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A Platform Studies Approach to the Role of Technology in the ICTD Ecosystem: The SMS in m4d Interventions

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We have good evidence – not least from widespread adoption – that mobile communications can improve the lives of the poor. Building on this success, interventions using mobile technology to tackle development problems have become common in ICT4D. The short message service (SMS), which works on even basic phones, is a popular platform for mobiles for development (m4d) apps and services.

This paper documents the historical origins and technical characteristics of SMS as a platform for m4d interventions, demonstrating how inherent technological rigidities in the platform combine with creative adaptation, appropriation and re-use to produce a particular set of affordances and constraints. I argue that optimism about the potential for new technologies to contribute to development should be tempered by awareness that the developing world is seldom the intended audience of technology development. Approaches from the social construction of technology – infrastructure studies and platform studies – contribute to a holistic and historicized understanding of the role of technology in the information and communication technology ecosystem.

Keywords: mobile for development; m4d; mobile services; short message service (SMS); ICT ecosystems; platform studies

1. Introduction

Mobile technology allows development interventions in the form of m4d apps and services to reach previously unserved populations, who now have access to communications through basic mobile phones. They can also extend the reach, capabilities and efficiency of social services, with mobile health, education and agricultural support being established sub-fields. Across both the mobile industry and the development community, m4d apps and services represent consensus that, although domain-specific nuances exist, mobiles offer the possibility of scalable, sustainable technological solutions to various development problems.

The World Bank's Information and Communication for Development Report for 2012, explaining the institution's shift in focus from basic connectivity to mobile apps and services, asserts that "mobile applications not only empower individual users, they enrich their lifestyles and livelihoods, and boost the economy as a whole" (World Bank, 2012, p. 3). The GSM Association, an industry trade group representing GSM operators, has programs that promote and support mobile apps and services in the areas of health, agriculture, financial services, job search, community services, disaster response and womens' issues in the developing world. They envisage their role as "Serving the underserved through mobile: Bringing together our mobile operator members, the wider mobile industry and the development community to

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drive commercial mobile services for underserved people in emerging markets” and describe mobiles as “one of the world’s most potent development tools” (GSMA, 2013).

As Gurumurthy (2010) points out, the telecenter era in ICT4D was also underwritten by a widely shared vision of technological promise. Public access computer venues – set up by government, non-governmental organizations or development agencies but often sponsored by information and communication technology (ICT) companies – for a while represented consensus on how to mitigate the “digital divide” (Heeks, 2008). Like its predecessor in the telecenter movement, the m4d intervention consensus has emerged from a constellation of interests and incentives, crystallizing around a particular set of technological possibilities.

The ICT ecosystem is continuously and rapidly evolving. New technologies promise new (better, cheaper) ways for people to communicate, and offer new possibilities for development interventions. At the same time, technology development is not neutral. Low-income users in the developing world are almost never the primary intended users of each new technology paradigm. As this paper demonstrates, even successful technology translation beyond the original design involves a resource-intensive process of re-invention. It is both less certain and more error-prone than the m4d narrative of empowerment through access. Feenberg (2005), citing Marcuse, reminds us that “the choice of a technical rather than a political or moral solution to a social problem is politically and morally significant” (p. 49). A consensus that relates technology to development in a discursively consistent way – as instrumental, a tool without prior inscribed meaning and part of a solution to an independently existing problem – is therefore politically significant.

In arguing for a “social process,” “human-centred,” “social constructivist” model of technology in development, May, Waema, and Bjåstad (2014) recognize that technology needs to be understood in relation to social systems. Ethnographic studies of mobile adoption and use often use social constructivist approaches to understand the practical and symbolic affordances of the mobile phone to a particular group of users. However, Burrell (2012) also demonstrates the value of “strong materialism” which seeks to understand how people construct technological worlds, but holds the technology central because of its relative persistence in space and time. In m4d, mobile technologies are the central organizing idea of a broad range of development interventions. A technology-centred perspective – one which takes into account the historical development, social and institutional arrangements and specific affordances of mobiles as a platform for m4d apps and services – is a necessary component of an ecosystems perspective on m4d.

This paper takes a technology-centred perspective on the short message service (SMS) as a platform for m4d apps and services. Using concepts and methods from infrastructure studies (Star, 1999) and platform studies (Bogost & Montfort, 2007), I describe the historical development of SMS alongside examples of innovation and appropriation in m4d SMS services. The findings identify affordances and constraints that arise from this combination of “embodied” structure and “emergent” properties (Orlikowski, 2000).

