Article

Society and Space

EPD: Society and Space
0(0) 1–18
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DOI: 10.1177/02637758221139857
journals.sagepub.com/home/epd
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Speculation on infrastructural ecology: Pigeons, Gaza, and internet access

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Abstract
This article proposes an Internet Pigeon Network as a prototype and a critique. As a prototype, it is a speculation for a community-organized, affordable, resilient internet infrastructure for the Gaza Strip that brings together different modes of building communication networks: one draws on millennia-long history of the pigeon post and the other on contemporary local WiFi and do-it-yourself networks. As a critique, it is a commentary on the possibility of establishing an infrastructure that is equitable, adaptable, sustainable, and grounded by the collaborative effort between humans, animals, and the environment that sets it in motion. The article discusses such a prototype's implications on mobility and the goal of an infrastructural ecology.

Keywords
Infrastructure, internet, infrastructural ecology, pigeons, Gaza, mobility

> The point of birdwatching is not simply . . . *to* see birds, *nor even to see a bird* no one has seen before, *but to see changes* in an ecology [. . .] *to* observe, *compare* and contrast forms of participation; . . . *to* ask when . . . *and where* different forms occur; . . . *to* ask how healthy the 'ecology' of participation is; *to* ask what forms of participation are emerging, *what forms are going extinct, and with what* consequences? (Adam Fish et al., 2011: 159)

The Internet Pigeon Network (IPN) is a prototype and a critique. On the one hand, the IPN is a speculation for a community-organized, affordable, resilient internet infrastructure for the Gaza Strip which relies on pigeons for data transfer, and simultaneously decreases technical dependence and complexity, offers infrastructural sovereignty, aims to prevent ecological damage, and considers the ecosystem as part of its structure.[1] On the other hand, the IPN is a commentary on what it might look like to establish an infrastructure

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that is equitable, adaptable, sustainable, and grounded by the collaborative effort between humans, animals, and the environment that sets it in motion.

Considering the revival and redesign of an old technology (the pigeon post) alongside newer democratic models of the do-it-yourself (DIY) infrastructure (local WiFi networks) reveals possibilities for different infrastructural efficiencies that account for Gaza's specific political, economic, and ecological limitations. But Gaza also proves to be a productive site in considering the feasibility, efficiency, and scalability of *any* communication network. Gaza's population – almost 2 million people with a density that is among the highest in the world – currently lives by energy standards that, despite being imposed unfairly by military and economic constraints,

> should be considered realistic in a world whose urban population must consume far less energy, recycle more materials, and use renewable sources of power. Gaza has been forced to rely on these high-efficiency solutions for political reasons. Soon, the rest of the world will have to do so for climate-related reasons. (Mudede, 2021)

The IPN also begins from the recognition that communication networks have become indispensable for many aspects of modern life, in Gaza as much as elsewhere. But these infrastructures have also grown in complexity that makes evident various kinds of dependence and concurrent costs (such as experts, technical knowhow, standards, protocols, material and financial resources, political resources, other infrastructures, and so on). Moreover, our communication networks bear a strong imprint on ecological life: underwater fiber-optic cables, integrated circuits, satellites, server farms, antennas, cloud computing are harmful in their dependence on, extraction of, or disregard to non-renewable resources, damage to natural habitats, or waste and pollution. As a meditation on reimagining technological infrastructures in the context of political, economic, and ecological concerns that are both local and planetary in scale, the IPN hopes to demonstrate that technological reliance and needs do not inevitably have to lead us to deeper excesses and dependencies, but instead acknowledge our 'entanglements' and help us imagine and create a world otherwise. Its ambition is to think towards an infrastructural ecology.

In what follows, I begin with the pigeon as a main player in considering infrastructural possibilities. I move on to address the context in Gaza and specifically the kinds of limitations that exist on its communications infrastructure. Thereafter, I discuss the IPN prototype and touch on some of its local benefits. I then expand on the IPN's implications on mobility and infrastructural ecology more broadly.

The pigeon paradox

Across the West, pigeons are a reviled scourge, referred to invariably as rats with wings, cockroaches of the sky, trash birds, even "public enemy number one" (Blechman, 2006; Jerolmack, 2013). It is difficult to think of London's Trafalgar Square, New York's Washington Square or Venice's Piazzo San Marco without their abundance of pigeons. Indeed, pigeons, humans, and cities have a long and intertwined history.

Urban pigeons are feral birds, descendant from stock doves deliberately bred by humans for racing, homing, eating, and other purposes. The pigeons we see today simply remained in the cities from their days of domestication, even as cities developed and urban residents no longer relied on or wanted the birds. Taking the example of Trafalgar Square, Clare Palmer (2003) argues that "the pigeon population is an accumulative outcome derived from the compounded actions of a large number of different people over a sustained timescale"

(74). Pigeons have been genetically and temperamentally shaped by deliberate human intention into the kinds of birds they have become, and have survived by scavenging in urban areas or in places where humans have chosen to feed them. It is precisely because pigeons live so intertwined with humans and human machinations, and especially in urban areas, that they provide insight into the biopolitical impacts of human atmospheric engineering (or if one prefers, the Anthropocene).

