Research Article

Caring for the "Next Billion" Mobile Handsets: Proprietary Closures and the Work of Repair

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Abstract

ICTD is profoundly interested in the "next billion" users and how information infrastructures might provide opportunities for enhancing their life chances. In this article we ask how the concept of care might be generatively extended to the "lives" of the "next billion" mobile handsets. We draw on a growing literature on repair in ICTD and HCI and on theories of care from the social sciences to make two contributions. First, our ethnographic study of mobile phone repair in downtown Kampala, Uganda provides new insights into how technologies are sustained in developing contexts, with a special focus on how independent repair technicians circumvent the proprietary closures that limit their work. Second, we show how attending to care in ICTD contexts can help us locate forms of technical work (here, repair) within wider moral and political orderings. Thinking about repair and care together opens new possibilities for ICTD to engage with the materiality of technologies beyond the points of design, adoption and use the field has more typically privileged.

Introduction

The "next billion" is a common phrase within ICTD (information and communication technology for development), often used to call out the startling growth rates of mobile telephony in developing contexts, particularly within the euphemistically named "bottom of the pyramid" of the world's poorest consumers. We repurpose this phrase to talk about the next billion mobile handsets that will feed this emerging market. Cellphones are globally circulating commodities that are being produced in astonishing numbers: Over 1.8 billion phones were sold in 2014 alone (Gartner, 2014), with over half the world's population maintaining a mobile subscription (GSMA, 2015). Nevertheless, the material lives of these handsets tend to be backgrounded in ICTD literature, as accounts of mobile adoption come to the fore. What might we learn by studying the precarious lives of mobile devices? We approach this question by exploring practices of repair, which we regard as fundamental to the shaping and sustainability of our social and technical worlds. Central to these are relations of *care:* the forms of (often invisible) work and attention needed to sustain welfare, minimize damage and risk, and approach the world around us on the basis of mutual concern and importance. We ask: What would it mean to extend relations of care to material objects in ICTD to the billions of handsets playing a role in this mobile revolution?

This article builds on a growing body of work in ICTD and HCI (human-computer interaction) that has drawn attention to practices of repair in the Global South and other contexts. Repair studies have called out the creative, resourceful, and improvisational work of getting technological systems and artifacts working and keeping them going long beyond their initial points of adoption (Graham & Thrift, 2007; Jackson, Ahmed,

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& Rifat, 2014). They have shown how repair workers contribute to the building of appropriate and resilient infrastructures, which may be particularly important in resource-constrained contexts (Ahmed, Jackson, & Rifat, 2015; Jackson, Pompe, & Krieshok, 2012). More broadly, repair studies have surfaced wider questions around how we live with sociotechnical systems that are always in flux, drawing attention to larger processes of valuation, breakdown, and wastage (Houston, Rosner, Jackson, & Allen, 2017). Through these processes, the materiality of technologies becomes visible in new ways. Plastics, glass, and minerals (often extracted under unethical circumstances) are broken down, repurposed, and discarded, prompting a wide range of environmental justice concerns. ICTD researchers investigating the problem of e-waste remind us that handsets can burn or decay into collections of toxic materials, with the potential for negative impacts on the environment and human health (Lundgren, 2012; Puckett, 2006).

A parallel body of work in the field of science and technology studies (STS) has addressed relations of *care*. STS scholars insist on the (a priori) inseparability of social and material worlds, and therefore, relations of care not only involve humans, but also include the material objects and environments around us (Callén, forthcoming; Denis & Pontille, 2015). STS research demonstrates how care establishes meaningful, practical, and affective relations between people and the material worlds in which they live (Mol, 2008; Mol, Moser, & Pols, 2010). Care as an object of study draws our focus beyond the functional, toward a range of affective connections, attachments, and commitments that may shape and give meaning to the work of providing for, protecting, and maintaining sociomaterial worlds. Repair is not simply a synonym for care; rather, care is an important part of the ethos and organization of repair work. In the mobile phone workshops of downtown Kampala, Uganda, the work of repair is shot through with precisely such extrafunctional concerns as technicians go about restoring phones for their customers: from the pleasure of cracking a difficult case, to the commitment to a job well done, to a professional pride of mastery that operates outside of any immediate economic calculation. At the same time, care can be a burden, as technicians negotiate frustrations attached to the recurrent and indeterminate nature of breakdown and failure. Caring for fragile technologies is often precarious work, as independent technicians piece together small payments for successful repairs into livelihoods subject to the pressures of competition, ambivalent social standing, and an influx of cheap handsets that favor discard-and-replace over repair strategies for dealing with broken or damaged objects. All this unfolds under the mediating influence of protocols, infrastructures, and broader economies, making the forms of care enacted through repair simultaneously local and global in character, recognizing of course that "locality and globalness" can be "effects achieved in and through the discourses and practices of ICT" (Suchman, 2002, p. 140).