2. Background

From 2005 to 2013, the number of mobile cellular subscriptions globally more than tripled, from 2.205 million to 6.835 million (International Telecommunications Union, 2014). Developing countries were largely responsible, with 1.213 million subscribers in 2005 increasing to 5.235 million in 2013. In 2003, the number of people with voice service on the continent having doubled over the preceding three years, and the International Telecommunications Union (ITU) began to refer to Africa’s “mobile miracle.” In 2008 the Economist described the mobile phone as “a potent force for economic development in the world’s poorest countries” (“Halfway there,” May 29 2008). Aker and Mbiti (2010) characterize the discourse on

mobiles and development as “a great deal of speculation and optimism,” sustained by both the apparent potential of mobile technology and its unprecedented diffusion.

Widespread adoption by users at the “bottom of the pyramid” (Pralhad, 2006) demonstrates that mobile phones are desirable and accessible to the poor. Over the last decade, research has provided further evidence of development impacts. Increased mobile penetration has been linked to economic growth (Waverman, Meschi, & Fuss, 2005). Mobiles have been shown to improve the livelihoods of various groups of small traders and entrepreneurs in the developing world (see review in Donner & Escobari, 2010), as well as the effectiveness of individuals’ job search (Samuel, Shah, & Hadingham, 2005), self-reported life satisfaction (Goodman, 2005) and their ability to maintain economically important social ties (Diga, 2008). By making it possible for previously disconnected groups to disseminate information and communicate rapidly and across distance, mobile phones have also been implicated in sustained, large-scale popular mobilization (Castells, Fernandez-Ardevol, Qiu, & Sey, 2007).

As the market for voice and text messaging becomes increasingly saturated and high-bandwidth data services begin to encroach on operator profits, value-added apps and services are increasingly seen as the natural evolution of the mobile network operator business model (World Bank, 2012). Mobiles apps and services have also been embraced by the development community as a way to reach previously unserved populations, who now have access to communications in the form of basic mobile phones. Unlike their predecessor in telecenters – beset by hardware failures, low user numbers and sustainability problems – mobiles offer an established user base, reachable at a distance through a device that users own and manage themselves. The example of Kenya’s m-Pesa, an operator-owned mobile money service with over 14 million users in March 2012 (Safaricom, 2013), is near ubiquitous in discussions of the potential for market-led development through mobile apps and services.

Work on m4d apps and services has also considered whether mobiles can contribute indirectly to development by improving the quality, affordability and accessibility of social services. For example, mobile reminder services for community health workers have demonstrated efficiency and care quality benefits (DeRenzi et al., 2012). However, downstream impact is predicated on incorporating the community-based care model into the health system (Estrin & Sim, 2010). There are also few cost-benefit analyses on m4d apps and services as development interventions (Rashid & Elder, 2009).

As yet, therefore, there is limited evidence to support strong claims about the development potential of m4d apps and services. Youth-oriented social networking (Kreutzer, 2009) and (in some countries) mobile money demonstrate the potential for widespread use among some groups of low-income consumers, but many questions remain. A survey of low-income mobile users in Bangladesh, India, Pakistan, the Phillipines and Thailand (Zainudeen & Ratnadiwakara, 2011) found very low levels of mobile service use, and only slightly greater awareness of mobile services. The same study reports that those that do use mobile services are generally better connected (most of their contacts have a phone) and more technologically savvy (they are also Internet users). Research ICT Africa (2012) found similarly for low-income users in South Africa, with notable use of social media and chat services among (particularly urban) youth but little use outside this group.

Equity issues in particular are cause for concern. Kang and Maity (2012), Velge (2013) and Dodson, Sterling, and Bennet (2013) document multiple barriers affecting access to more-than-voice services for low-literacy users, particular low-literacy women, older people and the very poor. Kang and Maity (2012, p. 18) note that among their survey respondents, non-use was attributed to “technical or cognitive usability rather than the commonly-assumed structural problems such as affordability or literacy.” Voice services using interactive voice response are sometimes developed for users who are prevented from using text-based systems effectively,

but usability problems such as documented by Lerer, Ward, and Amarasinghe (2010) support the notion of multiple barriers as an equity concern.

