Space of Communication: How To Address *Architecturality* of Wireless Networks?

Visibility haunts our idea of knowledge since early greek philosophy, and has found particularly fruitful ground in empiricism. If knowledge arrives to the mind through sensory experience, that which can be seen can be known; that which cannot be experienced is only to be doud debated. American philosopher Susanne Langer observed in the late 1950s how evidence derived from our senses dominated natural sciences (Langer, 1993). Reason is based on facts because they can be observed, identified: we believe what we see. At the same time, Langer continues, the space of observation in laboratory experiments has shifted from experiences directly accessible to our senses to phenomena whose behaviour is mediated with different measuring instruments. Scientists today observe objects that have never been experienced, through instruments and devices that give them access to the space of experiment, too small and dynamic to be observed by human eyes.

Our experience of the environment increasingly relies on something we like to consider invisible – an omnipresent wireless communication infrastructure. Places and services are recommended to us based on the location of our smartphone. We make phone-calls on our way to work, read the news on our touchscreens while waiting in a line, chat with remote friends while sitting in a café. We buy our tickets and book hotels while walking down the street. All these are made possible by continuous and reliable connectivity across our living space. Wireless communication technology, thus, plays a large role in our experience of space, yet it is veiled in a collective illusion of immateriality.

French philosopher Michel Serres observed that all living and non-living things communicate: "Information circulates through the inert, living and human world, where everything and everyone emits it, receives it, exchanges it, conserves it and processes it" (Serres, 2014). Serres presents these as the four universal rules of communication: emitting, receiving, exchanging and processing of information. What, if anything, makes wireless communication special?

Wireless communication signals propagate in waves that are of the same type as naturally occurring radio[1]. The main difference is that they are produced with man-made electronic equipment, their frequency and amplitude modulated to encode information. They propagate through air, invisible to human eyes and senses, accessible only through measuring instruments and communication equipment. The design of the infrastructure adheres to the logic of seamless connectivity, which backgrounds availability of connection in favour of continuous access to information. The waves also play an important role in the information economy, as a resource that is rendered scarce through governmental regulations, and frequency allocations[2].

The structure and dynamics of production, control and distribution of information in the era marked by "post-truth" and "post-factual" politics, makes it ever more interesting to discuss

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[1] Natural phenomena such as lighting and radiation from celestial objects generate radio waves, which exhibit the same wave properties as light. Naturally occurring radio waves were first discovered in the mid 19th century by Maxwell and Hertz and were soon after used for communication by Marconi.

[2] Frequency allocation is the division of the frequencies that make radio wave electromagnetic spectrum into frequency bands which can then be attributed to specific entities for broadcast.

some of the (mis)understandings of wireless communucation's materiality, visibility, spatiality. I will unpack some misleading conceptions: that waves are immaterial because they are invisible, immaterial because they seamlessly connect and immaterial due to the scarcity of bandwidth.

(Mis)Understanding the Materiality of Wireless Networks

The functioning and presence of wireless communication networks is veiled in a collective illusion of immateriality. The design of wireless infrastructures aims to blend them into the built environment so that they attract the least attention (attached to ceilings, niches or existing outdoor structures). This approach might be fit to address medical concerns for potential harmfulness of radiation, especially in the early years of Wi-Fi and cellular adoption. However, it continues to promote seamless integration of infrastructure and environment at the expense of clarity of its distribution. Interaction with networks is also attuned at seamless connectivity, which means a person has to make the least effort to connect – this act is automated and backgrounded. Our devices seamlessly switch between different types of networks (cellular, Wi-Fi) and remember networks they have already "seen". Finally, radio spectrum regulators present us with concepts of bandwidth saturation and spectrum scarcity. This presumes the spectrum to be a concrete and finite resource, its finitude being a manifestation of its materiality. In reality, radio waves licensed by governments are the spectrum – what is limited is the right to deploy transmitters and receivers.