This article makes two contributions to the ICTD and wider HCI literatures. The first concerns the role of repair in supporting and extending the lifetimes of mobile handsets: devices that are increasingly at the center of ICTD research, practice, and aspiration. Repair practices build new forms of durability and innovation that maintain and extend the core virtues of access, use, and participation that have long been central to ICTD work. However, in doing this work technicians are confronted with technical and organizational *closures,* measures of control that frustrate repair practices. These may be features directly designed into mobile handsets that prevent technicians from gaining access to phone systems, but they may also arise from wider infrastructural factors relating to the exclusionary organization of the global technology industry. Drawing on empirical fieldwork in downtown Kampala, we show how technicians inventively work around these closures. Our goal here is to highlight the difficulties that independent technicians in Southern contexts experience in accessing the resources that support repair, from spare parts and schematics, to software tools and firmware files that tend to be proprietary—owned and controlled by mobile manufacturers or their sub-contractors.

Our second contribution concerns the bringing together of repair and care as a useful way into the politics of proprietary infrastructures. Given its ethical valences, attending to care enables us to review wider moral and political orderings that are enacted in and through the everyday sociotechnical work of repair. We show how particular closures limit and channel action differentially, affecting independent technicians differently than the "authorized" shops certified by mobile manufacturers or network providers. Thinking along with technicians, through an analysis of their practices, we ask: What moral and material responsibility do ICTD researchers bear toward the next billion mobile handsets and the worlds they will touch? The notion of care thus calls attention to two things at once: the forms of care practiced empirically by the repairers in our study

and the forms of attachment and responsibility that we as ICTD researchers bring to our fields and sites of work. Asking Who cares? and Who receives care? provides a telling window on the complicated socio-technical orders that we engage. Our goal here is not to provide answers, but to activate a broader argument around the contribution of repair to a more ethical praxis with technological objects in ICTD.

The sections that follow begin by reviewing and bridging existing literatures around repair and care. We then turn to two empirical cases. The first compares practices of software repair in the authorized and independent repair sectors of Kampala, highlighting the stark difference in access to tools, knowledge, and materials that mark and separate these two related but distinct worlds. The second case explores the barriers and practices through which SIM locks are hacked and made open to third-party tool developers and technicians. In our discussion we ask how actors in the ICTD space might be persuaded to care differently about repair and problems of proprietary control—where handsets, and the infrastructures that enable them to function, are tightly constrained by manufacturers or network providers. We argue for an activist agenda that establishes repair as a central matter of concern for ICTD research, practice, and policy.

Bridging Repair and Care

Current studies of repair in ICTD owe much to ethnomethodological traditions within sociology, HCI, and the anthropology of work that understand social order as an ongoing performance, sustained through various forms of repair work. Orr's (1996) ethnography of photocopier repair at Xerox has explored the forms of diagnostic work needed to decode failures at the human-machine interface, and the role of "war stories" in sharing symptoms and strategies across the technician community. Henke's (1999) study of building maintenance engineers argued that processes of repair represent essential but invisible ways in which social and material order are sustained, emphasizing how maintenance and repair are moments of learning and of politics, as values and orders are being negotiated and re-made in and through restoration and reproduction.

Later research has shifted toward urban sites in the Global South, where experiences of infrastructural breakdown and the ongoing work of repair may be more prevalent and immediately visible (Graham & Thrift, 2007). Recent empirical studies in ICTD have explored the repair of newly adopted information technologies. Jackson et al.'s (2012) study of ICT repair in Namibia uses "repair worlds" as a theoretical framing to account for the complex ordering of repair practices across actors, sites, and organizational forms, generating insights for ICTD policy. In a series of empirical studies in Bangladesh, Jackson et al. (2014) and Ahmed et al. (2015) have explored collaboration, learning, and innovation in repair, arguing that independent repair economies are key sites for the development of appropriate and sustainable ICT infrastructures.

An important strand of work in HCI and ICTD has sought practical and imaginative links between Global South repair sites and moments of technological design. Jackson (2014) has argued for attention to repair and maintenance as an important corrective to the productivist outlook that tends to characterize research on human–technology interactions, where dominant discourses are centered on developing new innovations. Sites of repair may open up different moments and possibilities in the work of HCI, revealing actors and practices obscured under the field's focus on design and adoption. Wyche, Dillahunt, Simiyu, and Alaka (2015) have detailed the efforts of mobile phone repair workers in Kenya to speak back to technology designers. Rosner and Ames (2014) have explored the possibilities of designing for greater repairability by comparing the infrastructures of repair available to participants in the One Laptop Per Child project in Paraguay and volunteer fixer collectives in the United States. Houston et al. (2016) have articulated "values in repair," calling to light the range of normative and affective values that may be enacted through repair activities in both Southern and Northern contexts.

A parallel literature on care has been developing in the social sciences, where studies of care work have introduced new ways to conceptualize the forms of commitment and affective engagements that are entailed in keeping things working. Feminist readings of the labor of caring (both emotional and physical) have been particularly central to redefining conceptions of care. While continuing to study traditional sites such as hospitals and nursing homes, recent STS work on "care in practice" (Mol et al., 2010) has shown how practical arrangements of care may include nonhumans such as animals and technologies. Mol (2008) has argued that

technologies participate in providing care, and in return, depend on care work. In their ethnography of the Paris Metro signage system, Denis and Pontille (2015) have described how maintenance teams share the responsibility for monitoring signboards for deterioration, and then repairing and replacing those that have decayed or been damaged. Here, care is a matter of concern and an active practice of monitoring and intervening in a system in order to sustain the system itself and its wider relations over time. The decay of materials has become a more troubling process, according to work of Callén (forthcoming). She notes that European electronic waste has often been illegally exported to Southern countries, and the problem has been partially returned through the contamination of imported rice with high levels of lead from the leaching of discarded technologies. Callén uses care as a way to highlight the ethical and political stakes of deciding when and how to let technologies end. She argues that the vulnerabilities inherent in breakdown and repair call for a new ethics of care for the lives of technological objects in light of increasingly globalized systems of production and consumption. This resonates with recent work by Puig de la Bellacasa (2015) that has called for slowing technological timelines to make time for care.