Research that promotes good practice, documents challenges and identifies lessons for new m4d apps and services is valuable and increasingly available, augmenting an established body of work in ICT4D. At the same time, a pragmatic perspective on mobile technology risks obscuring persistent structural limits. The historical origin and technical realization of SMS give rise to specific affordances and constraints as a platform for m4d apps and services. Documenting these identifies the uneven translation of Western technology to the developing world as a persistent structural limit in the ICT ecosystem.

3. Conceptual framework: infrastructures and platforms

3.1. *The mobile network as infrastructure*

Mobile networks can be conceived of as infrastructure, as defined by Star (1999). Star's idea of infrastructure is holistic and integrative, appropriate to an ecosystems approach. It accommodates complex interactions between people, institutions and technologies, and can do so at different levels simultaneously (Horst, 2013). In relation to development, treating technology as infrastructure is useful because it can trace power through multiple sites. For mobile networks this includes the social, economic and political context in which standards, architectures and implementations have developed as well as local innovations and appropriation by users.

Understanding a technology system as infrastructure implies deep embedding in social practices – a state of being “sunk into and inside of other structures, social arrangements and technologies” (Star, 1999, p. 381). In addition to embedding, Star's definition of infrastructure requires transparency, such that users do not have to consciously “assemble” or “reinvent” the technology system for each task. Further, an infrastructure must have spatiotemporal reach beyond a single site or event (p. 381). Mobile networks, with global reach, widespread use and ubiquity in daily life, clearly meet this definition.

Mobile networks are both analogous to, and constructed in relation to, physical infrastructure such as the electrical grid, road networks and international telecommunications cables. Being “built on an installed base” (p. 382) enables and constrains an infrastructure in particular ways. Mobile phone networks provide unprecedented coverage to large parts of Africa, but the location of base stations is constrained by road accessibility and available electricity supply. Furthermore, a technology system can operate as infrastructure for some groups but not others. Functions such as text messaging may become intuitive (perhaps ultimately transparent) for those with basic literacy, but exclude those without. As feature-phone users with greater resources and technical skills move away from text messaging apps such as WhatsApp, and social networks such as Facebook, new infrastructures establish new patterns of exclusion.

There is no “greenfields” site for infrastructure development, and the process cannot be understood without historical, technological and social context. Star and Griesemer (1989, p. 390) liken the process of becoming infrastructure to a progressive “funneling” of interests – “reframing or mediating the concerns of several actors into a narrower passage point.” Once a passage point is passed, alternative design possibilities appear increasingly closed off. Eventually, a technology system becomes stabilized, an embodiment of the actors and interests that shaped its evolution. For example, the failure of the Wireless Access Protocol, which attempted to transition the mobile network to an open platform for mobile services, had as much to do with operator and manufacturer reluctance as technical limitations (Funk, 2007; Palomäki, 2004). As a result the mobile network “walled garden,” in which mobile operators acted as gatekeepers to content and services, persisted for many years.

Looking at the mobile network as infrastructure implies a focus on technology, but it is not a technologically determinist position. Layered over the “embodied” structure of the mobile network also “emergent” properties that are defined and redefined through use (Orlikowski, 2000). This is evident in the user-driven innovation literature (Bar, Pisani, & Weber, 2007; Horst, 2013; Sey, 2008), which describes how users and designers have worked around the limitations of mobile networks in interesting, creative and sometimes instrumental ways. However, the technological optimism of ICTD has tended to focus on adaption, appropriation and the potential or “emergent” properties for development rather than critical accounts of the histories and relationships embodied in the technology itself.

The taken-for-granted nature of infrastructure requires explicit work in order for this embodied structure to be made visible. Interrogating the technology platforms that are commonly used in ICT4D interventions is one way to do this.

3.2. *Studying technology platforms*

Bogost & Montfort (2007, p. 1) definition of a technology platform provides a way to conceive of the specific relationship between mobile networks as infrastructure and m4d apps and services. The platform is “whatever the programr takes for granted when developing, and whatever, from another side, the user is required to have working in order to use particular software.” Montfort and Bogost (2009) point out that platforms generally exist in layers – for example, a personal computer comprises a hardware platform on which an operating system is layered, on which execution environments for programs written in high-level languages such as Python or Java depend in turn.

Here, I choose to examine the mobile network as infrastructure for mobile services by defining the shared technology protocols that define how devices structure, display and solicit information from the user, and communicate with the mobile network as platforms for m4d apps and services. While this paper covers SMS, unstructured supplementary service data (USSD), the mobile web and mobile apps are other examples of technology platforms on mobile networks.

