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## **Unleashing the internet: the normalisation of wireless connectivity**

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### **Abstract**

This chapter explores the processes by which infrastructures and practices change together. It asks how Wi-Fi became the most normal way to access the internet at the same time as internet use itself has become so necessary to everyday life. It presents an account which focuses on the home and charts the role of Wi-Fi in the shift from desktop PCs and emerging broadband connections to multiple, mobile, personal and always-on internet access through laptops, smartphones and tablets. This suggests that the home has been an important ‘normalisation junction’, where shifting configurations, expectations and experiences have been endemic to the making of wireless internet use, even beyond the home. Yet far from being settled, the richness by which wireless connectivity has become embedded within multiple configurations of practices, devices and infrastructures also appears as a source of flux. It is as if the obduracy, and necessity, of wireless connectivity depends just as much on ongoing adaptations as it does on arrangements that have stabilised. This ongoing making of wireless infrastructures-in-use is referred to as ‘dynamic normalisation’.

### **Introduction**

The internet is a remarkable, complex and evolving infrastructure. As a physical network, it has expanded massively to connect and conduct data between billions of computers, servers, data centres and the computational circuits embedded in a huge range of devices, appliances and environments throughout the world. The services this provides and the practices it supports are also changing and expanding in range and number. Whilst the ‘consequences’ of these developments are many, varied and debated, this chapter focuses instead on an aspect of this expanding infrastructure that is often overlooked: wireless connectivity as provided by Wi-Fi networks. Over the last 15 or so years, wireless devices like laptops, smartphones and tablets have become the most common and preferred way of accessing the internet (Ofcom, 2017) and over half of all internet traffic (52%<sup>1</sup>) is now carried via Wi-Fi (Cisco, 2017b). In combination with the connectivity provided by mobile networks, the internet – as it is experienced, used and operates today - is to a large extent wireless. The nature of

this ‘wirelessness’ (Mackenzie, 2010) and the role it plays in mediating relationships between the physical infrastructure of the internet, the services it provides and the practices it supports is fundamental to how the internet is developing over time as an infrastructure-in-use (Shove et al., 2015).

By focusing specifically on Wi-Fi and its role in an evolving internet, this chapter pursues several aims. Firstly, it asks exactly how Wi-Fi is implicated in the growth of this infrastructure. Since this also entails a growth in energy consumption (Andrae and Edler, 2015; Van Heddeghem et al., 2012), a better understanding of this process is relevant to efforts to reduce global energy demand. Secondly, the chapter aims to develop ideas about how infrastructures become ‘normal’ and ‘necessary’. Today, it is easy to take the ‘usefulness’ of the internet for granted, but the nature of internet use has changed radically over time. The processes by which new infrastructures become ‘useful’, and thereby more or less obdurate, are complex and deserve further scholarly attention. In showing how Wi-Fi has been progressively implicated in the co-evolution of broadband infrastructures, mobile computing devices and a range of practices, the chapter describes a process of dynamic and ongoing ‘normalisation’ (Hand and Shove, 2007) in which certain of these elements have, thus far, become increasingly interdependent. In particular, it proposes that as with innovation in the design of information technologies (De Wit et al., 2002), some sites are more important than others for the co-evolution of infrastructures, devices and practices. These can be thought of as ‘normalisation junctions’.

By situating Wi-Fi as an important *part* of the wireless internet-in-use, the chapter develops a distinctive account of the development and expansion of Wi-Fi that contrasts with much of the previous literature on the subject. Scholarly attention has tended to focus either on the design of wireless technologies and the process by which, as a standard, Wi-Fi emerged, was agreed and adopted (Lemstra et al., 2011; Mackenzie, 2010) or on Wi-Fi as a potential infrastructure in its own right, for example: its conformity to sequenced stages of infrastructural development (Sawhney, 2003), the successes, failures, politics and modes of development in community and municipal initiatives to provide city-wide networks (Sandvig, 2004; Mackenzie, 2005; Powell, 2008) and the spatial and socio-economic implications of public hotspot distribution (Grubestic and Murray, 2004;

Torrens, 2008). Here, my interest is not so much in Wi-Fi as a separate or alternative communications infrastructure but rather how its integration with the wider, wired internet (to produce a wireless internet) makes possible certain kinds of relationships with everyday practices, and how these change together over time.