For these theorists, caring is both a practical matter *and* an ethical relation. Care is the moral center that guides action in the world, in responding to other humans and non-humans that are always assumed to be (somewhat) interdependent. This relation is richly articulated by Mol in her study of diabetes management in a Netherlands hospital, and in further theoretical work with colleagues Moser and Pols. Together, they explore care as "a mode, a style, a way of working" (2010, p. 7). This "logic of care" (Mol, 2008) refers to the rationale that illuminates care practices: "what it is appropriate or logical to do in some site or some situation, and what is not" (Mol et al., 2010, pp. 9–10). For Mol et al. care is a practical and collective accomplishment, framed through material interactions in the world. As an ethical proposition, care is also resolutely local in nature, eschewing universalist and rule-giving pretensions in favor of more modest and collaboratively framed ambitions. Care is what we do together to make the world a more livable place: a "persistent tinkering in a world full of complex ambivalence and shifting tensions" (Mol et al., 2010, p. 13). "Care" conjures more acutely than "repair" the stakes of how we organize to take care of the lives and deaths of the technologies that make up the ICTD revolution—or how we fail to. Following the work of Mol et al. (2010), we explore the ethical dimensions of care by focusing on situated material practices, which in turn generate questions about the accountabilities we hold as ICTD practitioners in the lives (and deaths) of devices.

Methods and Field Sites

The sections that follow report on six months of ethnographic fieldwork in Kampala, undertaken iteratively across three years, from October 2010 to September 2012. This included participant observation, with a core set of 21 repair-related enterprises within the downtown area, including 14 repair workshops, three mobile phone dealerships, one on-street broker, one repair school, and one spare-parts shop. During fieldwork, initial access to workshops was facilitated by Makerere University staff and expanded through referral sampling. Repair workers were shadowed as they traveled around downtown on foot, visiting other technicians and spare-parts shops—providing access to a much wider section of the repair ecosystem in downtown Kampala. Outputs from fieldwork included field notes from observation and hands-on participation in repairs, interview transcripts and photographs of repairs in progress. These were coded for themes after each fieldwork segment, allowing for the development and refinement of research questions as the work progressed. All workers and businesses have been given pseudonyms.

To undertake this research, the first author traveled from her home in London to Kampala. This journey traced historical circuits of colonial power. Legacies of language meant that she could speak English with participants, but in translation a layer of participation and meaning was inevitably lost. Taking up residence in repair workshops meant learning to inhabit the identity of a *mzungu* (foreigner, in Kiswahili), as assigned by participants. Mzungu is often used to describe white visitors and is deeply tied to wealth. Relationships with participants were refracted through differences in race, gender, and nationality, which often gave rise to convivial stories about how rites of passage for young people took place here (in Kampala) and there (in the UK). But at times, telling stories about differences also uncovered tense and uncomfortable mismatches of life

chances, opportunities, and mobility. Being mzungu meant accounting for the destructive effects of colonialism and current global inequalities. Paraphrasing Helen Verran (2001), this involved grappling with colonial histories in the making of a new, postcolonial present.

Software Repair in Authorized and Independent Settings

Although the rollout of mobile infrastructure has largely been funded by multinational corporate investment, repair workshops in downtown Kampala operate overwhelmingly as independent, informal, technician-owned microenterprises. In addition to spending time at these sites, we looked for workshops that were organized differently and found four in the downtown area that were divergent in size, ownership, and affiliation. These four workshops considered themselves "authorized" by mobile manufacturers or network providers. *Authorized* is a term used by repair businesses themselves to describe endorsements from other companies, namely mobile manufacturers or network providers. These relationships were often developed to fulfill warranties: the guarantees given by manufacturers and retailers to consumers that any faults with mobile handsets will be repaired (or the device replaced) within the first year of use. Following Mol and colleagues (2010) we argue that they constitute a particular "style" of caring. Warranties regularly form part of mobile marketing, speaking directly to consumer concerns about material fragility. The warranties are intended to catch manufacturing faults and to provide a minimum usage period. As such they constitute a highly visible relation of care among manufacturers, retailers, consumers, and devices.

To fulfill warranties, companies must put in place infrastructures of repair. To perform repairs successfully, technicians require information about phones, knowledge of their patterns of breakdown, and the ability to undertake physically dextrous repair techniques such as cleaning, parts replacement, and soldering. Effective repairs rely on having access to spares, not only material parts, but also digital artifacts such as firmware files. Technicians also require tools, most obviously the hand tools used in hardware repair such as the soldering iron, but also software repair tools that access the embedded systems on the devices. In this sense, repair relies on information and artifacts generated during moments of design and production, however repair can never be fully codified in these resources, as phones go out into the world and fail in multiple and idiosyncratic ways. We take time to elaborate the ties between sites of design and sites of repair that are enacted differently across these four authorized workshops.