Cities are constituted by socio-natural flows and exchanges, in which the materiality and the agency of humans and non-human bodies, relations and infrastructures, are deeply entangled (Heynen et al., 2006). It is thus in the urban context where any meaningful ecological impact derived from changes in our socio-technical behaviors may, and should, occur. *Conservation and sustainability increasingly depend on urban dwellers*, particularly since more than half the world's population is urban and the number and percentage are only growing. This dilemma has a name: "the pigeon paradox" (Dunn et al., 2006); it is described in the following way:

> under the status quo a great deal of future conservation will rely in part on our interactions with urban ecosystems and the organisms, including non-natives such as feral pigeons (e.g., Columba livia), that call them home. The paradox lies in the dependence of conservation action worldwide on peoples' direct experiences with urban nature. (1814)

In other words, global conservation starts in the middle of Trafalgar Square, Piazza San Marco, and Gaza City's Central Square. Ecological conservation should happen wherever and everywhere human lives and livelihoods are entangled with, and especially where they threaten, the lives and livelihoods of otherkind. Simultaneously, urbanization is, or certainly should be, "increasingly characterized by open source autonomous logistics infrastructure, technologies to mitigate anthropogenic effects on climate, an expanding urban sensorium of interlinked sensors" (Simone, 2018: 13). Consequently, the pigeon is a prime position from which to assess human relations with animals and the larger environment, as well as technological and urban 'development' and growth.

Diverse efforts aiming to conserve the natural ecosystem while also providing benefits to human populations mark an important shift, as demonstrated in green projects, resilient cities, conservation development, and ecosystem management. By and large, these practices aim to be proactive, systematic, multifunctional, and better integrated across various efforts to manage growth and development. Some, such as the DIY infrastructure, also illustrate participatory, local, informal, ecological and/or resilient uses of technology which are conscious and critical of the constraints of the socio-technical regime (Lukens, 2013: 26). Such efforts are often echoed in scholarship that speak of hybrids, becomings, cyborgs, becomings-with, dances of agency, networks, meshworks "in which all entities are fluid and promiscuous [. . .] constantly messing up and reconstituting technologies, texts, histories, wastes, flows, policies, communities, and materialities" (Franklin, 2017: 203). The IPN is imagined in a similar spirit.

Pigeon positionality

Throughout history, pigeons have served as spies, racers, messengers, urban neighbors, pets, scientific objects, art-engineering experiments, gender assistants, imperialist invaders, native species, protein-rich meals, and more. Donna Haraway (2016) argues that around the world pigeons and their partners of many kinds, including people, make history and create activations of 'becoming-withs.' As a model of human–animal collaboration or human–animal

co-engineering, the IPN cultivates and draws on the notion of multispecies entanglements and non-human beings' production of space (Lorimer et al., 2019; Tsing, 2015). Another particularly fruitful foundation in deliberating human–animal co-engineering is work that contends with how animal ecologies are rendered into infrastructure. This includes studies of animals as labor, as mediatic sensors, or cyborg assistants. The large-scale deployment of the black soldier fly in waste disposal (Zhang, 2020), marabou storks in urban waste landscape (Doherty, 2019), or the metabolic activities of oysters to absorb and diffract the energy of waves in urban settings (Wakefield and Braun, 2018) are examples of how animals (and here also their metabolisms) are relied upon to carry out infrastructural work. These examples also illustrate how animal labor is recruited into techno-political imaginaries of the automated, green city, and how animals' natural proclivities are increasingly regarded as a salve to climate change and ecological crisis (2018). Such scholarship also makes clear that non-human animals have always been co-constitutive of cities, rural areas, coastlines, and everything in between, and equally constitutive in the absence or impossibility of humans.

Taking up the notion of animals *as* infrastructure, Barua (2017, 2021; Barua and Sinha, 2017; Lorimer et al., 2019) compellingly works towards conceptualizing a wider infrastructural ontology (and I'd add ecology):

> one that sees infrastructures as emergent, continually folded into intra-actions with more-than-human company; one that locates infrastructuring as a continuous negotiation of the nature–infrastructure boundary where natural and infrastructural ecologies meld but also where infrastructures can revert back to nature. (Barua, 2021: 17)

Barua challenges us to think of how we can open or expand infrastructural improvisation to more-than-human collaborations. In other words, a wider ontology rethinks the very notion of infrastructure and the infrastructural.

The IPN thinks through the infrastructural as a process of human–animal–environmental *collaborative* work, in which the role and function of the pigeon moves beyond pre-existing categories. The IPN does not approach the pigeon as distant or distasteful worker, nor as laborer, pet, livestock, zoo artifact, or laboratory animal. Neither are the humans living with the pigeons considered animal trainers, zoo keepers, veterinarians, laboratory personnel, or farmers. Instead, the relations are dynamic, productive, mutual; they disrupt and set the stage for other configurations. Their shared lives "produce something new, [. . .] and give different life in unexpected, serendipitous ways" (Rautio, 2017: 724).

But first, let us turn to the abilities and positionalities of pigeons, of pigeon flocks, and pigeon towers. Pigeons have impressive visual memory and an acute sense of self-awareness; they remember and self-recognize (Epstein et al., 1981; Gaietto, 2019; Rose et al., 2006). In so doing, they contribute to the IPN positionality and self-reflexivity in a way that no wire, cable, or antenna could. Pigeons can also differentiate in the sense of making nuanced and generous distinctions; they can differentiate between people, works of art, buildings, and territory (Gaietto, 2019; Jerolmack, 2013). What these abilities highlight is pigeons' grasp for place and displacement, orientation, and disorientation. In our existing communication network, a data-packet relies on 'recognizing' its addressee, and while it can be awe-inspiring, its mode of travel does not possess intelligence, flexibility, and locative abilities, or certainly not of the kind a pigeon does. Pigeons' ability to remember through their 'map and compass' ability means that they "are competent agents who render each other and human beings capable of situated social, ecological, behavioral, and cognitive practices" (Haraway, 2016: 16).