The chapter draws on a range of secondary materials from consumer surveys and academic literature. It begins by introducing the scale and rapidity by which Wi-Fi has expanded globally. It then discusses how this process of expansion and normalisation might be understood, which leads on to an account of the shifting assemblies that have come together in UK households as Wi-Fi has come into use. This shows that the home is a key site at which configurations, expectations and experiences of wireless connectivity are established. The chapter concludes with reflections on what this case contributes to understanding the processes by which infrastructures and practices change together.

### **The growth of Wi-Fi**

Wi-Fi is a registered trademark that represents a certified protocol for interoperable wireless communication technologies to join or provide a local area network over short distances (tens of meters). This family of international standards (technically known as 802.11) is agreed by the Institute of Electrical and Electronics Engineers (IEEE) and continues to evolve to provide higher speed connectivity. These standards are widely integrated into mobile and digital devices as well as access points that connect, via routers, to the internet. As measured by the numbers of each the trend is clear: Wi-Fi has expanded significantly and rapidly since its first incorporation in a mass market product (the Apple AirPort system) in 1999. By 2017, the Wi-Fi Alliance had certified over 35,000 compatible kinds of products (Wi-Fi Alliance, 2017). In the same year, the estimated number of ‘hotspots’ worldwide reached 262.3 million, up from 26.5 million in 2013 (iPass, 2017).

More broadly, the internet was used by 48% of the global population in 2017, with 84% of households in developed countries having access at home (ITU, 2017). In the UK, almost all of the 82% of households with a fixed internet connection also have Wi-Fi (Ofcom, 2015b; 2017). And whilst Wi-Fi is not the only way to access the internet and the services it provides, it does carry the largest portion of internet traffic in the UK: in 2016 57.6% of traffic travelled over Wi-Fi networks

compared to 40% for fixed connections and 3.5% for mobile networks (Cisco, 2017a). Not surprisingly, then, to many people Wi-Fi is an inextricable part of what internet access means. This is playfully illustrated by an image that circulated on social media in 2012 depicting ‘Wi-Fi’ crayoned in at the base of Maslow’s hierarchy of needs (Weknowmemes, 2013).

As an example of technological innovation and diffusion, Wi-Fi is considered to be a global ‘success’ (Lemstra, Hayes and Groenewegen, 2011). Yet narratives of diffusion and of the construction of large technical systems, such as Hughes’ (1983) account of electricity networks, often make assumptions about demand, either concluding that it follows unproblematically from the provision of technologies or infrastructures or that it was already latent and unmet (Shove, 2016). But it is evident that the attractions and expectations associated with using the internet today, wirelessly or otherwise, were not the same in 1999 when the Wi-Fi standard was first included in a mass market product. So how can accounts of infrastructural change be more sensitive to the multiple ways in which infrastructures are used and ‘demanded’ at different times and in different locations? How do new infrastructures, and aspects of them, come to be so widely used and essential, in ways that are almost unimaginable when they first emerge? In other words, what are the processes of ‘normalisation’ by which new ‘uses’ and ‘needs’ for infrastructures arise and become established?

### **Normalisation junctions**

These questions can be approached by thinking about how infrastructures feature within and relate to past, current and planned sets of practices (Shove et al., 2015; Shove, 2016). Within consumption studies, theories of practice have been influential in emphasising and conceptualising the ordinary and ongoing use of goods and services (Warde, 2005; Warde, 2015). For instance, Røpke and Christensen (2012; 2013) note how extensively internet-connected technologies have been integrated into diverse everyday practices. It is this position, of being part of practices, that defines how technologies are used and the extent to which they are felt to be necessary. Wants and needs do not emerge from individual desires, but ‘emanate’ from practices: ‘the practice is the conduit and *raison d’être* for the gratifications which arise from its component moments of consumption’ (Warde, 2005: 142).

Therefore, as Hand and Shove (2007) argue in the case of freezers, the status of being ordinary and

necessary is not an inherent or singular characteristic of the object itself but of the pivotal roles it occupies in what people do: not just single practices but in inter-connecting systems of practices; and not just in a single, universal way but as ‘simultaneously embedded in strikingly different configurations of “ordinary” practice’ (2007: 95). In other words, products become necessary over time by co-constituting the practices in which they are used, and how these hang together with other practices in ways that only such products can allow (Shove and Southerton, 2000).

Importantly, this outcome of being normal and necessary is not fixed or final, even for technologically stable products, like freezers, that are widely owned and have been in use for many years. Whilst the normalisation of new technologies may be understood as processes of diffusion or domestication which ultimately draw to a close, Hand and Shove (2007: 79) argue that normalisation is best thought of as an ‘ongoing achievement’. They suggest there is a ‘persistent instability’ in the positioning and status of freezers precisely because they are ‘multiply anchored within diverse and themselves dynamic systems’ and in simultaneously multiple ways (Hand and Shove, 2007: 99, 95). As these practices and their inter-relations are reproduced, so too is the normal and necessary status of the objects on which they depend.