Two of the four authorized workshops in downtown Kampala maintained relationships with mobile manufacturers. The first workshop, Servicemob, was the service center of a fast-growing East Asian multinational company, one of more than 70 such centers dotted across the African continent. Here, repair knowledge circulated from centers of design and manufacturing to workshops via migration, as two technicians traveled from the mobile phone factory in China to found the repair facility in Kampala. Employees in the workshop drew on a rich ecology of repair knowledge provided by these founders, including schematics, proprietary tools, and firmware files circulated via the Internet. Warranted repairs were central to this business.

The second workshop, Riftphone, sold and repaired the phones designed by two multinational manufacturers—one East Asian, one European—who provided information about handset design and proprietary diagnostic software to technicians via an online knowledge portal. This included mandatory online repair training courses and a question-and-answer facility for troublesome breakdowns. Riftphone undertook warranted repairs for the authorized brands, but also fixed phones made by other manufacturers, leading to an interesting juxtaposition of authorized and unauthorized practices. In both sites, intimate ties between sites of manufacturing and repair enabled access to proprietary repair resources.

Network providers rather than manufacturers authorized the other two workshops. The third workshop, Cityphone, was a microenterprise of two staff members. It was owned by a Kampalan businessman, who had a small contract to repair network-branded phones under warranty. The final workshop, Repairtech, was the only technician-owned business. It had scaled up from a microenterprise to encompass multiple concessions, colocated in retail stores belonging to the network provider. Whereas Cityphone had access to proprietary software and "dead" sets to cannibalize for parts, Repairtech had no support from the authorizing company. In an inversion of the other sites, this workshop had to pay for its staff to undergo manufacturer-sanctioned training to become authorized.

Outside of these authorized relationships, mobile manufacturers restrict the circulation of information about the design of mobile devices. Most technicians in downtown Kampala, who work independently and informally, did not have access to information from sites of design and drew on different sources to patch together tools, parts, and techniques. In our first case, we draw out the differences between performing software repair in authorized and independent sites. We focus on repair techniques as situated material arrangements, where care for material objects is negotiated. These are not only technical procedures whose success hinges on individual mastery, rather they reveal wider and more systemic dynamics of access to, and exclusion from, repair resources.

The practice of software repair aims to fix any malfunctions, corruption, or errors relating to the software systems on board mobile devices. It usually involves a process called *flashing,* where technicians use software programs, cables, and hardware interfaces to gain access to the phones' embedded systems and then erase the content of the flash memory. After this is done, technicians rewrite a new and trusted copy of the firmware files that correspond to the device, hopefully removing any corruption in the process. *Firmware* refers to permanent software that is programmed into a read-only memory. Firmware is critical to the operation of electronic devices, from guiding the startup of the device and booting up the operating system. The vignette below describes the process of flashing at the manufacturer-authorized workshop Riftphone:

> A phone came in for flashing, so Peter took me over to the computer to show me the system that they used. He connected the phone to the computer via USB. Then he opened the [proprietary] software program, and typed in the model number from the back of the phone into a search box in the software window. Many different releases of firmware for that particular model were listed on-screen. The software also displayed the serial number of the phone, and Peter highlighted the first few digits. He explained that they were to do with the territory of the software release. Firmware was tweaked for different regions, and the newest releases weren't always available in all territories. . . . He selected the correct firmware file and then checked a box on-screen that indicated the phone was completely dead. He told me it was better to rewrite the firmware than to restore it, as this action entailed a proper erase and rewrite and not just an update or overwrite. Then he clicked the Refurbish button and followed instructions given by the software to turn the phone on by holding the power button. The flashing began, and information about the process began to read out on the software log window. (Field notes, August 31, 2012)

Proprietary software tools are produced by device manufacturers to make diagnostic and repair interventions on their phones. When Peter wants to undertake a repair, locating the correct version of the firmware file is straightforward. He simply types the phone's model number into the software search function. If a copy is not already stored locally, it can be immediately downloaded using a wired connection to the Internet.

In contrast, independent technicians take advantage of a small, but highly competitive global market for third-party repair tools that enable access to similar functions. Figure 1 shows a technician called Jason and the third-party tools he has assembled to access the phone's embedded system. The phone in his left hand is connected to two power cables that allow it to boot without a battery. The third cable carries data, linking the phone to the tape-covered hardware device in the center of the photograph. This peripheral is known to technicians as a *flasher box,* or simply, a *flasher.* The flasher contains a programmed circuit, which establishes a connection between the phone and the computer, acting as a hardware interface. On the computer screen, a window is visible. A software program operates with the flasher box and across the assemblage to enable a range of interventions into the mobile phone.