The power dynamics of pigeon *flocks* reveals structural flexibility. Pigeon flocks have fairly stable hierarchical decision-making structures, but when in a situation where the performance of the whole flock is in danger, they demonstrate "adaptive consequences of collective decision-making" (Watts et al., 2016: 1). They do so by filtering out "inaccurate information [. . .] through the rearrangement of hierarchical positions, preventing errors by former leaders from propagating down the hierarchy" (3). Pigeons recognize their own and one another's strengths and weaknesses within the larger collaborative network, and do so on the fly (pun intended). This capacity is equal to communicating one's doubts and needs while also moving forward together; no ISDN, fiber-optic, WiFi, or 5G network can do this, as far as I know. In fact, the pigeon flocks' structural flexibility is the definition of a robust communication network made up of *actually* intelligent nodes, as well as a healthy, democratic community. A prototype such as the IPN, then, builds on and benefits from its component parts (the pigeons) to be sensitive to and aware of positionality, orientation, and navigation, while the arrangement as a whole (pigeon flocks) illustrates a place-based, flexible, and smart mode of being and of travel.

Pigeon coops, lofts, and towers play a different role: they gesture towards the possibility of co-creation between pigeons, humans, and the environment. Pigeons are perfectly capable of finding food and shelter by themselves; a pigeon loft may make these easier but it does not actively change pigeons' lives (Gaietto, 2019). Instead, coops, lofts, and towers allow "for the potential of a new encounter, giving the continuously present and invisible pigeon a dedicated space" (71); they bring the pigeon into human view and provide the pigeon a space within the wider landscape. As Haraway (2016) says of the pigeon tower, it "certainly cannot *undo* unequal treaties, conquest, and wetlands destruction; but it is *nonetheless* a possible thread in a pattern for ongoing [. . .] multispecies getting on together" (29; emphases added). The built towers, lofts, or coops become embedded in the urban fabric, themselves outcomes of human–animal–technological–urban co-architecture. As an outcome of co-labor and co-care between pigeon and human, they constitute components in an arrangement of co-habitation. Neither the environment, nor humans, nor the pigeons are "damaged" by the installation and use of the loft. Rather, all interested parties are served: the pigeon receives healthy sustenance and shelter; the cityscape is unfettered by it; city dwellers gain from its presence; and, data can travel.

Approaching Gaza creatively

The pigeon post, which by many accounts originated in the Middle East and was arguably the earliest and longest-lasting means of distributing and circulating messages speedily over large territorial reaches, remained the fastest communication system across the world until the invention of the telegraph and radio. It functioned quite simply by training pigeons to carry and deliver messages to and from specific locations where pigeon lofts and towers were established. Well into the nineteenth century, pigeon posts were prevalent as the primary means of long-distance communications in the areas of modern-day Iraq, Syria, and Egypt, within which Gaza was a critical node (Allat, 1886; Blechman, 2006; Jerolmack, 2013). The IPN builds on this long history.

Situated at the nexus of three continents, Gaza's coastal wetland is a major stopping point along a migratory superhighway between Europe, Western Asia, and Africa for over five hundred million birds annually. The Gaza Strip's various ecosystems are home to 540 avifaunal species, including seven species of pigeons (Abd Rabou and Abd Rabou, 2019; Abd Rabou et al., 2015). Unlike in the West, across the Middle East, pigeons have not inspired the same ire, and are still popular as pets, as sporting elements (such as in races), as

meals, and even as messengers. Across the region, in the Palestinian Territories, and in the Gaza Strip, there continues to be communities of pigeon rearers and fanciers, and a handful of hobbyists training messenger pigeons (Ashraf, 2018; Booth and Davidson, 2017; Saad, 2022). But the reliance on animals for everyday infrastructural purposes draws on millennia of ways of doing things, and, in the case of Gaza, contemporarily, Palestinians' continued reliance on animals such as donkeys and horses is a response to Israeli-imposed closures and siege and the forced immobility these create (Gutkowski, 2020; Johnson, 2019).

The Gaza Strip[2] has been under an oppressive siege since 2006, which has come after decades of closures and de-development (Roy, 1999), followed by brutal bombing campaigns in 2009, 2011, 2014, and 2021. The difficulty of everyday life cannot be stressed enough, circumscribed by stringent Israeli policies and limitations on movement of people, capital, and materials, and control over land, air and sea space (Baconi, 2018; Tawil-Souri and Matar, 2016). Infrastructurally, the Gaza Strip is destitute: materials are forbidden, whether for building, sewage, healthcare, education, or foodstuffs. In some cases, Gaza has been forced into dependence on Israeli infrastructures and networks, such as with electricity (Salamanca, 2011) and communications (Author, 2012), and then only in extremely limited ways; or, on an almost regular basis, outright destroyed by Israeli military operations. The de-development of and repeated attacks on infrastructure have detrimental impacts across economic, social, political, and ecological systems. Electricity is only available for a few hours a day, untreated sewage flows in the streets, roads are unpaved, schools lack walls and roofs, waste management often takes the form of burning rubbish. It should come as no surprise that Gaza's population density, political instability and injustice, in addition to its limited and depletion of natural resources and general environmental deterioration, make it an environmental and ecological "hot spot" (United Nations Environment Program (UNEP), 2003).