Montfort and Bogost’s (2009, p. 3) intention for platform studies is to examine “how the hardware and software of platforms influences, facilitates or constrains particular forms of computational expression.” This requires a technically detailed focus on the features of the platform itself, and on how they have been exploited (or subverted) by the digital artifacts that build on them.

Understanding a platform as infrastructure also considers how the platform was developed and came to be adopted, and how particular design decisions came to be made. As Star and Griesemer (1989) demonstrate, studying the process of becoming infrastructure is an attempt to open the “black box” of a technology and expose the actors, relationships and interests that led to its existence in a particular form. Neither the historical and relational background nor the technical characteristics of the platform define what can be built on it – creative appropriation is always possible. However, both influence how designers, and in turn users, encounter it.

Combining platform studies’ emphasis on technical detail with the contextual focus of infrastructure studies makes it possible to consider not only how the platform interacts with material forms of m4d apps and services, but also the discourses of development in which they are embedded. Promoting a technology system as a platform can function as “discursive work” that attempts to funnel diverse interests into the particular interactions it supports (Gillespie, 2010 p. 347). Together with the accumulated embodied structure and emergent practices of users, discourses and interpretation “format” (Maurer, 2012, p. 594) the m4d ecosystem in consistent ways. Having identified a discursive formation in the m4d consensus, the remainder of this paper identifies embodied structure and emergent practices, and their implications for designers and users of m4d apps and services.

4. Research design

Infrastructure is by definition difficult to study. It is obscured by familiarity, and exists in relation to people, technologies, organizations and institutions, and other infrastructures. It is “messy” and “boring” (Star, 2002, p. 109). It extends across space and time, defying a clearly bounded field site, but is encountered through local and specific interactions.

Research on infrastructure is usually ethnographic in the sense that it is oriented toward observation and explanation, rather than hypothesis-testing, and to sense-making through the convergence of detail (Star, 2002). While no particular method is prescribed, historical research and documentary sources feature prominently, often supplemented by interviewing and observation. In the sections that follow, documentary evidence about SMS, gathered through literature search, comprises the bulk of the primary sources. This includes explanatory and educational material on the design of the GSM network, and accounts of the history of SMS such as those found in Acker (2014) and Hillebrand (2010). In addition to academic work, technical overviews of the architectures developed in various GSM phases were consulted, as well as a particularly thorough account of the standards-setting process (Hillebrand, Rosenbrock, & Hauser, 2013) sponsored by the European Telecommunications Standards Institute (ETSI). I also examined the ETSI standards database (<http://www.etsi.org/standards>), which contains the full text of all GSM standards.

To understand how m4d apps and services have innovated within the constraints and affordances of SMS as a platform, I examined mailing lists for popular m4d SMS tools including and RapidSMS and FrontlineSMS, as well as the ICT for Community Health Work (ict4chw) list and the (now defunct) mobileactive-discuss. I have also drawn on personal experience implementing SMS services in South Africa. Finally, an inventory of m4d apps and services drawn up in 2013 by the GSM association (GSMA, 2013), and my own inventory effort on m4d apps and services in South Africa, including around 20 SMS services operational in the last five years, provided examples of practice.

5. SMS as a platform for m4d services

SMS is a popular choice for m4d services because of universal handset support, extensive coverage over all operators and handsets and (relatively) low cost. Two-way messaging via SMS was a largely unintended success. The original design anticipated that most use would fit the far narrower “paging” model of operator to end-user messaging, analogous to pager devices that were popular in Europe at the time (Hillebrand, 2010). The “paging” use-case of SMS was intended for notifications from a network operator to their own users. For example, an early use of SMS was to notify a user of a waiting voicemail (Hillebrand, 2010). Another proposal was to add SMS sending capabilities to full-keyboard terminals like the Minitel device in use in France (Hillebrand, 2010, p. 37), which would allow end-users to send SMSs to mobile devices. Users were not expected to type and send SMSs themselves, not least because of the difficulty of typing on the numeric keypads common on phones at the time (Taylor & Vincent, 2005).

SMS was also anticipated mostly as an in-network service. As person-to-person messaging grew in popularity, inter-network messaging was accommodated through protocols designed for roaming (Holley, 2010, p. 94). Third-party access to operators’ SMS infrastructure was an afterthought, however (Harris, 2010, p. 112), with resulting lack of standardization across operators and equipment manufacturers.