If infrastructures are similarly conceptualised through their relationships to practices (Shove et al., 2015; Shove, 2016), we can expect that the roles, functions and meanings of ‘infrastructures-in-use’ are also dynamic and heterogeneous, even as their material basis stays fixed and obdurate (and plausibly vice versa). But the relationships between practices and infrastructures are more complex than those with single products. As Shove (2016) suggests, infrastructures are conjoined, directly and indirectly, with multiple practices that are often co-dependent on other infrastructures, and in multiply articulated webs of relationships, such that changes can take place simultaneously at different rates and in different directions. Infrastructures are also spatially extended, and studies often emphasise dynamics that emerge through the challenges of geographical expansion (De Wit et al., 2002). This is not necessarily a helpful approach for Wi-Fi, whose geographical expansion is a case of ‘second-order’ bolting on to wired networks and building into billions of access devices. Nor is it necessarily a helpful approach for analysing the ongoing development of infrastructures-in-use, since use occurs in specific places, as part of specific practices.

An alternative approach to studying the ongoing normalisation of infrastructures-in-use is to focus on particular locations. Drawing on Cowan (1987/2012) who described the household as ‘the consumption junction’ at which consumers decide between competing technologies and thereby significantly shape their diffusion, De Wit et al. (2002) propose the concept of ‘innovation junctions’. These are sites at which multiple technologies co-exist and are used, resulting in ‘interactions and exchanges [that] lead to location-specific innovation patterns’ in the design of technologies (De Wit et al., 2002: 51). Similarly, I suggest that investigating the interactions and connections that form between various devices, infrastructures and practices – at what might be called ‘normalisation junctions’ – enables us to analyse the processes by which infrastructures become necessary and normal. After all, relationships between infrastructures and practices are mediated by appliances or other interfaces (Shove, 2016), and this is likely to be concentrated at particular locations.

Thus, to analyse Wi-Fi as part of an evolving wireless internet-in-use, it makes sense to start by asking: where and how is Wi-Fi used? As the rest of the chapter shows, the home is an important ‘normalisation junction’ for the wireless internet: a key site in the process by which wireless connectivity has become the most normal way to access the internet *and* at which internet use itself has become so necessary to everyday life.

### **Wi-Fi at home: Shifting wireless internet assemblies in UK households**

Even though it has not received much attention in previous research into Wi-Fi development, the home is an exceptionally important site both for the initial uptake of Wi-Fi and for its ongoing use. For a start, most Wi-Fi hotspots are domestic: of an estimated 262.3 million worldwide hotspots in 2017, 242 million are located in homes (iPass, 2017). The following discussion focuses on UK homes, reflecting the availability of a series of annual surveys conducted by the national telecommunications regulator, Ofcom, which show high levels of home Wi-Fi ownership. By 2015, the last year that Ofcom separately reported on the uptake of Wi-Fi routers, this applied to the majority of UK households (75%), encompassing almost all households with fixed broadband internet access (78%) (Ofcom, 2015b). In 2014, the survey also asked about the use of Wi-Fi inside and outside the home: more respondents reported using Wi-Fi at home (79%) than anywhere else, such as when abroad

(28%), at a place or work or study (15%), while travelling (14%) or in a public place (11%) (Ofcom, 2014). This section explores the shifting assemblies of devices, infrastructures, services and practices that have formed, with and through Wi-Fi, at this most significant site of use.

### *The wireless laptop*

The early commercial development of wireless local area networks (WLANS) in the 1980s was not focused on the home. Instead, one of the leading ‘application(s) in which customer demand was recognised’ was in wirelessly connecting cash registers in large American department stores (Lemstra et al., 2011: 41): as these systems were computerised, stores faced costly rewiring whenever sales floors were reconfigured. Other notable deployments took place in universities (e.g. Carnegie Mellon’s Wireless Andrew initiative). Yet by the time the first standard for WLANs was adopted as IEEE 802.11 (a and b) in 1999, later to become known as Wi-Fi, interest in domestic applications had grown as home computing took off in the 1990s. In fact, in 1997 a group of major companies including Intel, Microsoft, HP and IBM started work on a competing standard called HomeRF, which for various reasons was not ultimately adopted. Nevertheless, the very first application of the IEEE 802.11 standard brought the technology directly into homes: this was the launch of the Apple iBook laptop in 1999 (Lemstra et al., 2011).