Infrastructural projects in and for the Gaza Strip must contend with severe and restricted circumstances imposed by Israel, frequently exacerbated by destruction at the hands of the Israeli military (Weinthal and Sowers, 2019). This condition inevitably forces creativity.[3] Everyone is compelled to make-do, to circumvent, hack, rig, recycle, and improvise, surviving in what Simone (2018) would describe as "an atmosphere of things continuously being worked out and proportioned" (4). What elsewhere might be called alternative, ad-hoc and do-it-yourself solutions are the norm. Smuggling tunnels under Rafah are used to import everything from food, medicines, and animals to car parts, computers, and construction materials from Egypt. Power generators for homes and hospitals are rigged to run on cooking oil. Rubble from destroyed buildings is recycled as construction materials. Horses, donkeys, and rickshaws are used as primary modes of hauling and transportation. Gaza is a real and extreme condition where infrastructural possibilities must be reimagined (see Al-Qudwa, 2021; Sorkin and Sharp, 2021). Put another way, the extreme condition and difficulty of infrastructural development in Gaza can be approached as a challenge in a "positive" way that directs us to generate novel effects (Barry, 2021; Simone, 2018; Stamatopoulou-Robbins, 2019). As such, a speculative design for Gaza can serve as a model of what might be possible not only in Gaza, but also *universally*.

Given the continued blockade of Gaza, the internet has become the primary means of connection and communication to and from the outside world (see Raheem, 2021). Globally, lack of internet access exists for different reasons: poverty, inaccessible or remote landscapes, limited profit motives, lack of supporting infrastructure, among others. In Gaza, however, not only are poverty and de-developed and limited infrastructures largely imposed by Israeli policies, all electronic communications are under the *complete* control of Israel who has the sole power to allocate spectrum, connect landlines and cables

to telephone and internet exchanges, determine bandwidth, surveil content, as well as the power to shut down or destroy physical infrastructure – and make a profit of such control. Gaza lives under a digital occupation (see also Abou Jalal, 2017; Author, 2012; Christiano, 2020).

The internet's physical structure has multiple tiers. The backbone, sometimes also called the core, is made up of the terrestrial and underwater fiber-optic cables that interconnect all of the network's end points which enable all the possible paths between end devices (such as phones and computers), between servers, and between end devices and servers (Antoniadis, 2018). Across much of the world, access to the backbone is for the most part available through providers ("middlemen" who own, control, or manage connecting wires and machinery to local exchanges). Consumers purchase access from these middlemen who in turn pay fees for interconnecting and exchanging traffic with larger providers. Network access, commonly called the "last mile", refers to the part that enables a person with a device to connect to the backbone; it does not necessarily connote an actual mile but the last step of connection, be that a home, corporate headquarter, internet café, or municipal WiFi provider.

In Gaza, connection is only available and permitted through Israel: consumers subscribe to Palestinian local providers, but every local provider must purchase access from commercial Israeli middlemen who purchase connection from larger backbone providers connected to landing points along Israel's coastline. The main data routes that connect the computer networks that sustain internet traffic and data mobility that Gaza (and the rest of the Palestinian Territories) rely on are a conglomerate totally controlled by Israel, precluding the possibility for Palestinian infrastructural autonomy. Economically, for example, 100% of internet and telephone connection to the backbone ends up in Israel's economy, while politically, all service delivery and security information are governed and surveilled by Israel and only nominally managed by the Palestinian Authority in the West Bank and by Hamas in the Gaza Strip (Christiano, 2020: 9).[4] For Palestinians across the Occupied Territories, cyberspace is "an additional layer of spaciocide"(Christiano and Distretti, 2020; see also Author, 2012; Raheem, 2021). As such, circumventing Israel's infrastructural grid becomes a political and economic choice, and illegibility against economic profit, political oversight, or surveillance, does not suggest illicit or illegal activity. Current models of network structure, development or expansion either cannot circumvent Israeli controls and profits, or prove too costly and complex. For example, Wi-Fi piggybacking relies on 'stealing' signals from nearby Israeli towns and could conceivably be free, but easily surveilled or shut down; terrestrial or under-water connection through neighboring Egypt or Jordan, through the West Bank, Cyprus or anywhere elsewhere is forbidden by Israel, as well as prohibitively expensive; satellite connection cannot dodge Israel's control over the electromagnetic spectrum (Author, 2012, 2021).

Alternative, radical, and more democratic formations of computer networks, such as local WiFi networks, mesh networks and hands-on networks, increasingly exist across the world – in public squares (Stockholm), urban neighborhoods (Brooklyn's Red Hook), small towns (Leiden), and larger city-regions (Athens, Barcelona, and Berlin) (Antoniadis and Apostol, 2014; Solomon, 2020). In the case of Gaza, these remain open to surveillance[5] and destruction, prove expensive, rely on electricity and relatively complex technologies, are neither locally made nor available, and consume a lot of energy. Such networks *do* prove instructive, however, in terms of political and ideological goals: realizing infrastructures according to individuals' and communities' values and objectives; embracing ideals of democratic governance and independence; enabling individuals, communities and organizations to own their infrastructure and providing a "sense of belonging to a collective place"

(Antoniadis and Apostol, 2014: 4; see Dulong de Rosnay et al., 2019 for instructions on assembling different models).

To sum up, the challenge of imagining a blueprint towards reliable and high transfer speeds, operational sustainability and affordability, imperviousness to interception and surveillance, decreased dependence on and cost of technologies, expertise, and contingent infrastructure, and minimum interference, control, and profit by Israeli and foreign entities, is a considerable one. It requires an altogether different communication network paradigm. Enter the IPN.