In everyday conversations, materiality of wireless networks can be understood in terms of the infrastructure they run on – web of cables, routers, switches, access points. Besides these, we are able to observe that signal and accessibility are not evenly distributed in space, and thus we sometimes have to change location in order to connect. A more specific approach to the observation of wave materiality came from contemporary media art and design practice, where the interest in rendering the waves visible, audible or tangible has been high in the past decades (Savić & Heitor, 2014). In spite of these efforts, the dominant perspective on wireless communication is still haunted by misconceptions about their immateriality and the way they operate. We will address three of these here: that wireless network signals are immaterial because they are invisible; that they are rendered immaterial through seamless connectivity; and finally that network materiality is manifested through scarcity of bandwidth.

With the use of the term "(mis)understanding" I do not intend to hint at a single understanding of the phenomenon that needs to be corrected, but rather to promote alternative interpretations and intentional misunderstandings. Each of the misunderstandings that follow is attuned at demonstrating that through this specific act of (mis)understanding wireless signals as invisible or scarce we gain an insight into the nature of their materiality.

(Mis)understanding Invisible Cities and Infrastructures

The parallel between invisibility and immateriality, which the first (mis)understanding is based on, conflates *invisible* with *non-measurable* or that which cannot be sensed. The relationship between built structures and wireless infrastructures is hence often under-interpreted in this coupling of the *invisible* with the *immaterial*.

Italo Calvino's *Invisible Cities* book has often been a point of reference for explorations of invisible urban infrastructures. In his book, Calvino uses the *city* as a metaphor for a mix of psychological, physical and sensory states in this expedition through the author's moods and

reflections. It is a hunt for the hidden reasons that bring men to cities, in light of what the author perceived as the crisis of the overgrown metropolis[3]. Calvino transformed everything into a city: books, exhibitions, personal discussions. At the same time, everything makes a city for him: memories, desires, words. Calvino instrumentalizes the city metaphor in order to organise immaterial phenomena he wanted to explore. His cities are entirely immaterial constructs, fictional entities that summon ungraspable sentiments. Memories, moods and discussions are not quantifiable with scientific instruments and communication equipment. Wireless communication signals, on the contrary, are only perceivable through them. The kind of immateriality Calvino is discussing, however sensible and inspiring for a contemplation of a city experience, is entirely inadequate for a portrayal of wireless communication signals in space. It is even more misleading when taken in the context of the city – where wireless infrastructures are so pervasively installed. Networked, location-aware devices mediate the experience of contemporary city and its services. It would be simply insensitive to disregard the materiality of infrastructure that enables this.

Visibility, or the lack thereof, is a common theme when talking about infrastructures. Engineers design infrastructures that remain in the background and that enable seamless functioning of systems they are engineered for. We could say that systems become infrastructure when they work sufficiently well so that we stop noticing them (Star, 1999). Discussing infrastructures demands the extra effort of getting a distance from something we are half-consciously engaged with on everyday basis. Adam Rothstein wrote about the privilege to experience our infrastructure in first person (Rothstein, 2015). Infrastructure, for him, implied anything from container shipment lines, refrigerated food sites map, worker's body in the eyes of the employer, and finally the fiber-optic cables that transmit 99% of our Internet and other telecommunication traffic (the remaining 1% being the wireless portion). All these infrastructures were designed to be visible only to the ones who are supposed to install and maintain them (Star, 1999).

(Mis)understanding Seamless as Immaterial

The development and deployment of wireless infrastructures was always attuned at seamless connectivity across technology and territory. Why do we want seamless so much? For obvious reasons of the ease of access while on the move; for letting people focus on information rather than the availability of connection. In the context of networking, seamless stands for the lack of effort and attention required from the person, and thus conflate this minimisation of experience (interaction) with immateriality.

Against the seamless design principle, Matthew Chalmers put the idea of *seamful design*: a design approach that makes a system's features visible and accessible (Chalmers, 2003). This lead to a series of projects which aimed to work creatively with these seams, such as the *Seamful map* and the *Seamful* game, arguing for design which allowed user appropriation. The concept of *seamful* design draws upon Mark Weiser's ideas about integration of digital tools. Weiser, a chief scientist at Xerox PARC, insisted that the design of interfaces should preserve the agency of users while the technology disappears in the background of attention.