The iBook was the first Apple laptop aimed at domestic and educational markets and included the 802.11 standard, under the branded name of AirPort, as an optional extra consisting of a plug-in card and an access point for the home. Over the next few years most laptop manufacturers rapidly followed suit and made their new products compatible with the Wi-Fi standard, embedding it into hardware, processing chips and software. Sales of laptops grew steadily through the following decade: from an estimated 1.5 million units in UK households in 2000 to 17.3 million in 2010 (BEIS, 2017). But unlike the name suggests, this ‘diffusion’ was not physical process of dispersion: what lies behind such figures is the fact that laptops were becoming useful. But how, and did standardised wireless connectivity play a role?

Wireless connectivity was certainly integral to Apple’s vision for their portable home computers and it was also central to how the company presented and marketed the iBook: positioning

it as both technologically cutting-edge and as a useful addition to the home. This was in two ways: firstly, this wireless laptop was said to offer a new kind of freedom from ‘doggone wires’ and the ‘liberating experience to surf the internet from your iBook while freely moving about your home or classroom – without any power or networking cables to tie you down’ (Steve Jobs, quoted at the 1999 MacWorld launch (Thinkingbricks, 2009) and in a press release (Apple, 1999)). Secondly, ‘AirPort lets everyone surf at the same time’ (Apple, 2001): a claim illustrated by a schematic image of a home with an iBook and two other Apple desktop computers, each in different rooms, each wirelessly connected to the AirPort. In this way, wireless connectivity helped establish the iBook as an *addition* to the desktop PCs that target customers may already have had. From this it is evident how Wi-Fi facilitates the presence of multiple connected computers in the home and supports the concept of *personal* devices that can be used in variously private spaces including bedrooms.

Empirical research has demonstrated just how important wirelessness is to the ‘place’ that laptops have ‘found’ within homes: not just in terms of where they are used, but also what they are used for. Based on qualitative interviews with new laptop owners in 2009, Spinney et al. (2012) argue that laptops are woven into home life, both aesthetically and in terms of the temporal and spatial organisation of domestic activities in a way that desktop PCs are not. Without unsightly wires and with physical dimensions that fit to the body reclined on a sofa, laptops have made themselves at home in the living room. This allows couples to spend more time together in the same room whilst engaging in different activities (some online, some not). Just as important, the mobility of the laptop means that conflicting activities can be disentangled and taken to different rooms (such as teenagers playing games when particular TV programmes are on). In other words, wireless connectivity is essential to the way that laptops have come into use as additional to and different from desktop computers that may already have been in use. At first, some PCs may have continued to be used alongside laptops but in more specialist roles (Røpke et al., 2010); over time, however, ownership of desktop computers has declined as that of laptops has increased (see Figure 8.1).

