Demanding connectivity: The co-production of mobile communication through electrical and digital infrastructures

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Abstract:

Smartphones, tablets, and laptops connect users to the digital services of the Internet (email, social and locative media, etc.) while on the move: the operation of these networked devices harness always-on wireless, digital connectivity and are powered by batteries in need of regular charging. This digital overlay to everyday life cannot be separated from its underlying energy demands. Supporting ubiquitous digital communication is both the infrastructure of wireless connectivity but also the wired, global telecommunications systems of the Internet itself. These systems require not-insignificant amounts of electricity. Conceptualizing the energy demand of mobile communication begins by considering the interweaving of infrastructures with expectations of constant service pulsing through social practices of connectivity and charging. While the energy consumption of each device is low, the sheer number of devices in use aggregates higher, and ties into the energy consumption of digital systems themselves. Emerging social practices of charging smartphones in transit offer an entry-point to theorizing the energy needs surrounding information and communication technologies beyond home and workspaces, in public and in motion. The widespread adoption and constant use of smartphones signal the end-point of electricity consumption patterns as well as digital services stretching globally yet relying on locally-generated, co-produced electricity and digital infrastructures at the same time. Nested case studies of charging practices in train stations in the Northeast United States, on trains passing through these stations, and finally an examination of the electricity use of a prominent Philadelphia data center provide an overview of how the powering of smartphone batteries and the Internet represent conjoined infrastructures and, as such, frameworks for new practices to develop that create qualitatively new forms of energy demand.

Introduction: Charging smartphone batteries, powering the Internet

From cell phones to stem cells, stuff of all kinds increasingly makes us what we are.
-Braun and Whatmore (2010, x)

For many if not most people, the experience of travel goes metaphorically and literally hand-in-hand with a constant connection to a smartphone or other mobile computing device.

Social media, the Internet, locative media and mapping applications are all accessed through these pocketable computers. All these uses demand energy, in the form of electricity, and not solely through maintaining a charge of the device's battery. Every stage of communication from connection to transmission, to storage and maintenance of digital information requires electricity. As use of smartphones becomes prevalent throughout the day and across multiple practices, from home to work and in transit between, the need to maintain connection to the pervasive, wireless Internet, and to maintain a device's charge away from the readily accessed electricity at the home and at work means multiple conjoined infrastructures, social practices, and business opportunities are arising around patterns of mobility, smartphone use, and energy provision.

By number, mobile phone subscriptions are nearly equivalent to worldwide population; each device consequently requiring regular inputs of electrical energy (ITU 2014, cited in Horta et al. 2016, 15). 68% of adults in the United States have an Internet-enabled smartphones and 45% have a portable tablet computer such as an Apple iPad (Pew Research Center 2015). All these devices function through battery power; all these devices therefore must be charged regularly to remain useful. While the focus of these devices is on their wireless, connective abilities, this disposition functions through electricity.

The goal of this essay is to conceptualize the co-production of wireless digital connectivity, also commonly termed mobile communication, as a medium of social exchange predicated through telecommunication infrastructures and and the energy systems underlying both the telecommunications infrastructures and personal charging provision. Building off of Jasanoff's scholarship on co-production as "the constant intertwining of the cognitive, the material, the social and the normative" (Jasanoff 2004, 6; Jasanoff 2005), considering mobile digital connectivity as an emergent social practice necessitates also conceptualizing the energy demand of smartphones, the energy systems that power the devices, and the energy consumption of data centers holding the informational back-end enabling digital connectivity. Behind the expectation of connectivity lies multiple energy demands. The co-production of social things (communication, connectivity, and mobility) is constituted through layered infrastructures (transportation, telecommunication, and energy). Untangling energy demand thus entails both conceptualizing social practice around charging in public as well as the electrical demand of digital infrastructure itself. This essay is not intended to provide a comprehensive overview quantifying the energy demand of these intertwined systems in any one location; the essay's objective instead is to make visible emergent practices and infrastructures surrounding charging in motion.

Background: The conjoined energy infrastructures of mobile, digital connectivity

Pervasive, wireless digital connectivity is constituted through telecommunications and energy infrastructures, what Shove et al. call "material arrangements"; infrastructures that "reflect and shape multiple social practices […] and are, in turn, shaped by past and present forms of planning and design" (2015, 1). In this approach, energy "is best understood as part of the ongoing reproduction and transformation of society", underlying the sites of social practice and "realized through artefacts and infrastructures that constitute and that are in turn woven into bundles and complexes of social practice" (Shove and Walker 2014). Digital, mobile connectivity as a social practice is constantly produced through its underlying demands for device's electrical energy as well as the electricity and information-communication technology (ICT) infrastructures that provide the connection.