The Internet Pigeon Network

Albeit largely displaced by newer technologies, homing pigeons' ease of traversing variegated and wide geographies, astounding reliability, and ability to carry small items renders them useful to this day as message carriers, transporters of scientific samples, drug smugglers, and otherwise (Shell, 2015). Pigeons' navigational abilities have contributed to innovations in behavioral science and military aerial technologies (Epstein et al., 1981; Schultz-Figueroa, 2019), aerospace optimization and GPS mapping (Zhou et al., 2021), new mathematical formulas (Haidar, 2017), and artificial intelligence (Qiu and Duan, 2020). Pigeons have also been used in bio-recycling programs (Gaietto, 2019) and countless art projects (Blechman, 2006; Haraway, 2016).

One study has contemplated providing internet access through homing pigeons in developing countries when other types of connectivity are not options. The researchers who proposed a Columba Livia-based Delay Tolerant Network suggest that: "It is quite conceivable that CoLi-DTNs will in fact be competitive against DSL, ISDN, and point-to-point WiFi connections in many settings" (Scholl and Lindgren, 2012: 14). In South Africa, one experiment used pigeons to prove that the speed of pigeon delivery was markedly faster than a local internet provider's ISDN lines (Govendor, 2009). Well before these, in 1990, one scientist proposed an experiment whereby an Internet Protocol diagram printed on a small scroll of paper would be wrapped around a pigeon's leg (Waitzman, 1990, 1990). The IPN is not imagined as an experiment to prove how slow a provider's connection is, nor a solution that can work only for poor areas or in exceptional circumstances, nor a flight of fancy experiment sending internet protocol via a pigeon – in fact, in the latter example, the IPN would be inscribing the pigeon *as* the protocol. The IPN echoes examples across the world where animals and 'lesser' or 'alternative' technologies are used for eliminating middlemen, increasing profits over distance, or minimally harming the environment, and equally puts into question the assumption that more complex devices are necessary, better, or faster.[6]

The IPN proposes multiple nodes inside and beyond Gaza connected via homing pigeons carrying lightweight micro memory cards to send and receive data. Pigeons would replace last mile and middlemen suppliers, with the goal of direct and affordable access to backbone providers outside Israel. The IPN's nodes (pigeons' lofts to fly in and out of) would be located in various locations in the Gaza Strip.[7] Outside of Gaza, nodes would be set up in Aqaba, Jordan, and in Suez, Zaafarna, and Alexandria in Egypt.[8] Smaller points (pigeon-feeding stations) would be necessary along the route in the Sinai in Al-Arish, Hasna, and Nekhel, and along the Mediterranean coast in Arish and Port Said. Based on conservative calculations, it takes a pigeon less than three hours to get from Gaza City to Aqaba, and the same to return. As an effective transfer rate, the IPN proves to be quick and reliable: for one pigeon carrying a 64 GB drive flying from Rafah (Gaza's southernmost city) to Suez at a rate of 100 km/h, the resulting speed is an effective 69 Mbps (megabits per second), not accounting the time to copy data, attach the drive to a pigeon, detach it, and download data.

For a pigeon carrying three memory sticks, the rate is 207 Mbps, a pigeon carrying five drives increases the rate to 345 Mbps (micro memory cards weigh less than half a gram and pigeons can easily carry 50 grams or more in a pouch strapped to their bellies). Even with these relatively moderate calculations, this is faster than any internet speed currently available in Gaza, and, as a matter of fact, many parts of the world.[9]

To ensure redundancy and protect against interruption or loss, the same data would be sent and received to at least two different nodes in the network by separate pigeons. Increasing the number of pigeons and lofts, agreeing on regularly accessing (e.g. every hour or every day), pre-emptively saving data (e.g. news sites, videos, emails) and otherwise scaling-up or making the network more robust would easily be determined and managed locally. This is by necessity an asynchronous and delay-tolerant network – i.e. non-continuous (given the dismal electricity network, this is already the case in Gaza) – but nonetheless provides substantially faster download/upload speeds (pigeons flying in/out) than currently available, at a fraction of the cost, and neither dependent on electricity for data transfer nor payment to Israeli providers.

Pigeons and pigeon lofts would become integral parts of a closed-loop paradigm: lofts, coops, and towers could be built from recycled, found, and otherwise available material. Once built, lofts and towers could double as public installations, art, playgrounds extensions, architectural experimentation, etc. Pigeon feathers could be used in crafts, toys, cleaning supplies, fashion. The high-nitrogen content of pigeon excrement would make for an excellent, robust, and free fertilizer. Pigeons eat different types of insects and worms and thereby keep the environment safe and the ecosystem in balance. Older pigeons would eventually be consumed in tasty protein-rich meals.[10]

By relying on pigeons rather than cables, wires, modems, routers, antennas, electricity as well as doing away with the transportation of these materials and their dependence on foreign experts to license and install them, the IPN would be an infrastructural model which maximizes efficiencies by decreasing the network's dependence and complexity, and by so doing, (re)places agency in the communities it serves. Similar to how alternative infrastructures are being imagined in and for Gaza (see Al-Qudwa, 2021; Mackey and Segal, 2021), the IPN would be built from the ground-up through the participatory and collective decision-making and management of those depending on it. As a community-driven network, it can continuously and organically be re-assessed and re-configured, and provide "opportunity for residents to write themselves into a milieu that otherwise might seem to marginalize them" (Simone, 2018: 5).