Technicians can use third-party repair tools to access self-test procedures, reset factory settings, rebuild serial numbers, and remove SIM locks (among other functions). However, to flash a phone they must find stable and working copies of the firmware files to be written back onto the phone to complete the repair. Independent technicians lack ties back to design and manufacturing sites and, therefore, easy access to firmware files. Instead they look to two repair knowledge networks: (1) their peers located within walking distance in the downtown area or (2) translocal sites of repair knowledge online, as this brief snapshot of repair action from the first author's field notes illustrates:

> Jason's close friend Ibra came into the workshop with a Nokia 6500 phone. He wanted to flash the phone, but explained that he didn't have the firmware files. He demonstrated the phone's problem: on startup it

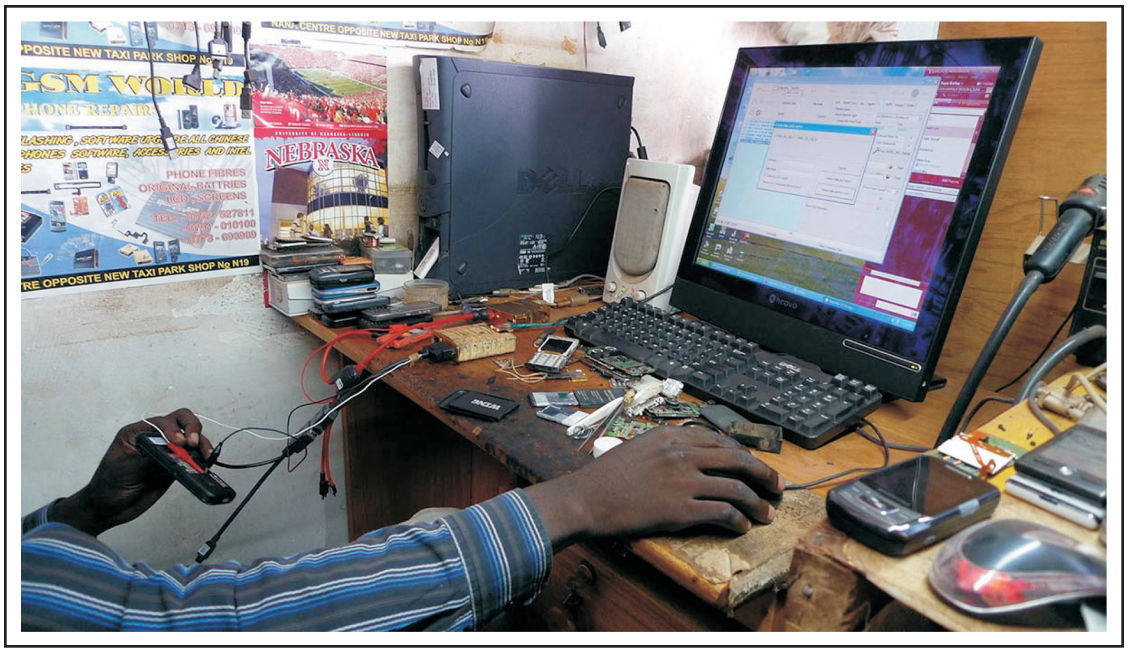

Figure 1. An "independent" software repair tool assemblage, Jason's workshop, May 19, 2011.

> just showed the Nokia logo, and then went black. Jason connected the phone by USB to the Turbo Flasher box, and using options on the software window, he tried to flash the phone using the firmware files that he had to hand on his computer. The rolling software log on-screen notified Jason that this process had failed. He connected the phone to the hardware box using a different connector—FBUS—and tried again, but that also failed. Then, Jason used Windows to search his own computer for other matching files, using the internal model number of the phone "rm-240." He was not satisfied with the search results, and so he went online to the Shrak Mobile firmware file store and browsed through the sections, seeking the latest uploads for the rm-240 phone. Next, he searched on Google for "rm-240 latest flash file" and afterward "rm-240 v10.60" and then "rm-240 v12.35." (Field notes, September 7, 2012)

Independent technicians do not have access to proprietary repair tools and resources. The struggle to locate and download firmware files—particularly in the context of unreliable networked infrastructures—becomes a part of repair work for independent technicians Jason and Ibra. In contrast to the instant access to manufacturer resources available at Riftphone, independent technicians search longer and harder for the same resources. This exclusion drives technicians to participate in collaborative networks. (Authorized workshops also participate in these networks in limited and often clandestine ways.) For independent technicians, peer support becomes a significant part of the infrastructures of repair they assemble—the networks of tools, techniques, and information that they piece together in and through their daily work—as they cultivate a network of colleagues in the downtown area who can assist with difficult repairs or bridge gaps in their knowledge. Sometimes, peer support was given freely between close friends, such as Jason and Ibra, but often technicians subcontract work to others for a small fee.

Independent technicians also take advantage of the circulating copies of firmware files hosted online, which are available through Google, but also hosted on specific repositories such as the Shrak Mobile file store (used by Jason in the vignette above) that are created by technicians for other technicians. This example highlights deeply networked knowledge practices, where infrastructures of repair are geographically distributed and crowdsourced, providing at least partial access to proprietary firmware. Here, infrastructures of repair are not given, but are actively pieced together by technicians in the work of searching, connecting, and collaborating, leading to a different style of care in independent workshops. These two vignettes foreground some of the

Figure 2. Two dead J.A.F. boxes in Gilson's workshop, November 13, 2010.

most significant relations within the mobile ecology in downtown Kampala, which will be revisited in our later discussion on care.