Briefly, to produce constant wireless connectivity requires the ongoing broadcast of blanketing electromagnetic waves through wireless fidelity (wifi) routers that can cover a small area such as a home, office or cafe, with fast upload and download speeds, and cellular antennas that, mounted on tall structures or atop tall buildings offer more distributed connection but without the upload-download speeds of wifi (Barratt and Whitelaw 2011). To maintain their functionality, smartphones typically rely on both systems, always connected to cellular networks (assuming there is a signal) and automatically switching to wifi when available, such as at home or work. This always-on pattern is required for a phone call or a text message to go through, but producing this ethereal connectivity effectively requires transforming the atmosphere into a send and receive, broadcasting telecommunications medium through electricity. This is not new: radio has done the same for over 100 years (Mitchell 2003), but the sheer number of individual devices tethered into the system, the constant back and forth between user and network, and the standby nature of devices always broadcasting demand not insignificant amounts of energy. Additionally, the mobile aspect of this ubiquitous connection necessitates each and every mobile device to be battery-powered. In turn, those batteries must be charged regularly.

Transmitted through a wifi router or cellular antenna site, the bits and bytes of information, for instance a request to load a website, typically travel through a local then regional fiber-optic backbone that is most often routed under or alongside major transportation corridors, especially in the US along railroad right of ways, arriving at a colocation node where a variety of mobile and terrestrial telecommunication providers transfer that information between their different networks and send it through the Internet backbone the specific data center that holds the website (Wiig 2013). While the particular location of a data center does not matter to the user, only that the digitized information on their smartphone, there are specific, infrastructural places that hold the Internet, a point that will be returned to below. Returning the information to the user entails a reversal of the process. The energy demands of mobile devices and data are dynamic and anchored in expectations for constant connectivity (Bates et al. 2014; Spinney et al. 2012) that in turn both necessitate regular charging of devices and also tie into the above-mentioned cellular and wifi networks as well as the charging needs of individual devices, but also into the storage and transmission of data between a user's smartphone and the data center holding the information.

The connective, information-retrieval, social networking, and entertainment functionality of smartphones presents multimodal opportunities to spend time on these devices, and "patterns of use depends significantly on both location and social context" (Do et al. 2011, 2). Do et al. observe that mobile devices like smartphones are used most at places other than home or work (where other computers were likely to be available), reflecting that "The use of [the mobile Internet] is highest at transportation-related places such as bus stop or train station. In such contexts, the Internet is likely to be used for reading news, looking for information or killing time" (2011, 5). The study purposefully did not track use of smartphones while in motion, nor did it measure when and where users charged their devices, but regardless the study identifies that using smartphones in transit complements use at home and at work, whether on a smartphone or another computing device like a laptop (Spinney et al. 2012). Other research on "human-battery interaction" builds off human-computer interaction research on digital interfaces, identifying two types of smartphone chargers: proactive users who habitually charge regardless of battery level and reactive users who charge depending on battery level (Rahmati and Zhong's 2008). Users' expectation was that a fully charged battery should last one day of smartphone use, leading to routines of charging overnight to have a full battery in the morning (Ferreira et al. 2015, 386). Most participants in Ferreira et. al's study (2015) carried a charger cable and plug with them everyday, and some augmented this by carrying an external battery pack. Considering charging as a social practice (Horta et al. 2016) locates this mundane but necessary activity within the embedded habits and expectations that the smartphone *and* the wireless connective ICT network are always-on, at the ready to as needed, and consequently, constantly demanding energy.

These above-mentioned studies indicate what can be qualitatively seen and experienced: that the majority of the population of a city like Boston use smartphones a lot, especially while between other places. The more a smartphone is used, the more likely its battery will need to be charged before reaching home or work, leading to emergent practices around charging in public, either surreptitiously at a power outlet intended for another use, or at approved charging stations located in areas of high traffic such as train stations. These charging practices often extend onto long-distance trains and onto some commuter trains, where providing electricity for laptop computers has become an amenity to attract and maintain ridership (Amtrak 2013a). This essay unfolds as a travel narrative built out of fieldwork between 2013 and 2016, synthesizing numerous trips into one journey. The goal with this approach is to assemble the multiple, layered relationships between transport infrastructure, telecommunications and mobile connectivity infrastructure, and energy infrastructure, as well as the social practices around using and charging digital computing devices while in transit, in motion and in stations.