The IPN's local benefits also reverberate to new employment opportunities, development of new businesses, and creation of offshoot materials and industries: software coders, veterinarians, experimental architects and engineers, new eco-conservation groups, research and educational programs into local birds, flora, and fauna.[11] Assembling open infrastructures and services need not stop at the level of hardware, and can be aligned with economic systems that are market-based, or state-based, voluntary, non-profit, or household-based. Thus, the IPN can equally engender alternative ideological and political benefits by embracing free and open source software or community ownership. Douglas Schuler (2017), for example, proposes that an open-ended, non-profit, easy to use, citizen-led-public alternative communications infrastructure more easily enables and aligns with goals that can include

> conflict resolution, disaster management, peace education, transparency and anti-corruption, equal access to information and communication, cross-boundary communication and cooperation, sustainability and environmental stewardship, early warning systems, access to communication tools, access to news, organizing, deliberating using a variety of approaches, making

> things, collective awareness, translations, education, and an information and knowledge commons. (29)

The IPN could, for example, spur local data centers, a local internet exchange, and the creation of local software based on open-source programs. Its network architecture could further allow a governance model that can be *locally* defined, representing and embodying possible systemic change, in order for individuals and communities to have the capacity to challenge – or bypass parts of – current political, economic, and socio-technical regimes. Building (and imagining) alternative infrastructural systems, modifying existing ones, setting up collective ownership of infrastructure, challenging corporate or state interests and monopolies, reprioritizing other responsibilities over profit, curtailing data harvesting and surveillance are some of the benefits of DIY infrastructures. Like open source urban projects, part of the goal is to generate new designs, techniques, and rules (Jiménez, 2014).

There is no network design that can be completely impervious to Israeli violence, profit, control, or surveillance.[12] The same is true for the IPN. Israel has in the past banned the import of birds in Gaza, and could use hawks or drones to intercept, divert, or stop pigeons. In neighboring Egypt, for example, authorities have even gone so far as accusing and subsequently detaining a stork for espionage (Amin, 2020). Nonetheless, IPN's pigeons would be camouflaged amidst the heavy traffic of the migratory super-highway. And in the event that Israeli (or other) authorities capture the pigeons and destroy the coops and lofts, losing $10,000 worth of pigeons and lofts and another $10,000 in drives is substantially cheaper and easier to replace than a severed fiber-optic cable; consider, for example, that in May 2021, one Gaza-based local internet provider suffered losses upward of $2 million when its equipment and devices were destroyed in an Israeli bombing campaign that flattened an entire office building (see EuroMed, 2021; Raheem, 2021). Modeling the IPN as a prototype applicable to Gaza of course addresses Gaza's unique context and limitations, but it also proposes that a prototype can be a productive site within which Palestinians can be located inside the processes in which they are active subjects, and not simply victims of violence and suffering (see Simone, 2018; Tawil-Souri and Matar, 2018).

Intelligent networked mobility

Pigeons – like all humans and animals – map territories, contract forces, fold their bodies, and establish relations. Through movement, animals define themselves and define space and time as their own (Buller, 2012; Hovorka, 2019). Movement is also a way of bridging the human/non-human divide. Animals often make themselves known to humans through movement, traveling in and out of the human 'frame' (Buller, 2012: 146). Across history, it has principally been through movement that animals have been regarded by humans to have agency. Consider, for example, that domestication, in opposition to being 'wild' and 'free', is first and foremost, an act of corralling, enclosing, and denying free movement to animals; and it is often the human-imposed lack of free movement over animals that has come to symbolize cruel practices (the same can be said here of Israel's treatment of Palestinians). What constitutes animality is the faculty and power of converting energy into action, the ability to move, and the ability to decide to move: motility. Movement is function and agency, constantly changing, never fixed.

If movement describes a shift in spatial coordinates, mobility refers to the politics and ethics of movement and stillness. The conceptual shift from 'movement' to 'mobility' recognizes that animal movements are always produced and gain meaning within and productive of relations of power between different actors (Hodgetts and Lorimer, 2020;

Hovorka, 2019; Philo and Wilbert, 2000). Irus Braverman (2013) advances the concept of 'animobilities' to denote an animal's physical actancy within complex socio-geographies. She explains:

> When animal and human trajectories collide in the built environment, to the extent that animals cannot be tamed or controlled, there is an underlying existential human experience of social disorder. *The capacity of flight makes the pigeon a particularly effective transgressor*. While we have legislated spaces for these birds out of existence, we cannot put up fences or easily set traps to limit their 'animobilities.' *They can freely move across state and national borders*. (107; emphases added)

The fact that birds can fly, and do so both freely and across any imposed political borders, makes them all that much more symbolic in a context of politically imposed closure and immobility such as Gaza's.[13]

Animals exist in trans- or supra-national spaces. Efforts to control them have historically been connected to colonialism and the projects of nation-states. In part because animals have meant both physical mobility and socio-economic mobility, particularly among the most marginalized groups, the control of animals has been "a way for states to control the movement of people (literally, limiting them to reserves and designated African areas, and figuratively, as in upward social mobility—to escape the static designation allowed them by the segregationist and later the apartheid states)," as Swardt explains in the context of South Africa (2015: 92). Natalia Gutkowski's (2020) research on animal and animal-produce control in Israel/Palestine demonstrates how the political lives of nonhuman bodies are integral to Israel's control mechanism and restrictions on Palestinian human mobilities.[14] Israeli policies go to great lengths to stop animal and socio-economic mobility: seizing horses, quarantining donkeys, enforcing uneven veterinary standards, imposing vaccine import barriers for Palestinian animals, criminalizing century-long practices of shepherding camels, or expropriating land pastures for goats, among other examples. Nevertheless, "Palestinian-owned animal parts and nonhuman bodies" can and do cross borders more easily than Palestinian human bodies (Gutkowski, 2020: 143). As such, animals' mobility are important objects and subjects in the political geography of walls and settler/colonial borders in Israel/Palestine in that their movement contests "hierarchical separation of bodies that was put in place" and so challenges the colonizing power (136). Human/animal entanglements can be subversive and illuminate the ways that nonhumans, particularly when 'recruited' by humans, challenge border regimes across time and space (Braverman, 2013; Shell, 2015).

