hearing aids to include presence and proximity of wireless networks. In this way, Swain continuously listens to the wireless network "population" and perhaps develops a sensitivity or understanding of patterns that emerge in signal propagation.

Proposal 2: Building Materials in Function of Connectivity

The presence and distribution of wireless networks in buildings can be optimised through architectural design. Architects can account for the use of materials and disposition of routers in a more instrumental manner, resulting in better signal propagation. This would require in-depth studies of network propagation similar to the ones currently done with building performance metrics. Building performance studies currently focus on energy use, daylight performance, thermal, visual or aesthetic comfort, but their interest could be extended to wireless connectivity.

Accounting for signal propagation would also require rethinking the use and qualities of existing materials in order to design connectivity according to the use of space. In the most basic case, one might want to isolate a sleeping room from signals while providing uninterrupted reception in the office or living room. This can be done by isolating the space applying the principle of the Faraday cage in the first, while using a thin and transparent enclosure in the other. A notable example of this in practice was the isolation of Sistine Chapel during the 2013 Papal conclave. A Faraday cage and electromagnetic jammers were set up in this space, sub-optimal for keeping a convention secret in terms of wireless communication. The outcome emphasized the discrepancy between architecture as a shelter from the weather and from electromagnetic radiation. The need for information secrecy is probably not going to diminish in the future, but to the contrary, will demand more elaborate solutions. The use of metal in building material might become a standard for any kind of business, religion or other convention purpose that seeks to prevent information leaking, hinder intrusive technologies and intelligence organisations.

Conversely, most working environments require fast and reliable signal propagation, yielding the need for architecture to become nearly transparent to the propagation of wireless networks. In the light of recent discussions on the future of wireless networking, the transparency of architecture to wireless signals might become even more important. One strategy for increasing the current capacity of wireless infrastructures is reduction of the cell size in cellular communication [12]. The impact of obstacles, such as buildings and walls would be significantly greater in this case, thus the need to think about materials that do not absorb signal. Materials will thus increasingly be tested for propagation, while fulfilling other demands such as sound isolation or opacity to light.

Given the advances in material research and the integration of computational systems into buildings, dynamically changing materials that respond to connectivity demands might be an interesting field to explore.

Conclusions

Beyond energy efficiency or post-occupancy evaluation, design of our interaction with the built environment needs to be rethought in terms of core infrastructures it relies on.

This paper proposes a *seamful* approach to design of interaction with wireless communication infrastructures. Such approach would improve our understanding of connectivity as a social and technical infrastructure. If we take a step back from the standard, utilitarian perspective on wireless connectivity, we can observe that, while serving their main purpose, these network signals make changes to our environment that are not reducible to the act of communication itself.

The questions of transparency to propagation, building capacity to adapt, and cultural consequences of connectivity in building context spark an interest in careful design of interaction with wireless networks in the built environment. The approach proposed here helps to develop a *design sensibility* towards the availability and behaviour of wireless communication signals through awareness. This *design sensibility* is not equal to a recommendation. This is not a suggestion for architects to begin making interactive buildings that represent network activity. Rather, by engaging with experiments with wireless connectivity, architects and designers might learn to understand propagation of signals and their use by people, devices and rooms. This should open an *agential* perspective on wireless network signals, but also other *actants* in the environment (light, sound, electrical signals, wind, rain, earth movements, etc). Such a perspective on the environment will empowered the designer to account for and envision more dynamic environments that are able to accommodate change as well as information in a completely new way.

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