Expectations of constant connectivity and public charging: An Amtrak rail journey

After traveling from my home via a regional commuter train, I arrive at Boston's South Station for a train trip to Philadelphia on the Amtrak Northeast Regional Railroad Corridor, the busiest rail travel corridor in the United States, with 457 miles of track between Boston and Washington DC, carrying over eleven million passengers a year (Amtrak 2012 and 2013b). I am early, so I walk around the large, crowded station looking for a place to sit and check email on my smartphone for a bit. South Station is the main Amtrak station for Boston, the final stop for eight of the region's twelve commuter trains, a stop for the subway and city buses as well as adjacent to Boston's long-distant bus terminal. South Station's electrical outlets are covered and locked shut, preventing the public from accessing the plugs. While there are many tables to sit at, there is no accessible electricity provision. There are, however, three private companies providing charging services for a fee.

Figure 1. GoCharge's pay-per-use smartphone charging station in Boston's South Station. Photo by author, August 2013.

The oldest vendor (Author's fieldwork 2013), Gocharge, has a wall-mounted unit dangling a number of charging cords for popular phones right outside the mens' bathroom that when functioning charges $3.00 for twenty-five minutes of charging (Figure 1). As observed in fieldwork over the last two years, this unit is often broken and sporting a hand-drawn "OUT OF ORDER" sign. Additionally, the unit is in a high traffic area with no tables or sitting nearby, so to charge their phone, a customer would have to stand in the way of men hurrying to and from the bathroom. In a more central area adjacent to the station's main food court sits two kiosks offering external smartphone batteries. The Mobile Qubes Portable Battery Rental offers, as the name implies, portable batteries for $4.99 to rent or $44.99 to buy. The kiosk has bright screens flashing advertising messages such as "NO OUTLET, NO CORD, NO PROBLEM". Directly adjacent to this kiosk is a smaller Morphie illuminated kiosk offering "universal batteries" similarly sized to a deck of cards or smaller, and protective cases with batteries built in for popular phone models like the Apple iPhone. Morphie's products cost between $35.00 and $129.00. All three kiosks are automated; the only way to pay for charging or to purchase a battery is with a credit card. South Station's largest concession is a two-level drug store that features a prominent display of smartphone cords and plugs for sale right before the checkout line, indicating the market for smartphone charging equipment in transit and in general (Author's fieldwork, 2016).

Once on the Amtrak train, travelers can tak advantage of the two electrical outlets at each seat on Amtrak's passenger cars, free to use with the purchase of a ticket. I board and sit and then, as the train pulls out and the passengers get settled, seat-back trays release and laptops emerge from bags, in addition to smartphones and tablets and traditional paper-based media. These outlets were installed around 1998 (Trainweb 1998). On longer journeys such as the six hours to Philadelphia, the outlets prove useful. Even if a device's battery will hold a charge to last the journey, people seem inclined to keep these objects topped off. One Yelp commenter praising Amtrak's provision of outlets writes "you have time to sit back and relax while charging your phone in the outlet next to your seat, score! The seats are huge so you have tons of personal space" (Yelp 2015), one indication of the service's usefulness to passengers.

The train passes through suburban Boston, running alongside the Atlantic Ocean in Connecticut, chugs through metropolitan New York, then enters the marshy wetlands of northern New Jersey before finally crossing the Delaware River and entering the post-industrial fringe of Philadelphia. The scene inside the train retains a similar feel even as passengers come and go: people pass the time on laptops, smartphones, reading books or magazines, eating, or looking out the window. Digital devices have, to an extent, replaced books and newspapers as a means of passing the time in transit. In a sense this is an evolution of the habit of reading, working, and generally passing the time in motion. Schivelbush in The Railway Journey mentions (1986, 67), "the habit of reading while traveling was not only a result of the dissolution and panoramization of the outside landscape due to velocity, but also the result of the situation inside the train compartment" where "reading became a surrogate for the communication that no longer took place" as it did in hired coaches before the advent of rail travel" (1986, 67). Reading on the Internet does involve maintaining a connection to the Internet, a process that has been fraught with complications.