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[3] Calvino explains his approach to cities through the invisibility metaphor in a lecture given at Columbia University on March 29, 1983, a transcript of which can be found in: Italo Calvino on 'Invisible Cities'. *Columbia: A Journal of Literature and Art*, (No. 8 (Spring/Summer 1983)), 37–42

The device that is part of this project, coming with the printed publication, operates on similar principles, working creatively with the presence of wireless network signals. Is a customized microcomputer providing wireless internet connection as an open access point, able to receive and transmit signals. When turned on, the device creates a hotspot, to which multiple devices can connect. But its accessibility has a second function: it is used to measure the intensity of received signals from surrounding access points, and illuminate the pages with ultra-violet light, for the special ink to become luminescent and thus visible. The intensity of the light depends on the intensity of signals coming from other devices that operate at the frequency of 2.4GHz (Wi-Fi access points, babyphones, wireless video surveillance, micro-ovens, etc). The device thus works with what we could call electromagnetic pollution.

The discussion on *seamful design* is attuned at establishing a different kind of materiality. This materiality shows through events that occur at the intersection of wireless infrastructures with the built environment. Timed interactions between the infrastructure, its users and external conditions are normally orchestrated in a manner that takes the least cognitive effort and makes the least difference. By specifically focusing on these events – establishing and loss of connection; transfer of packets between devices; handoff from one access point or cell to the other – materiality of connectivity is exposed and felt.

(Mis)understanding Scarcity of Wireless Spectrum

The electromagnetic spectrum is difficult to grasp and we often resort to tangible metaphors of roads or territories when talking about it. Roads can be congested, territories crowded. We tend to say that wireless communication channels are saturated today.

Access to the electromagnetic spectrum is regulated in terms of available frequencies (both licensed and unlicensed), the maximum signal strength permitted, the geographic region over which the licence applies and the designated service provided by an operator. Traditional amplitude (AM) and frequency modulated (FM) radio broadcast is a one-way centralised transmission, with only licensed stations allowed to broadcast at specific frequency bands. Network operators buy rights to use these frequencies from national regulatory authorities (FCC in the United States, RED in Europe, BAKOM in Switzerland). A relatively small portion of radio is reserved for the unlicensed spectrum[4]. Contemporary wireless communication technologies (such as Bluetooth, Wi-Fi, GSM, etc) make use of the different bands in both licensed and unlicensed spectrum and are based on continuous exchange between networked devices. In this way we are able to both send and receive information over the air.

The capacity of a frequency band or the amount of information we can send over the air depends largely on the way information is encoded (modulated) on the waves. Spectrum mask – the set of protocols that define different channels and regulate frequency use is provided by the Institute of Electrical and Electronics Engineers (IEEE). This spectrum mask is as an international standard which ensures device interoperability while minimising interference with devices that share the same frequency range – amongst them microwaves, Bluetooth gadgets, Zigbees, Baby phones and wireless surveillance cameras.

In contemporary discourse on overcrowding, wireless networks are often seen as something

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[4] For a discussion of spectrum management approaches, see: Cave, M., Doyle, C., & Webb, W. (2007). Essentials of modern spectrum management. Cambridge ; New York: Cambridge University Press,

scarce, something we need more and more of. This view conflates the capacity of communication equipment to transmit information with efficiency of protocols and techniques to encode this information onto signal. It is the spectrum mask that renders networks scarce. Researcher in cultural and economic aspects of networking technology, Rachel O'Dwyer noted that spectrum policy is broadly emblematic of the prohibitions operating over what she calls the "substrate infrastructure" (O'Dwyer, 2013). She sees ownership of infrastructure, which implies both the right to use specific frequency bands and access to telecommunication cables, as a central asset in valorisation of wireless communication technologies. Management of interferences through spectrum masks renders unlicensed frequency bands scarce.