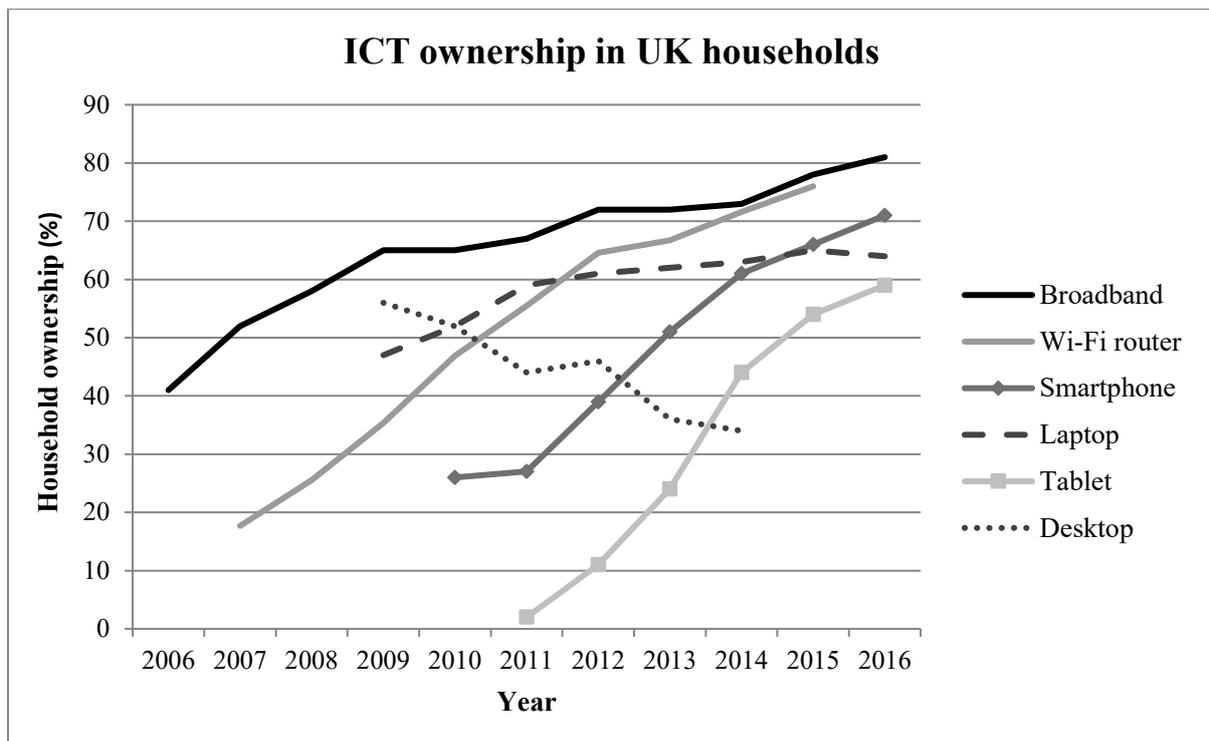


Figure 8.1: Household ownership of internet-related technologies in UK households. Source: derived from Ofcom (2015b, 2017). Note: data from all years is not available.

The ‘wireless-laptop assemblage’ (Spinney et al., 2012: 2360) that is stitched together within homes, does not simply reflect the coupling of wireless connectivity to a particular kind of computer, nor of how that combination then fits within domestic routines and spaces, but also speaks to the use (or not) of other devices, like the non-wireless PC. Moreover, concepts like assemblage, ensemble or (my preference here) assembly are important in emphasising the mutual constitution of collectivities of infrastructures, devices, practices and places through which discrete objects like laptops or routers are used and ‘together constitute the collective conventions of everyday life’ (Shove, 2003: 60). Yet within this wireless internet assembly, the roles of laptops or routers are far from fixed: they may characterise one configuration but the advent of other wireless devices, such as smartphones and tablets bring re-configurations. I consider this in a moment. But first, there is another significant and prior part of this wireless internet assembly worth highlighting: broadband.

### *The broadband connection*

Broadband refers to a type of communication protocol that allows for an always-on connection to the internet in which telephone calls and internet traffic can simultaneously co-exist on the same, existing telephone line. Yet in the early 2000s, at the time when Wi-Fi was becoming increasingly standard in laptop design, not many UK households had broadband access (only a quarter did in 2004 (Ofcom, 2005)). Ownership increased throughout the following decade, preceding Wi-Fi take-up, which did not catch up until around 2014 (see Fig 8.1). In other words, broadband ownership appears to have preconditioned wider Wi-Fi ownership, and this makes sense: it is possible but not very practical to use Wi-Fi with a dial-up connection. Moreover, Wi-Fi helps to realise the benefits of broadband - without the need for extra wires throughout the house. Perhaps reflecting this symbiosis, Wi-Fi routers were increasingly included as part of broadband marketing. For instance, BT, the primary incumbent telecommunications company in the UK, first included their Home Hub router in a broadband package in 2004. By 2011, Ofcom commented that such packages had become the norm (Ofcom, 2011). Thus, just as Wi-Fi was integrated into laptop design, so too was it integrated into the provision of broadband.

These two key aspects of Wi-Fi connectivity, as embedded into laptops and broadband provision, were distributed and arrived in homes by very different channels and at somewhat different times; yet they were nevertheless assembled at this 'junction' as laptops were used wirelessly via routers connected to broadband networks. Importantly, it seems that the relationships between these parts are mutually reinforcing: the take-up of laptops benefited from, but also reinforced and perhaps further facilitated the earlier up-take of broadband.

However, that earlier up-take of broadband was itself closely connected with desktop PCs, and not laptops. Numbers of desktop PCs actually increased until 2007, and would not be matched by laptop ownership rates until around 2010 (Fig. 8.1). In other words, at least one of the key parts of the wireless-laptop assembly first came into use in quite a different assembly: one of 'fixed point internet access'. Similarly, even though laptops first helped to establish wireless means of using internet services, they are no longer the sole, or even primary, device for this: smartphones and tablets are increasingly important.