Pigeons can be trained to fly from point A to point B, and be re-trained to fly from point C to point D. But their mobility is nonlinear. Pigeons have flexible behavior in their flight paths, the distances they travel, their foraging strategies, and timing of their activities (see (Rose et al., 2006)). As such, pigeons and their 'networks' are capable of and demonstrate much more than some kind of uncontrollable or illicit mobility. Pigeons' atmospheric geometries are complex (Lorimer et al., 2019: 32), their converging is flexible, their "worlding is expansive" (Haraway, 2016: 16). Pigeons are a means of expansion, of continuation, of observation and assessment in the moment, they traverse and create spaces. Their movement and mobility is a process of interrelation, of communication. As data carriers, they extend humans' inability to overcome the friction of distance and time. As a network, they expand the opportunities of human interaction with other humans, with non-human beings, with the whole ecosystem.

Life, movement, and mobility are symbiotic. The very capability to move is a fundamental freedom (for humans and non-humans), and being deprived of it means being deprived of an essential component of self-determination, autonomy, and agency. As such, in allowing 'free' movement and agency, the IPN is a model of an intelligent network. Such a smart network is adaptive, flexible, interactive, more legible in its technicalities as well as its ties to various actants. It encourages interconnectedness and synergy across ecologies. A smart network or smart infrastructure is not about blockchain technologies, self-driving cars, or the Internet of Things, but about putting intelligence back into human, animal, and ecological components.

Our existing high-tech communication networks do not emerge from or take place against a neutral substrate, and neither does the IPN. But the IPN demonstrates and embraces that this substrate is *itself* "active, lively, fragile, powerful and connected in ways that matter more than we imagined before" (Franklin, 2017: 204).

Conclusion: Towards an infrastructural ecology

By drawing on models of DIY infrastructure, which are conscious and critical of the constraints of the socio-technical regime and which illustrate more participatory, local, informal, ecological and/or resilient uses of technology, the IPN seeks to expose and challenge the 'radical monopoly' of existing infrastructure – where the ubiquity of a tool or service is so great that its use becomes compulsory. Another way to put it is that even if an IPN proves quixotic, its contribution is in revealing *possibilities* for different infrastructural efficiencies, collective political and economic functions, community-based values, and ecological co-existence (Lukens, 2013: 15).

As a critique then, the IPN hopes to make visible the problematic and excessive ways that our lives are regulated by the design of technical systems, as well as problematize the contingent nature of modern life. It is not a proposal to return to old technologies as a Luddite move, but a challenge to our perceived need for ever-increasingly complex and expensive systems. Human's (technological) communicative needs can continue to grow and thrive, but energy consumption and impact on animals and ecologies, for example, cannot be reduced by simply designing and building more energy-efficient equipment.

The IPN model recognizes that our infrastructures *can* incorporate a wide range of species relationships or entangled assemblages (Haraway, 2016; Tsing, 2015) and recognize the extent to which we *already* live in a multispecies world that is networked, one that generates "different and inequitable relations, circumstances, and experiences among all those involved" (Hovorka, 2019: 755). This evokes the notion of an organic infrastructure as defined by Star and Ruhleder (1996) as one "evolving in response to the community evolution and adoption of infrastructure as natural, involving new forms and conventions that we cannot yet imagine" (33).

The IPN is not without its limitations, for example, in being asynchronous and delay-tolerant. But *all* infrastructures create opportunities and limits, promoting some interests at the expense of others. In the case of the IPN, what is lost in immediacy, synchronicity, and 'newness' is gained in economic, political, operational, and ecological sustainability. As such, the goal of imagining new infrastructural arrangements moves beyond a critique about what it takes to survive amidst political destitution, inevitable decline, or "the possibility of life in capitalist ruins" (Tsing, 2015). It equally moves beyond imagining a post-Enlightenment natural world. Instead, speculating infrastructural (re)arrangements helps us envision new ways of ethical and ecological living and becoming together with animals and

otherkind, allowing us to envision "what kind of form of life an infrastructure is" (Berlant, 2016: 393).

As a co-creation between man and animal, between animal and environment, between man and surrounding ecosystems, the IPN is a co-constituent prototype within which we can act and think with the world rather than against it. Such projects certainly should not be relegated to be of use in remote regions, conditions of extreme poverty, or during crises, nor only in environments as politically and economically constrained as Gaza's. The IPN could work in cities, rural areas and farms, rich or poor, dense or sparse, hard-to-reach or easily accessible (for humans); across state lands, natural parks, and military installations; it can appeal to 'off-the-gridders' and others conscientious of cost and surveillance or the extraordinary amount of energy and resources internet traffic uses.[15] And it is in the Global North where reliance on newer technologies is abundant and used with little regard on the wider ecology where the IPN prototype could make the biggest impact.