The problem with misunderstanding scarcity as a given goes beyond misunderstanding the principles of spectrum availability. Because it is so tangible, scarcity tends to stand for a manifestation of network materiality – as if we only had a limited amount of radio waves that propagate at a certain frequency. Without wanting to repeat what was already said about the way frequencies are allocated, it is important to note here that the amount of traffic transmitted over a network does not change the amount of broadcast signal – it manifests in the energy a device had used to encode this information in order to send it. The total amount of electromagnetic radiation broadcast by networked devices stays the same whether these devices are congesting the network or exchanging beacon frames[5].

The Posthumanist Turn or the Agency of Everything

The past twenty years have brought an inflation of non-anthropocentric theories and studies in a wide range of fields. Literary studies have seen titles such as Neil Badmington's *Alien Chic Posthumanism* or Katherine Hayles' *My Mother was a Computer*, culminating with Richard Grusin's recent edited volume titled *The Nonhuman Turn*. This turn originated in several different discourses, most notably Norbert Wiener's cybernetics and complexity theory. One of the consequences of such a turn is the rise of interest in articulation of cognition *agency,* distributed cognition in the environment and specifically the discussion around non-human agency.

In contemporary humanities discourse and philosophical frameworks (Bruno Latour's *flat ontology*, Graham Harman's *object-oriented philosophy*, Karen Barad's *agential realism*), *agency* is the inherent property of a token (a unit, an object, a phenomenon) by means of which it is granted activity. *Agency* can also be understood in terms of cognitive sciences, which originally used the concept to discuss the possibility for cognition and intelligence embodied in non-living things. Next to this, *agency* is an elastic concept which can be suitably applied to questions of the effect that something (a roundabout, an urban plan, a computer in a call shop or a wireless signal transmitting data) has on something else. *Agency* therefore acts as "a conceptual currency across different [sub-]disciplines" (Barandiaran, Di Paolo, & Rohde, 2009, p. 1). From anthropomorphic expectations that evaluate consciousness and volition in living and artificial systems, the concept of *agency* has expanded to include non-living, non-volatile things that interact with other things. It is, thus, possible to discuss the *agency* of phenomena such as wireless communication signals.

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5 Beacon frames are sent in regular time intervals to communicate basic information regarding the communications process with a wireless network access point. For more information see for example: http://www.wi- planet.com/tutorials/article.php/1492071/80211-Beacons-Revealed.htm

Agency: a Mechanistic or a Performative concept?

The radical re-conceptualization of *agency* in philosophical discourse crystalizes in Gilles Deleuze and Felix Guattari's argument for recognition of *agency* in cellular automata and non-living units that make up our world. The fascination with cellular automata comes from their consideration of the machine as an organism. Drawing from Samuel Butler's chapter in *Erewhon*, "The Book of the Machines", they conceive a vision of the unconscious as a factory and the body as an assemblage of machines producing desire. Because we are part of the reproduction processes of all types of machines (desiring, abstract, mechanical machines, computers) there is no clear line to be drawn between humans and machines. To describe the distributed and deterritorializing (and reterritorializing) thinking that happens within and between these machines, Deleuze and Guattari put forward the concept of rhizome. Rhizome is contrasted to with the arborescent tree structure, where everything branches out from a central trunk (Deleuze & Guattari, 1987). Balanyine observed how Deleuze and Guattari connect abstract large-scale networks with the networks in the body, and between bodies, so that we start to see things like temperament and identity as emergent properties that are products of the machines immanent in the initial conditions (Ballantyne, 2007).

The cells which are "completely mechanistic, computational, and non conscious but nevertheless display complex patterns that appear to evolve, grow, invade new territories, or decay and die out." (K. N. Hayles, 2005, p. 173) are a perfect unit for a rhizomatic organisation. Hayles finds Deleuze's and Guattari's "biophilosophical" descriptions of agency insufficently constrained by an understanding of evolutionary biology and cognitive science to give a productive account of contemporary shifts in consciousness (N. K. Hayles, 2001). She argues for an articualtion of distributed cognition and agency given the fragmentation and deconstruction of subjectivity in what she perceives as the posthuman era.