Figure 2. On an Amtrak Northeast Corridor train a sticker on the window states "Your seat is now a [wifi] hot spot." Photo by author, November 2013.

As important if not more important than the ability to charge is Amtrak's provision of wireless Internet, although to continually use the Internet eventually requires charging a battery, so the two operate together. WiFi was added to the faster Acela business class trains in 2010 and the regional trains in 2011 (Berman 2011). An unobtrusive sticker on the window by each seat states: "Your seat is now a hotspot: Wifi on this train" (Figure 2). However, the strength of the wifi signal is dependent on the trackside cellular coverage that transmits the data from the moving train into the terrestrial digital infrastructure, coverage that varies due to location, environmental interruptions like a hillside or dense forest, the blanketing strength of the signal, and the number of users on the train. Streaming video websites with high bandwidth needs like Youtube are blocked; Amtrak states: "Our WIFI bandwidth supports general web browsing, not streaming music and video, or downloading large files" (Amtrak 2014).

This level of connectivity was not reliable enough for some travelers nor the media. While batteries can supplement laptops and smartphones if the electricity to the train car goes out briefly, there inherently can be no local backup of the Internet. Immediately upon initiating the service, complaints about spotty Internet coverage emerged in the media. *The New York Times* titled an article "Wi-Fi and Amtrak: Missed Connections" (Nixon 2012) and *The Economist* complained that the "Wi-Fi should actually work" (No Author 2011). The expectation implicit in these two articles is that travelers, especially business travelers or politicians passing between

New York City and Washington DC must have constant connectivity or they will find other means of travel. Consequently, in 2014 Amtrak's sought a contractor to build a trackside wireless network alongside the Northeast Corridor by 2019 (Koebler 2014; Meyer 2014). The new network will be comprised of base stations near the rail line that will connect trains via fiber lines or microwave, building a wireless network just for its trains and passengers instead of sharing existing cell towers that weren't built to support speeding trains filled with travelers demanding connection. In the meantime, it seems more passengers attempting to access the network has reduced connectivity even more (Tangel 2015). For many travelers, train travel on this Amtrak corridor cannot be separated from the presumption of constant digital connectivity as well as access to electricity, and the absence of the perfect, high-speed connectivity leads to significant complaints.

Figure 3. A waiting traveler hunches over his smartphone plugged in to an electricity outlet in Philadelphia's 30th Street Station. April 2015.

Once at Philadelphia's 30th Street Station, I have a few minutes to wander around and stretch my legs before my local commuter train to Temple University arrives. At 30th Street Stations as well as Boston's South Station, the bathrooms are freely accessible, as is heating or cooling the air and tables and chairs in the terminal, but electricity is approached differently. South Station as mentioned above has privatized, fee-based charging or none at all, while at 30th Street Station, services are available for travelers for free, with a "Cell Phone Charging Station" with numerous outlets along a wooden bench is tucked alongside the Amtrak ticket counter. The electricity outlets in the public areas of the terminal are open, even though they are at floor level in a pedestrian corridor, leading to travelers in need of electricity to crouch or hunch with their baggage, transforming their posture in order to charge and use their smartphones (Figure 3).

My regional train arrives so I board for the short, fifteen-minute trip across Philadelphia's downtown. The commuter railcars do not provide outlets for charging, though there are outlets for the cleaning and maintaining of the trains. Here I see my final example of charging practices, with a Temple University student sitting in the corridor-side seat by the door to access the outlet and charge his smartphone before, I assume, classes. He is resting, eyes closed head down on crossed arms but phone plugged in, sitting on his lap. Even on a relatively short journey, and before spending time on a university campus with many, many opportunities to charge a battery, the student was still compelled to use this informal source of charging (Figure 4).

Figure 4 A passenger uses an outlet on a Philadelphia commuter rail train to charge his smartphone while he rests. November 2013.