### *Smartphones and tablets*

Smartphones began to be marketed from around 2005 onward, and the Nokia 6136, launched in 2006, was the first with Wi-Fi (Ofcom, 2006). Prior to this, it was too energy-intensive for mobile phone batteries to sustain a Wi-Fi connection (The Economist, 2004). The first iPhone, one of the most popular smartphones, was released in 2007, and the first successful tablet, the iPad, in 2011. Uptake of both smartphones and tablets has been rapid in the UK, and to some extent seems to be predicated upon, and facilitated by, the availability of home Wi-Fi networks. Almost half of households had Wi-Fi routers in 2010 (Fig. 8.1); meaning that for many a key infrastructural requirement for these newer generations of wireless device was already in place.

Over the last 10 years, smartphones have become the most widely owned internet-connected device: in 2017 76% of UK adults owned one and 42% of internet users felt they were the most important device for accessing the internet; greater than for laptops (26%), tablets (16%) or desktops (11%) (Ofcom, 2017). Indeed, of the average 83 hours per month per person ‘spent online’, 89% is spent on a smartphone (as measured in March 2017; Ofcom, 2017). Moreover, a survey in 2015 suggests that much of this occurs at home: only 9% of those who use internet services on a smartphone reported doing so *only or mainly away* from home (9%), with others reporting an equal share of internet use on their smartphones at home and elsewhere (63%), or mainly or always at home (27%) (Ofcom, 2015b). Thus, despite the fact that many people will not leave the house without their smartphones, the home is still a major site where they are used as part of a wireless internet assembly.

Much of the internet access that occurs over smartphones and tablets is via Wi-Fi. This is clearest for tablets, which are often not fitted with the data-SIM cards needed to access mobile phone networks (Lord et al., 2015). But even for people with fast mobile network connectivity (4G) from their smartphones, monitoring surveys suggest that the majority of internet access (69% of connections) occurs via Wi-Fi rather than mobile networks (Ofcom, 2017). This is likely to be because mobile phone data contracts are often capped, whilst those for fixed broadband-Wi-Fi connections are usually ‘unlimited’. In addition, the actual speeds experienced are higher over Wi-Fi networks than 4G (Ofcom, 2017).

In sum, the home is a key site where newer generations of wireless (and largely Wi-Fi) devices have come into use, further underpinning the ‘need’ for broadband Wi-Fi provision. It is at this ‘junction’ of broadband, Wi-Fi routers and multiple devices where reliable, quick and cheap access to a wide range of internet services is experienced, and is being integrated into an increasing range of practices. Since the changing wireless internet assembly is knitted together actively and on an ongoing basis *through* practices, it is important to now turn and consider them more directly.

### *Services and practices*

In describing the sequential layering of parts in this shifting wireless internet assembly, it is easy to take the use of the internet itself for granted. Yet this is something that has also changed over time alongside the increasingly wireless and multiple ways of accessing internet services. Indeed, the attractions of wireless connectivity and the practices that constitute wireless internet assemblies in the home cannot be the same in 2017 as in 2001, when Apple marketed their wireless AirPort system with the strapline ‘put a 10,000-volume library on your bedside table with a wireless iBook’ (Apple, 2001). Now that the web is populated by YouTube, Facebook, Snapchat, video streaming services, shopping websites and so on, the wireless ability to read digitised books in bed is perhaps not the first attraction we would think of today.

Surveys suggest that levels of participation in internet-related practices and the time spent doing them have increased significantly over the last 15 years (Ofcom, 2015a; 2017). Whilst general browsing and emailing have always been the most common activities, the internet has become a more plural ‘place’ for entertainment, shopping, social networking, video-calling, banking, paying bills and much more (Ofcom, 2017). The diversity of these activities suggests that the internet is embedded in very many different configurations of practice. It is therefore challenging to explore how practices have co-evolved along with the wireless internet assembly. Undoubtedly, Wi-Fi has been instrumental in facilitating multi-computer households where most, if not all, members access internet services throughout the house on their ‘own’ devices. In principle, this facilitates greater participation in internet-based practices, both broadening and deepening their role in everyday life. But in more specific terms how has this happened? How has the wirelessness of internet access at home helped to

the shape the very practices for which it has become a necessary part, and vice versa? I do not have the space here to offer a full answer. But we can usefully begin to consider this question by examining the role of wireless connectivity in specific internet services.