SIM Unlocking

Our second case concerns techniques of SIM unlocking and the third-party flasher tools used to perform the unlocking function in independent workshops. SIM locks are operational restrictions encoded into mobile phone firmware by mobile manufacturers on behalf of telecommunications companies. The SIM locks limit a device's operation to certain networks, providers, or geographic areas. These are a prominent example of proprietary closures, given that the GSM standard otherwise enables the interoperability of devices and networks. SIM locking in Kampala is problematic in two ways. First, the aftermarket for used mobile handsets is particularly significant in developing regions. Mobile handsets travel to Uganda from other places, with their SIM locks intact, through the reselling of used mobiles by recycling companies in the Global North. SIM locking renders these devices useless in Kampala as they have traveled outside of a circumscribed geography, or they remain tethered to a network provider not present in the Ugandan market. If these phones are not unlocked, their useful lives are over. Second, we observed an increasing trend for low-cost handsets to be SIM-locked by multinationals operating in East African markets. SIM locks inhibit the strategy of managing multiple phone numbers used by customers across the Global South to reduce the costs of telephony, which is widely recognized in the literature (James & Versteeg, 2007; Sey, 2010).

Our case study tells the story of one particular flasher box and its accompanying software program, called Just Another Flasher, or J.A.F. This flashing system unlocks Nokia models from the early 2000s with DCT4

architecture. Technicians draw on computers, flasher boxes, software, and cables to remove the SIM locks on the devices so they can work on the Kampalan mobile networks—a form of care for devices that extends their material lives.

Independent technicians described how they relied on the geeks and hackers, who developed the flasher systems, to perform software repairs. They met these tool developers at online repair sites such as the virtual message board known as GSM Forum, which was frequented by all the technicians in our study who had access to the Internet (a total of 11 workshops). To produce unlocking tools, third-party developers must reverse engineer the cryptographic algorithms that protect the SIM locks and embed these into flashers. Together, these software and hardware systems read information held locally on each handset and calculate unlocking codes that are then written back onto the phone.

According to threads on GSM Forum, the DCT4 unlocking algorithm was extracted from a Nokia "authorized" repair tool and then built into a whole generation of flasher systems. Tool developers hack mobile manufacturers' systems to develop ways to remove SIM locks. However, this was not the only form of hacking we saw within this ecosystem. During the first round of fieldwork the first author heard technicians complaining about how their J.A.F. boxes had died. A technician called David explained:

> I thought it had gone just because of electricity problem, just like any other gadget—a shock. . . . When I saw it wasn't responding I had to consult others who get this problem. When I logged in [to GSM Forum] so many people were complaining so I realized it was this MXKey. (Interview excerpt, September 20, 2012)

The piece of malware that "killed" the J.A.F. box was written into the update of a rival tool called MXKey by the MXKey developers. Technicians who owned both devices unwittingly downloaded and installed an update that killed the J.A.F. boxes. The GSM Forum online community of repair technicians was a prominent location where this malicious update link was distributed to technicians. The death of the J.A.F. system raises wider questions about the practical dynamics of opening proprietary closures within this highly competitive market of third-party repair tool developers. It also highlights the instability of repair tools, and the continual change and reworking inherent in practices of repair, in finding and combining new tools to bring about access. These tools were difficult to care for as the systems were fragile and vulnerable to attack. Caring necessitated vigilance on the part of technicians for emerging conflicts within the developer interactions on GSM Forum and other online sites.

As part of wider and ongoing discussions about the development of SIM locking and unlocking technologies, technicians highlighted how SIM lock cryptography was becoming increasingly complex in newer, smarter devices. The SL3 security systems used in Nokia handsets presented a special challenge. A technician called Stephen explained that flasher systems:

> will read what we call the LBF file. That file it consists of the security info, which you have to decrypt to get the unlock code so that's what we do. That's the procedure. We read the file, try to decrypt via using a method like brute forcing. Brute forcing, it will require a more powerful computer with higher processing features and everything. . . . We don't have those supercomputers so we send that file to servers, to people who have so much high-speed computers, they process it quickly and easily and in return you have to pay. (Interview excerpt, September 21, 2012)

This form of cryptography cannot be circumvented locally, but must be subjected to brute force attacks, which require server power that technicians do not have access to. Technicians download the LBF file and submit it to an unlocking service via the Internet, which requires buying expensive credits as payment. This raises multiple challenges for technicians, and the wider repair market in downtown Kampala, as David, a technician and part-time Masters student in economics, explains:

> SL3 has been the most challenging phones we've had, since I joined repair. Because they require codes from the manufacturers or other contractors. So these people require Visa card and all other online money transfer, so that they can get the money first and then they send you the codes, okay. It requires that strong trust in those agents, and these are people that are outside Africa. They are not in our neighborhood that in time, if they mess up with one thing, I can run there and say, "What have you done? You didn't send. I sent

> you this money, you know." It involves a lot of procedure. So that's it. I can't do SL3 unlocking, basically for fear of the risks. I don't know the right people to deal with online. . . . There are those people that are timid, they are risk-averse. Like I'm an economist and I'm risk averse, no? (Interview excerpt, September 20, 2012)

In the case of SL3 phones, SIM unlocking must be performed by actors far outside the local Kampalan market. Technicians like David are excluded from these advanced forms of unlocking because of their inability to confidently access and pay for online repair services, which represents a real limit to their business practice. If breaking through increased cellphone security requires significant computing power, a stable Internet connection, and a reliable electrical infrastructure, independent technicians will continue to be beholden to expensive online services for the foreseeable future. This may prevent a new generation of used smartphones from being adopted on Ugandan networks or being used flexibly across network providers. In this sense, SIM locking may inhibit the potential for the increased range and uptake of mobile applications often highlighted in the ICTD literature.