In their project to challenge the Kantian view on objects as products of human cognition, object-oriented philosophers put things at the centre (Harman, 1999). Oposing causal relations typical for Newtonian paradigm, object-oriented philosophy advocates instead "to think imbroglios of difference" (Bryant, 2009). We read here again Latour's influence in the rejection of intentionality in the action of an actor, because "an actor is what is made to act by many others" (Latour, 2005). Latour's definition, thus, entails certain mechanistic determinism.

Differing from the previously stated concerns with recognition of activity and causality, the performative perspective on living and non-living entities is concerned with becoming. The ongoing critique of representations and constructivist worldview, as in the work of Karen Barad, challenges the positioning of materiality as either a given or a mere effect of human *agency* (Barad, 2003). Materiality is evaluated through experience, not mere measurement. Promising to "sharpen the theoretical tool of performativity" Barad destabilises the idea of accurate world representation in scientific knowledge and the process of its acquiring. She proposed studying phenomena as primary epistemological units constitutive of reality. Phenomena are produced "through agential intra-actions of multiple apparatuses of bodily production." These intra-actions may or may not involve humans.

Performative is opposite of representational, but it is also different from performance. Philosopher and gender theorist Judith Butler distinguished between performance, which presumes a subject or some-body performing; and *performativity* which contests the very notion of the subject – it exists in action, it is made through discourse. Butler's idea of *performativity*

was central to the feminist critique of deterministic social roles but proved inspiring for dismissal of other types of determinisms, such as the *givennes* of matter or our physical environment. Architecture scholar, Jan Smitheram writes: "performative … [in architectural discourse] is used to critically re-describe how we experience space, as being of equal importance to the end product of architecture" (Smitheram, 2011, p. 57). Making a bridge between Butler's writing on space and her interpretation in the contemporary critical architectural discourse, Smitheram proposed the concept of a composite between performance and performativity: between a constructivist subject and a performing subject. Spatial performativity, observed through the experience of the built environment is "a way to understand how power relations structure, and are embodied and performed, in relation to architecture". In the context which explores architecture as an active performative agent, Butler's notion of the inherently discursive subject (one which is disciplined through regulatory power of discourse) is often lost.

Architecturality

The term *architecturality*, instead of the adjective *architectural*, designates a property which is found in built artefacts, such as buildings and urban spaces. *Architecturality* of architectural artefacts can be understood in terms of *agency* and experience these inert entities create. "The notion of *architecturality* is significant in the question of what makes architecture architectural?", Adrian Lo, the author of the blog "*Architecturality*" states[6]. Just as the suffix -ness in Adrian Mackenzie's concept of *wirelessness* conveys the notion of a state, condition, or mode of existence (Mackenzie, 2010), Lo argues that -ity in *architecturality* re-forms it into an abstract noun which expresses a state or condition.

Architecturality has to do with organisation and structuring of both construction elements and people. It also has to do with the message built structures are trying to convey – whether it is an implicit political propaganda (people walking on top of the parliament as in Niemeyer's Brasilian Parliament, or Foster's German Reichstag dome), eclectic visual stimulation (typical of contemporary media façades) or purist and declared functionalism which is engineering lifestyles together with the rhythm of windows (as in the case of post world-war II housing projects). *Architecturality* is a way to discuss activity inherent in architectural artefacts, built structures and other organisers of space.

Architecturality of Wireless Communication

Issuing from the above, we observe wireless communication signals as *agents of connectivity*. Their appearance (propagation) is determined by algorithms which are inherent in their equipment and protocols (Mackenzie, 2010). This also means that they are in an active relationship with the rest of the environment. Through its own activity or performance, this infrastructure becomes structural. Their goal is not to simply transmit *a* message but to exist as radiation, covering as much area as possible with as much signal strength. Connectivity is inevitably linked to a spatial configuration, connecting one point with another through mathematical propagation models. A wide range of devices (base stations, access points, smartphones, laptops, Bluetooth headphones) broadcast wireless communication signals, but the ideal propagation models used in infrastructure planning and disposition can never fully account

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6 Adrian Los' blog can be consulted here: https://architecturality.wordpress.com/

for their actual propagation. Built space and people, as well as natural effects, have a significant impact on waves. On the other hand, connectivity has its own materiality, which is articulated through its continuous performance on space and people.