YouTube is a platform that hosts millions of videos, and is one of the most visited sites on the web (about 42 million people in the UK visited YouTube in March 2017 (Ofcom, 2017)). It is most commonly accessed on laptops or PCs (by 71% of respondents) but smartphones are also frequently used (52%); and in this case ‘people typically wait until they are connected to the internet via Wi-Fi’ (Ofcom, 2017: 132). A monitoring app installed on over 4,000 android smartphones found that compared to wireless connectivity over mobile phone networks, 76% of YouTube sessions took place over a Wi-Fi connection, taking longer than those carried out over 4G and 3G connections, and using even more data (83% of the total data by that app) (Ofcom, 2017). In other words, Wi-Fi connectivity, in contrast to other forms of wireless connection, is especially important for one of the most popular of all internet services. The popularity of YouTube itself no doubt reflects the diversity of practices in which it is used: from streaming music to accompany work or leisure activities, to watching TV programmes and funny videos, to instructional and information videos relating to a huge range of other practices, like learning a musical instrument or fixing a vacuum cleaner. Speculatively, the wirelessly-enabled ability to watch such videos anywhere in the house, and even in the garage or garden, may also be part of why YouTube is so widely used.

Video calls provide another example of a predominantly Wi-Fi-dependent internet service. Voice and video calls are offered by a range of Voice over IP (VoIP) platforms (such as Skype and Facebook) and are usually free to use. Though not as widely accessed as YouTube, VoIP services are still well used (by 44% of internet users in the UK in 2017 (Ofcom, 2017)). Surveys from 2015 suggest that smartphones were the most frequently used device for accessing VoIP services (61% of respondents), with declining use of laptops (42%) and desktop computers (24%), and growing use of tablets (39%) (Ofcom, 2015b). Across all devices, most VoIP calls in 2015 seem to have been made over Wi-Fi networks at home (mentioned by 75% of those who use a laptop, 73% with a tablet, and 46% with a smartphone) (Ofcom, 2015b).

This example shows how in the case of communication-related practices, specific combinations of infrastructures, devices, and services are more or less common at any one time. Making ‘a call’ used to be the sole domain of telephones (fixed line or mobile), and making a video call used to be something that required a desktop PC or laptop. As the practice of ‘calling’ evolves in the context of wireless internet connectivity, possibly also facilitating this development, so too does wirelessness become increasingly necessary in order to engage in this relatively common and valued form of practice. And whilst people may have become accustomed to activities like video-calling, watching videos, emailing, browsing the web and using social media primarily at home these practices and the expectations they carry are not limited to the home. For instance, in a campaign for free Wi-Fi to be provided in UK hospitals, it was argued that ‘in the modern world, where we are used to communicating all the time, not being connected makes you feel incredibly cut off from the real world’ (John Popham, quote in Scott, 2013).

#### *Wireless assemblies: Moving ‘out of home’*

Whilst most people in the UK still use the internet at home more than anywhere else, an increasing proportion is also using internet services when away from home; this has been attributed to ‘increased smartphone take-up and the increased availability of Wi-Fi’ (Ofcom, 2015b: 308). Indeed, Wi-Fi networks are now provided in diverse ‘public’ locations including hotels, cafes, restaurants, shops, workplaces, buses, airplanes, trains, on city streets and, of course, hospitals. In 2015, the NHS adopted a target to provide free Wi-Fi in all its buildings by 2020 (The Guardian, 2015). The traffic carried by ‘public’ networks is also growing (from 45 GB on average for each of 33,851 hotspots in 2013 to 73 GB across each of 44,804 hotspots in 2015 (Ofcom, 2015c)): so it seems they are being used, perhaps for very similar practices that take place at home.

The volume of traffic carried over mobile phone networks is also growing, and more rapidly than Wi-Fi traffic (Cisco, 2017b). With the take-up of 4G, higher-speed mobile connectivity can increasingly play a similar role to Wi-Fi in wireless internet assemblies. Yet rather than competing, these alternative forms of wireless connectivity appear to facilitate each other. Wi-Fi at home has helped to promote increasingly widespread forms of communication, entertainment and other

activities that now ‘depend’ on wireless connectivity, however that is achieved. In many ways, this has helped to make faster (4G) mobile networks more useful. Thus the home appears to be an important ‘normalisation junction’ not just for Wi-Fi but for wireless connectivity more generally.

At the same time, the capacity of mobile networks remains limited; and mobile services are increasingly being designed to work alongside Wi-Fi networks to ‘off-load’ traffic on to them wherever they can. The same is true for many smartphone and tablet apps, which are now designed to switch to Wi-Fi wherever available, or otherwise tailor their operations. For instance, Snapchat is an incredibly popular app for sharing images and videos but it was also notorious for eating up mobile network data allowances; so a data-saving mode was introduced for non-Wi-Fi connections (Plummer, 2015). In sum, default Wi-Fi connectivity is being designed into smartphone apps and operating systems to provide higher quality services and a more seamless transition between Wi-Fi and mobile networks.