However, technicians were confident that a local service for SL3 SIM unlocking would eventually be produced by the geeks and hackers within the developer community. Their narratives reveal interesting expectations about breaking into security systems:

> In the future I think [an SL3 solution] will be, because we had SL1, SL2 . . . from SL1 things were not easy, the Nokia programmers, they did so much in that area. . . . We were using test points, it was hard, then they developed a software which can read and write back. So we are expecting the same thing to happen to SL3 anytime. Just because these people are still making money from the market, then they will produce a simpler method. That is the game behind. (Interview excerpt, September 21, 2012)

Stephen frames breaking into the SL3 security system as inevitable, where systems get broken down over time as part of larger trajectories of technological development. However, technicians will not necessarily get access to new technical breakthroughs as and when they occur. Only when outlays on servers have been recouped and when the market slows due to increased competition will there be a greater impetus toward disseminating a more accessible solution for SL3. He comments:

> It's a game because a group of people are making money. For sure people are investing and if someone invests, they expect to get something. If you think you have got enough profit, then he has to release a cheaper one so everyone can use it. So it's a game, and I enjoy that game. (Interview excerpt, September 21, 2012)

In this situation, independent technicians occupy a difficult position: They are restricted from accessing authorized tools and knowledge by mobile phone manufacturers, yet the tools made by third-party developers offer only partial solutions. This case also shows us that it is becoming more difficult for technicians to unlock newer devices, as manufacturers increase the sophistication of mobile cryptography. Unlocking requires advanced tools that are inaccessible to technicians in downtown Kampala and perhaps in many other independent sites across the Global South. This means they risk exclusion from caring for newer devices entirely—or at least until time passes and "the game" evolves.

Discussion

The empirical cases above make visible both the centrality and the complexity of repair work within the wider infrastructures that support and sustain the much-celebrated explosion of mobile telephony in Uganda and the rest of Africa. Our two cases speak to the skilled techniques of assembling and improvising that are central to repair work in downtown Kampala. They also reveal the complex local and global trajectories that sustain repair work, ranging from forms of local collaboration and competition that connect technicians like David and Jason, to the wider translocal networks of knowledge, third-party tools, and crowdsourced expertise that local repair workers regularly draw on in tackling mobile breakdowns. Such findings confirm and extend a growing body of ICTD work that affirms the value and complexity of repair work in Southern contexts, and the deep skill and ingenuity associated with repair under what are in some ways technologically marginalized and resource-constrained environments.

Our findings also speak to the distinct role that proprietary closures play in challenging and limiting local repair work. Our first case illustrates the gap between authorized and independent forms of repair, surfacing problematic dependencies between sites of design and sites of repair. Authorized relationships forge a form of connection between these worlds, facilitating the travel of technicians from manufacturing to repair sites and the movement of repair knowledge through corporate communication channels. Mobile manufacturers and network providers authorize local sites of sociotechnical practice to offer their customers care that has been validated or endorsed by the company. Local practices of getting phones working therefore unfold within wider regimes that incorporate the resources—but also the policies, standards, and interests—of multinational companies. Relationships of authorization are often tied to particular styles of care for devices (Mol, 2008; Mol et al., 2010), such as warranties, where manufacturers or network providers undertake to repair or replace a faulty handset free of charge within the first year of use. This is a common relation of care for devices within the global market of mobile telephony, but it is oriented toward a limited postmanufacturing horizon.

By contrast, stories of software repair in independent workshops present a different set of sites and actors, and different forms of connection. Third-party flashing tools purchased by technicians provide access to embedded systems that would otherwise remain closed. Local peer networks in downtown Kampala and global hosting sites offer the means to obtain the firmware files needed to repair phones. Our research reveals that resources generated in and through collaborative production and peer organization are extremely important for independent technicians, in finding and assembling the tools and files that can work around proprietary closures designed into mobile handsets. In comparing the two organizational contexts and sets of practices, our empirical vignettes raise critical questions about the distributions and possibilities of care at repair sites in downtown Kampala. Although relationships of authorization evince a form of care (for some), they are also exclusionary, giving rise to deeply asymmetric knowledge flows that prevent particular forms of repair from being more widely available. They also protect the power and prestige of (distant) global manufacturers over the interests of (local) users, extending proprietary privilege and control well beyond the point of sale.

Our second case reveals complex patterns of access and exclusion in practices of SIM unlocking. When used devices reach Kampala from elsewhere, SIM locks are artifacts of previous lives that must be removed to allow the phones to work on Ugandan networks. Caring here means repurposing phones that would otherwise be wasted, giving them a second life in the hands of a Ugandan customer. SIM locks are also encountered by customers buying new phones, where caring is about enabling more flexible and affordable practices of use. The story of the J.A.F. flasher and its demise shows how tool developers work hard to circumvent the security systems encoded by manufacturers and to provide technicians ways to remove SIM locks. But this is not a story about heroic hackers who go up against powerful corporations in pursuit of openness for the good of the community. Instead, it is a portrait of an ecology of tool developers, who sometimes hack each other's devices in the pursuit of unlocking algorithms as they seek to make the most of their position in the market. Technicians used the metaphor of "the game" to lay out the different positions played by actors in this space: manufacturers designing more sophisticated cryptography, tool developers working hard to crack it, and technicians as end users trying to navigate unstable tools and a continually changing market. While technicians understood that breaking security systems was eventually inevitable, they also struggled in the short term with the proprietary locks and barriers that limited and sidelined their skills. They are increasingly priced out of unlocking newer smartphones with more advanced security systems, which requires intensive computing power and reliable electrical infrastructures. Heroic hacker (or fixer) stories aside, manufacturers generally remain one step ahead.