What all wireless communication systems work against – from radio transmission to near field communication – is distance. Thus they always act on space, allowing interaction between remote actants in real time. Wireless communication signals, together with the rest of the equipment, perform on space the way they propagate through, changing the stream of activities through (dis)connectivity. There are two types of effects we should consider here: the first is the way signal availability organises people's movement in space or their spatial preference; the other is the form of wireless signal's activity, what Mackenzie calls *conjunctive envelope* (Mackenzie, 2010).

Spatial Preference in Wireless Communication Space

When networking technology emerged as a means of personal communication, scholars believed that it was going to "liberate" people from space, or at least diminish the role of distances. Globalisation theorists such as Manuel Castells or Edward Soja argued that in compressed space distances play no role any more. The critique of such oversimplification with reference to infrastructures and their global distribution was strong in the work of their contemporaries such *Splintering Urbanism* authors Steven Graham and Simon Marvin. Nevertheless, with the expansion of wireless network technologies, the information became even more easily accessible – anywhere and at any time.

Today, we no longer need to go to a particular place to retrieve a particular piece of information (like a birth certificate from a city hall). However, we are more likely to be scrolling on a smartphone in a cafe than in front of a desktop screen at home. We are more likely to spend our time somewhere where we can make use of connectivity. That signal availability is acting on people to make them change their location has been demonstrated in numerous studies in the past ten years (Gordon & de Souza e Silva, 2011).

Research in mapping signal availability and propagation in space sprouted with the appearance of first wireless communication standards (Wi-Fi and Bluetooth). The Senseable City Lab researched the impact of WiFi on people's spatial preferences through real-time map visualisations of space/time use patterns (Sevtsuk, Huang, Calabrese, & Ratti, 2008). Pervasive urban gaming projects also studied spatial preference, showing how people are likely to adapt their paths to signal availability (e.g. take the bus instead of the metro to stay online, as in Mogi game) (Gordon & de Souza e Silva, 2011).

It is important to note, nevertheless, that we are attracted to places by a combination of social and technical connectivity, not by their mere function or a working connection. Laura Forlano's research in *Wi-Fi geographies* (Forlano, 2009) explored the material and spatial relevance of wireless networks in public space, from the perspective of the resulting lived experience. Forlano pointed to the fact that Wi-Fi does not map onto existing architectural boundaries and that people who use a network are not necessarily present within the boundaries of an entity broadcasting the network, such as Starbucks or McDonald's. She concluded that people are attracted to space by the availability of the network (Forlano, 2009).

Keith Hampton's investigations of the social life of wireless spaces (Hampton, Livio, Trachtenberg, & Mcewen, 2010) focused on interactions within the overlapping wireless and built

environments and the emergence of private spaces within public space due to connectivity. Hampton's study found that the availability of Wi-Fi was attracting people to the space of a park or a square (Hampton et al., 2010), but only in combination with the presence of other people.

What Could be the Form of Wireless Signals' *Conjunctive Envelope*?

Adrian Mackenzie's perspective on connectivity focuses on the experience of relationships. Mackenzie used William James radical empiricism[7] as an intellectual framework which he expanded to contemporary network media conditions. In *Wirelessness*, Mackenzie (2010) situated connectivity at the edges of consciousness, both ours and the infrastructure's. Being connected is site-specific – as it passes through numerous intermediaries (mouses, keyboards, local interfaces, pop-ups, passwords, AirPort lists, reception details, etc.) and more complex than information on signal availability can explain. This sense of connectivity adapts to the state of the device, lighting up when it's working and disappearing when it's not. Thus, it becomes geographically and ontologically more correct to locate these sensations in the realm of signals and devices.

How might we account for the expression of this infrastructure? Mackenzie gives us two useful tools to work with. One is the empiricist perspective on the equipment involved. The other is the notion of the *conjunctive envelope* formed out of wireless chipsets, radio frequency signals, algorithmic processes, space, time, etc. A conjunctive envelope is "a spatial-temporal fold that configures and concentrates" what Mackenzie calls "arrivals" and "departures" or what we might interpret as different interactions with the infrastructure. It is the envelope that alters sensations of location and situation. In Jamesian terms, it alters the way the world hangs together.