The IPN contemplates how an open and participatory form of infrastructural building and imagining can enable new forms of association, building on what Alberto Jiménez (2014) calls the right to infrastructure. "The right to infrastructure allows us to escape the human-nonhuman and epistemology-ontology dichotomies altogether by opening up the agential work of infrastructures as a source (and open source) of possibilities *in their own right*" (343, original emphasis). Recognizing and embracing the interdependence and equality of all of the components of our collective existence is a direction to work towards, rather than an immediate end-goal. The aim is to think towards a wider infrastructural ecology: to traverse and incorporate human and technological needs, infrastructural design, animal rights, and environmental sustainability.[16]

Reflecting on the future of planetary living, Achille Mbembe (2018) writes that

> many are wondering [. . .]: how we should *inhabit anew and share* as equitably as possible [. . .] how should we *re-member* [the planet. . .], put back together its different parts, reassemble it and reconstitute it as an integrated system in which humans and non-humans, physical, chemical and biological components, oceans, atmosphere and land-surface are all interlinked in a grand gesture of mutuality. (5, original emphases).

He is evoking the need of an infrastructural ecology: and approach that considers how we (re)distribute our resources, how we (re)imagine our place, how we (re)configure our concept of growth, how we (re)constitute the organization of our society, and how we (re)generate our entanglement within nature. The IPN is a speculative prototype that is premised on expanding communication and relationality (an outcome which emerges from the activities of various actants across different scales). It is a speculative process of seeing anew, co-engineering new geographical processes, holistically being with what-is and what-can-be, and leading us towards unimagined ends. It is in every sense a prototype: it "never quite reaches closure [. . .] it keeps forking and enabling novel extensions to itself" (Jiménez, 2014: 348). That it begins with solutions specific to Gaza, that it imagines and builds different forms, locations, and relations of movement and mobility from within the world's "largest open air prison," the IPN is a prototype for our collective futures.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Notes

1. Decreasing dependence and complexity here refers to establishing a network that relies minimally on expensive, expert, difficult to manage and to maintain systems. Sovereign signifies maximizing local ability to govern, manage, and maintain the infrastructure, as well as curtailing controls such as in the form of surveillance, capturing of revenue streams, or destruction of infrastructure.
2. I use Gaza and Gaza Strip interchangeably here, although usually the first refers to the city and the latter to the whole enclosed region, which itself is only about 25 × 5 miles. The Gaza Strip is itself a manufactured territorial entity as a result of being sealed and cordoned off in various ways since 1948.
3. Life in Gaza demonstrates the existential need to survive, create, and innovate under the harshest of conditions – echoing what Simone (2018) calls the "rhythm of endurance." Politically, this 'stubbornness' is often pointed out by Palestinians as an illustration of their unbreakable will and the unshakability of the national cause, a term best known in Arabic as *sumud*.
4. In lieu of control on infrastructures and service delivery, for example, both the PA and Hamas enforce their controls and security through restrictive policies of information security, censorship, and the like. For more on the governing framework of Hamas in Gaza, see Baconi (2018) and Tannira (2021).
5. While I am referring primarily to Israeli surveillance, this equally applies to the PA and Hamas.
6. For example, "smugglers, peddlers, independent truckers, women selling cassava tubers at local markets and elephant riders turn out to be just as skilled logistical entrepreneurs as the high-paid experts of multinational transport companies" (Schouten et al., 2019: 782).
7. At approximately 40 kilometers long and 12 kilometers wide, the area of the Gaza Strip is equal to twice the size of Washington, DC.
8. These are the three closest fiber-optic landing points of the internet backbone outside of Israel.
9. For live internet speeds in Gaza and elsewhere see https://www.broadbandspeedchecker.co.uk/isp-directory/Palestinian-Territory/Gaza.html (as I write this, the average speed in Gaza is 9.83 Mb/s, 67.9 Mb/s in the nearby Israeli city of Ashkelon, and 81.6 Mb/s in the New York City).
10. While Egypt comes to mind for popular pigeon-based dishes, the birds are consumed across the region. For a recipe from one of the authors of *The Gaza Kitchen*, see Schmitt, 2010.
11. I have elsewhere detailed geographic and technical aspects and costs of the IPN as well as its possible offshoot industries and contributions (see Author, 2021).
12. Of course the very notion of a network is that it is open and thus dependent and susceptible to external elements.
13. This echoes different – perhaps more predictable – ways of thinking about Gaza as a result of "the Israeli model" of contraction, containment, incarceration, and enclosure. In considering these practices as part of the very contradiction of our modern world, Mbembe (2018) states "Gaza might well prefigure what is yet to come" (12).
14. For a powerful analysis of the animalization of humans and humanization of animals in Gaza, see Braverman (2017).
15. Calculation of energy and resources should include the breadth of renewable and non-renewable energies, transportation, mineral and materials extraction and mining, manufacturing, waste, pollution, electrosmog, etc. necessary for electronic communications (see McKinsey & Co., 2017).
16. I move away from Hilary Brown's (2018) definition of infrastructural ecology, who describes it as a planning framework which "promotes physical and administrative integration across a combination of critical systems: energy, water, sanitation, local agriculture, transport or IT" (188). For Brown, the aim is to transcend the compartmentalized planning that largely informs urban

infrastructure systems, common across engineering perspectives, and instead consider how systems relate to each other and to the whole. In my use, infrastructural ecology is not only thinking and planning across various industrial systems per se, but traversing and equally incorporating human needs, infrastructural design, animal rights, and environmental sustainability.

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