Data centers and the electricity underlying digital connectivity

On the commuter rail trip through Philadelphia I pass by one of the largest data centers in the Northeast United States; this physical proximity offers a narrative tie-in to finish this essay by returning to the most prominent source of energy demand of the Internet: the data centers that hold the information. This energy demand is not insignificant: "Direct electricity used by information technology equipment in data centers represented about 0.5% of total world electricity consumption in 2005. When electricity for cooling and power distribution is included, that figure is about 1%. Worldwide data center power demand in 2005 was equivalent (in capacity terms) to about seventeen 1000 MW power plants" (Koomey 2008). Furthermore, "Worldwide electricity consumption for all communication networks is 1.8% of total energy use" (Lambert et al. 2012). These points are underscored by the recognition that: "As of 2007, the average datacenter consumed as much energy as 25,000 homes. There are at least 5.75 million new servers deployed into new and existing data centers every year. Data centers account for at least 1.5% of US energy consumption and demand is growing 10% per year" (Bartels 2011). Globally, these digital warehouses use about 30 billion watts of electricity, roughly equivalent to the output of thirty nuclear power plants (Glanz 2012). Interestingly and importantly when considering this energy use, data centers "were using only six percent to twelve percent of their electricity powering their servers to perform computations. The rest was essentially used to keep servers idling and ready in case of a surge in activity that could slow or crash their operations" (Glanz 2012). Maintaining information at standby, because of the expectation of near-instant access, accounts for essentially 90% of a data center's energy demand. The information of mobile connectivity, while accessible, essentially, everywhere around the world, is inseparable from regional electrical power grids, which are a very grounded, equipment-heavy, resource-intensive infrastructure: not mobile at all. The infrastructure of mobile connectivity is not not just data centers, network equipment, fiber-optic cabling, and cellular antenna sites, but also and more importantly, the electrical energy that powers these interconnected digital systems.

Mobile connectivity relies on constant connectivity to data centers, and while the location of data centers does not inherently matter, only the connection, data does embody spaces, forming an infrastructural geography layered within and between cities, co-produced through and alongside transportation networks especially the railroad, even within city streets where the railroad has been absent for decades, and functioning through massive amounts of electricity. The Terminal Commerce Building is the largest data center in Philadelphia: an eleven story, 1.3 million square feet structure located just north of Philadelphia's City Hall. It is an Art Deco building that takes up an entire city block, completed in 1930 and originally containing wholesale furniture showrooms and warehousing for furniture. The structure has a railroad spur going into the basement to load and unload goods; this is where the fiber optic cables run into the data center; this otherwise unused railroad right of way cutting through downtown is what makes the building useful as a data center. According to a report submitted to register the building into the National Register of Historic Places, a status granted in 1996, the Terminal Commerce Building was "large enough to command its own post office, and later its own zip code, [and] by 1948 the building housed 175 companies employing some 5,000 people". By the early 1970s this was the largest single office building in the city. By the late 1990s became a co-location point center where multiple carriers house their respective data centers in one building. Today there are approximately eighty carriers in the building, which also acts as an interchange between data storage providers and telecommunications companies (DiStefano 2014; Verge 2014). Far less than 5,000 people work in the building now. The energy needs of the data center are manifest in an electricity sub-station located across two blocks behind the data center. The presence of the sub-station highlights both how much energy is consumed to power the building and the digital services within, so much that it links directly into the power grid itself.

Conclusion

Mobile, digital connectivity is a factor of conjoined engagements with energy powering devices, network equipment, and data centers. This connectivity is bound up in infrastructures, expectations of constant connection, and emergent charging practices. The demand for standby, 'always-on' wirelessness (Mackenzie 2010) entails a constant provision of wireless signals pulsing between smartphones and base stations, transnational telecommunications systems, and data centers scattered around the world. These systems of connectivity have a particular, material spatiality stretching beyond each user that are produced through and grounded in electricity. Beyond the infrastructure of mobile connectivity, the expectations of connection in particular have led to, in the case detailed above, transportation providers like Amtrak to become Internet service providers, to enroll the provision of mobility into the provision of constant wireless communication for travelers. The expectation of connectivity on Amtrak's Northeast Corridor also includes supplying electricity to power these computing devices throughout the journey. As a social practice, charging in public is built around the assumption that energy for smartphone batteries is either a traveler's right, such as in Philadelphia, a business opportunity, such as in Boston, or a factor of the rail provider retaining passengers who might otherwise drive or fly. This all speaks to the digital complexities involved in managing public transportation systems today. While a traveler's focus is on maintaining their linkage to the Internet, the underlying electricity needs of the device speak to the continuous appetite for energy fundamental to the digitization of society in the twenty-first century.

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