Wirelessness was published at the time mobile broadband standard was just introduced, thus it doesn't account for a completely pervasive spatial connectivity – Wi-Fi is static and mobile connectivity is mobile. Although *conjunctive envelope* is a very spatial concept, Mackenzie offers us only hints at the spatial experience it accommodates, staying focused on a rather general notion of experience (of humans and of devices).

Artists and designers too worked on rendering wireless connectivity visible and tangible, especially around the time when the technology was massively deployed. Intuitions about the experience of connectivity in the realm of chipsets and communication signals lead Anthony Dunne and Fiona Raby to work on, what they termed Hertzian space (Dunne, 1999), and subsequently the influential Design Noir (Dunne & Raby, 2001). Designers and artists working with digital media used the terms wirelessness and hertzian space to refer to the vague terrain of wireless communications, electromagnetic radiations and their spatial, social, cultural and political representations. Between 2006 and 2008, an artist trio (Usman Haque, Bengt Sjölén, Adam Somlai-Fischer) developed the WiFi Camera, which uses waves in a way similar to the

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7 William James was critical of the traditional epistemological dichotomies: objectivity/subjectivity, body/mind, external/internal. He put forward the concept of the "pure experience" which regarded perception as direct, coordinating coalescence of perceptional and conceptual experience. See: James, W. (1912). *Essays in Radical Empiricism*. Cambridge, Massachusetts, US: LONGMANS, GREEN, AND CO. Radical empiricism was also meant to turn the attention away from these dichotomies, while acknowledging thinking, reasoning and theorising as experience. More on James' radical empiricism in: Heft, H. (2001). *Ecological psychology in context: James Gibson, Roger Barker, and the legacy of William James's radical empiricism*. Mahwah, N.J: L. Erlbaum.

photographic camera's use of light, and reveals the invisible electromagnetic space[8]. Activity within different wireless network channels (laptops, Wi-Fi hotspots, smartphones and microwave ovens) is represented by the intensity of points in the image. Another team of designers and artists use the light painting technique applied to Wi-Fi, visualising the presence of wireless network signals in space. In 2011 Timo Arnall, Jørn Knutsen, Einar Sneve Martinussen performed walks around the Oslo School of Architecture campus and created a series of long-exposure photographs of Wi-Fi signal strength. Immaterials: Wi-Fi Light Painting created a set of 'cross sections' of network signal strength in space[9]. While their intention is primarily to show the presence of wireless communication signals in space around us, these artworks concurrently reveal the operation and seams contained in the design of wireless network communication.

There is more to this propagation than the laws of physics or economy can describe. Mackenzie defines *wirelessness* as "a sensibility", which is attuned to the wireless communication infrastructure (Mackenzie, 2010). The artworks concerned with representations of different measurable properties of this infrastructure illustrate a possible form of Mackenzie's conjunctive envelope. By taking a single parameter such as signal strength, they concentrate the perception of changes in its value around a specific aesthetic experience.

The Space of Wireless Communication

(Un)correcting the (mis)understandings

Coming back to the three contested aspects of wireless communication discussed in the beginning, I propose to address materiality of wireless communication signals in a different way: in terms of their *architecturality*, or the way they affect our experience of space.

The conflation of visibility with materiality, rooted in our expectation of sense-evidence, misses out precisely on what Langer pointed out half a century ago – scientific studies favour access to the natural as well as synthetic worlds through measuring instruments, to the direct bodily experience. Wireless communication thus demonstrates its materiality through measurement, measurability by the different pieces of communication equipment. The activity of this equipment delimits and determines a communication space which coexists and interferes with the space of the built environment. What is interesting to observe is not the fact that there is interference between these spaces but to look at them together, through the perspective of their *architecturality*.