## **Conclusion**

There can be little doubt that wireless connectivity, in the form of Wi-Fi, has been important to the development of the internet as an infrastructure-in-use. It has shaped commonly-used devices and services and thereby the very ‘usefulness’ of the internet itself. The chapter also shows how Wi-Fi plays a key role in the expansion of the internet: in the numbers of connections, the volume of traffic, the time spent online and the range of practices that have come to depend on it. Whilst the vision of a multi-computer household has already been realised through laptops, smartphones and tablets, Wi-Fi is increasingly being built into other kinds of everyday devices and appliances, from e-readers, TVs and games consoles to thermostats, cars and kettles. Thus, thanks to Wi-Fi, the number of internet-connected devices continues to grow, from an average of 5.7 devices per capita in the UK in 2016, to a forecast figure of 9.4 by 2021 (Cisco, 2017a). This further entrenches the need for Wi-Fi. Moreover, this ongoing extension of wireless internet assemblies arguably represents ‘a transition in the wrong direction’ as far as energy demand is concerned (Røpke and Christensen, 2013). Understanding, and perhaps seeking to shape, the ongoing normalisation of Wi-Fi is thereby relevant to efforts to manage and reduce energy demand.

In following co-evolving assemblies of wired infrastructures, wireless technologies, computing devices, internet services and practices, this chapter provides some insight into processes of sequential, path-dependent layering associated with rapidly changing and yet increasingly normal and taken-for-granted arrangements. In facilitating the uptake of laptops, smartphones and tablets, in shaping the design and use of internet services like YouTube, Skype and Snapchat, and in prefiguring faster mobile phone connectivity, Wi-Fi has become twisted into these arrangements. Thus, the assemblies that Wi-Fi makes possible simultaneously hold it in place as an ordinary and necessary infrastructure for everyday life. Yet, it is not just Wi-Fi that has become more embedded amongst other technologies, systems and practices but also, seemingly, the whole assembly of wireless internet use which is becoming (more thoroughly) embedded at sites like homes, hospitals and public transport.

Across the board, a sense of the institutional obduracy of Wi-Fi, and more generally of wireless connectivity, is emerging based on a gradual building up of heterogeneous 'layers' that assume wireless connections: in the design of devices, apps, even homes and the configurations of practice. Opportunities for physical internet connections are increasingly absent, favouring a wirelessness that stands in contrast to the assumed material obduracy of large networked infrastructures, but that may be just as enduring. To many, the multiple embeddedness of wirelessness goes a long way to explain its apparent obduracy and irreversibility (see Hommels, 2005). But in building on Hand and Shove (2007), it can also be argued that the richness of embedding within multiple configurations of practices is a source of flux, as well as obduracy. For instance, the embedding of wireless-laptop assemblies eventually marginalised the role of desktop computers, and helped to facilitate that of smartphones and tablets, which in turn lead to changes in the roles of laptops. Importantly, these changes have sustained wireless connectivity. So whilst this chapter presents evidence of 'co-existing forms of adaptation and obduracy' as might be expected when studying infrastructures-in-use (Shove, 2016: 4) it also suggests that these are not necessarily opposing: that is, the obduracy of particular arrangements may depend on ongoing adaptations.

I refer to this process as dynamic normalisation. Whilst this includes technological and design adaptations, such as the launch of smartphones and the progressive development of Wi-Fi standards, it

is not a process of innovation or diffusion that concerns just one product. Instead, dynamic normalisation refers to technologies-in-use: a conceptualisation which positions technologies within the wider assemblies in which they are used. A core assumption of this chapter has been that such assemblies are rooted in practices. Yet, in giving an historical account of shifting wireless internet assemblies, it has been difficult to single out particular practices, and easier to focus on proxy changes in device, router and broadband ownership, and the use and design of particular internet services. Other kinds of adaptations, including within particular practices, are surely possible, and likely to be more evident to research methods that are less heavily dependent on secondary material.

Nevertheless, the strategy of studying the interactions and relationships between infrastructures, devices, services and practices at a specific site, or ‘normalisation junction’, has proved useful. The chapter shows how the distinctive intermingling that takes place in homes has been endemic to the making of wireless internet use, even beyond the home; and this looks set to continue. Thus, when studying other infrastructures-in-use, methods that investigate site-specific relationships, be it in the home or elsewhere, may be equally valuable.

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## Notes

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<sup>1</sup> This figure excludes IP traffic on managed networks (such as cable TV networks).