Beyond these empirical observations, putting repair and care into dialogue powerfully displays the moral and political orderings of ICT infrastructure—the second contribution of this article. Care shows us how the consumption of technologies is (following Latour, 2004) both a matter of fact—of practical acting in the world—and a matter of concern. Closures in wider infrastructures determine how and when care is withdrawn and devices die, with affective and practical impacts on customers, whose communication practices are disrupted, and on technicians, whose work and livelihoods are challenged. Furthermore, the empirical accounts of repair analyzed here raise wider questions of proprietary closure that structure and subtend the

mobile ecosystem within which ICTD operates. Voices within the field have argued that ICTD has failed to engage with the political economy of mobile telephony, promoting it uncritically as the predominant infrastructure for development. As Gurumurthy asserts, "In its atheoreticism, the discourse studiously avoids any examination of the incumbent mobile telephony architecture—the fact that the mobile phone model is a proprietary network with most applications and services locked in with the network provider" (2010, p. 60). Similar concerns motivate an emerging strand of work on "open development," which is built around open source and open standards. Galperin (2010) has weighed the complex tradeoffs between proprietary investments in mobile infrastructures and the increased access to phone services that they provide. Under such circumstances, attending to the logics and limits of care offers ICTD researchers a way to explore infrastructures as a site of critical work. In particular, a focus on care uncovers the affective and material consequences of infrastructural politics that may be obscured in more abstract discussions of infrastructural standards and architectures.

Care as an analytic lens also poses questions to ICTD scholars regarding the kinds of moral and material responsibilities that we as researchers and practitioners bear toward the "next billion" handsets (and the lives they touch). Care recognizes the wider interdependencies between humans and technologies in a shared environment over the lifetimes of people and devices. Handsets that die and are wasted may emerge as causes of concern, as they may get stripped, burned, or buried, with deep and negative consequences for the health of people and local environments—including, as Callén (forthcoming) reminds us, through forms of physical and environmental degradation and contamination. An ethics of care for materials may help us better recognize human and material vulnerability, arriving at local and good-enough resolutions through processes of patient inquiry and experimentation that may help us turn toward new strategies for sustaining and remaking the ties that matter to us. Mol advocates good care as "tinkering in practice" (2010, p. 13). Tinkering in turn, we propose several implications that might follow if relations of care were moved to the center of ICTD practice and concern.

At the most immediate level, this study adds to calls for repair to be taken into consideration during processes of design and manufacturing. This necessitates designing devices in ways that anticipate the actions required to repair common malfunctions: screwing instead of gluing cases, using standard rather than proprietary fittings, making spare parts widely available for an extended time. Repair relies on a range of embodied skills such as screwing, levering, bending, and soldering. Designers might treat the inner workings of devices as truly user-accessible areas, and mark out more and less attainable tasks based on the complexity of these techniques.

Yet as Rosner and Ames (2014) point out, breakdowns happen in ways that cannot be anticipated at the design stage, suggesting that mobile manufacturers must also intervene in the aftermarket to support wider infrastructures of repair. Manufacturers could contribute to this project by selling their proprietary software repair tools on the open market and providing access to firmware files (if necessary, using licenses to allow for repair). This would lessen the marginalization of informal, independent technicians, enabling them to avoid some of the circumvention work that currently lengthens and frustrates mobile repair in these contexts. It would also diminish asymmetries between authorized and independent repair settings. Such a move would parallel commitments recently undertaken by automobile manufacturers in the United States—inspired in part by Right to Repair legislation in Massachusetts, subsequent Memoranda of Understanding reached with aftermarket groups, and the looming threat of antitrust action against what have been decried as the "repair monopolies" of the U.S. auto industry (Wiens, 2014). Under this arrangement, proprietary repair tools and manuals are being made available to customers and independent repair shops, in the first of a staged series of reforms that will enable access to the internal systems of vehicles from model year 2018.

Finally, mobile manufacturers and network providers could radically rethink the use of artificial limits on technologies such as SIM locking. SIM locks are significant in a model of consumption where the up-front costs of handsets are subsidized, most obviously in mature markets, where SIM locks are linked to contracts of 12, 18, or 24 months. Under such conditions, manufacturers have strong economic logics for SIM locking, but not all markets operate in this way. SIM locking may be ill-suited to a world in which handsets circulate more globally and over longer stretches of time, including as they move into the global mobile aftermarket. These questions around the lives of devices are notable in light of consumption trends in mature markets of

the Global North, where smartphones are increasingly similar in baseline functionality. Discussions of good-enough computing (Crichton, 2014) point toward new modes of consumption organized less around an upgrade culture and more around longer relationships with material devices. Such insights remain partial and exploratory, an example of the kinds of tinkering with care that we believe can open up new avenues and challenges for ICTD research and practice. In this article, putting care at center stage has moved us from empirical insights toward new sites and avenues of advocacy and activism. More generally, thinking with theories of care and repair may offer new and deeper engagements with the rich and necessary interconnections between social and material lives as they unfold and are sustained through time. ■

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