The (mis)understandings around materiality of wireless communication signals presented in the beginning articulate some properties of these signals – the way we experience them (through measurement), the way we interact with them (seamlessly) and their ownership (scarcity). Starting from here, we can observe more precisely the experience of wireless communication space – both in terms of spatial preference determined by signal availability and in terms of *agency* exhibited by wireless communication signals and equipment, summed up as the form of the *conjunctive envelope.*

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8 For more details on the Wifi Camera project, see: http://wificamera.propositions.org.uk/

9 More information on Immaterials: Light Painting can be found at: http://www.nearfield.org/2011/02/wifi-light-painting, as well as in the article: Arnall, T., Knutsen, J., & Martinussen, E. S. (2013). Immaterials: Light painting WiFi. Significance, 10(4), 38–39.

Ethnographic studies of Forlano and Hampton demonstrate the scope of change that the presence of wireless connectivity can bring to experience of space. Beyond the correlation between people's space preference and their lived experience, there is very little to observe in terms of spatial experience of wireless connectivity. Wireless signals do not change our experience of space in a specific way like rain, walls, ceilings or music would do – they simply afford connectivity. But this affordance is significant in terms of organising the flow of information and people in space. On a purely material level, a specific articulation of information and flow performed by wireless communication networks forms a spatial layer whose *architecturality* can be measured by the extent to which it determines people's spatial preference.

The notion of conjunctive envelope is a concrete proposal for a material framework to discuss and design wireless communication signals. Conjunctive envelope is something that is not specific by its definitive form but rather by the way it changes and operates.

The multitude of perspectives I presented here might seem as an odd way to address spatial effect of wireless communucation signals. While my intention is certainly not to, in Frankfurter's terms, "bullshit" the rational engineering account of how wireless communication propagates in space, truth is not my goal either. The (mis)understandings are presented exactly with the intention to offer alternatives to common understanding and concerns. The opinions on waves immateriality were confronted with scientific and philosophical accounts of the phenomenon, with the intention to demystify and not correct these perceptions of networks effect on space. In order to understand more about the way materiality and architecturality of wireless networks relate to the production, distribution and control of information in space, we need to practice this multitude of perspectives and truths, caring for the way to make these truths relevant to each other, rather then how to exclude them.

Everything Communicates: What makes Wireless Communication Special?

Everything communicates, insists Serres. "the wind traces it musical partition over the waves of the sea and the dunes of the desert; […] Magnetism marks itself and remains etched on soft rock on its way to crystallization, indicating the time of its hardening; radio activity counts time" (Serres, 2014).

There is something special about wireless communication. It is human made and thus specific for all the engineered intentionalities involved in it. For example, Wi-Fi network technology has been mainly conceived to provide a best effort service, without any guarantees on packet delay. The unreliable behaviour of wireless network interfaces and the interferences in the radio channel are inherent to the design of wireless communication infrastructures. Still, engineering and design intentions resulting from human agency do not suffice to describe the behaviour of networks. In order to address communication signals properly, we need to be able to discuss agential spatial performance of wireless infrastructure, beyond their utilitarian performance and beyond what we recognize as human agency.

The discussion on non-human agency is more productive if we leave behind the idea that we are the only subjects in the world. "Do you really think that machines and techologes would be able to construct groups and change history if they were merely passive objects?" (Serres, 1995, p. 48) There is less need to prove and obssess with the posibility of cognition in non-living

organisms; more effort should go into changing our conception of thinking. We are not thinking alone in blank spaces using only our grey cells. In his writing, Serres offers us a productive framework: "We have always been artificial […] Certain objects in this world write and thing; we take them and make others so that they can think for us, with us, among us, and by means of which, or even with which, we think" (Serres, 1995, p. 50).

If the subject-object relationship in thinking (as in a human subject thinking about an object) is not able to explain all thinking that takes place in the universal circulation of information, we should be asking how are other things thinking. Connectivity is one of the many ways we seamlessly exchange information in space – certainly not the only one. Mackenzie (2010) describes the way in which information is managed, produced, distributed and controlled on the level of devices. Forlano (2009) and Hampton (2010) describe the way information is consumed in (public) space. *Architecturality* of wireless networks begins to describe the way wireless networks are thinking.

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