Each of these design factors has implications for m4d apps and services built using SMS. SMS has been immensely profitable for operators, with a near-zero marginal cost due to its use of an existing control channel for message transmission (Song, 2009). At the same time, third-party access, which is required by any m4d service not run by a mobile operator directly,

has been layered over the SMS system in non-standard, operator-dependent and sometimes convoluted ways. The sections that follow cover various technical issues commonly encountered by m4d apps and services using SMS, tracing their origin, mitigating strategies and implications.

5.1. Message transmission

Message transmission for third-party-originated, mobile-terminated SMS (in which a third-party service sends SMSs to users on one or more networks) is relatively straightforward because it mirrors the person-to-person case. The network components involved are shown in Figure 1.

In the person-to-person case, the sender’s message is delivered to the recipient via a component called the short message service center (SMSC). Every network has an SMSC, but message delivery from sender to recipient is the responsibility of the SMSC on the sender’s network. The sender’s SMSC obtains routing information for the recipient from the home location register component on the recipient’s network (Holley, 2010, p. 95), and then tries to deliver the message to the mobile switching center (MSC) on the recipient’s network, which passes it on to the base station at the recipient’s current location, which in turn transmits it to the recipient’s mobile device. The SMSC handles retrying the message if it cannot be delivered immediately, continuing either until the message is delivered to the MSC or the validity period expires (Acker, 2014, p. 565).

The sender is billed by their own network, which in any case has no contract with the recipient or the information required to bill them directly (Harris, 2010, p. 112). With the exception of services requiring very large concurrent messaging volumes (such as emergency alerts), third-party services can send mobile-terminated SMS using the same network infrastructure as person-to-person messaging.

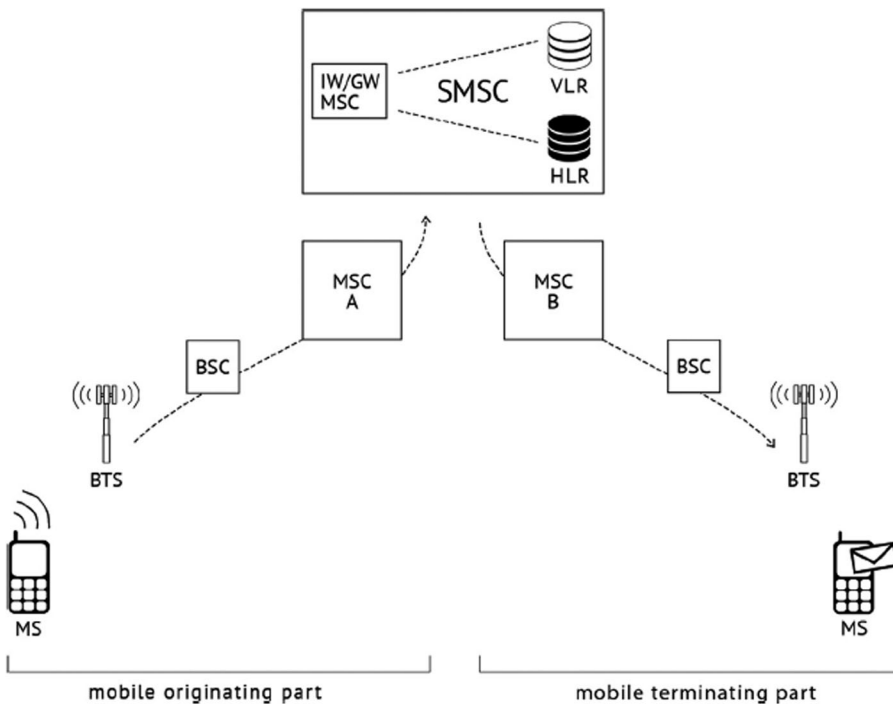


Figure 1. Person-to-person SMS transmission (Acker, 2014, p. 565).

To transmit SMSs to the relevant SMSC, third-party services generally employ a Wireless Application Service Provider (a WASP, also called a value-added service provider) – a company that maintains a direct communication link to the SMSC of one or more networks, with which they also have a billing agreement. Figure 2 shows the relationship between third-party services, WASPs and networks.

Commercial WASPs such as Clickatell and BulkSMS allow third parties to send SMSs through online and desktop software well as by connecting to application programming interfaces. Dealing with a WASP gives third parties access to discounted bulk messaging rates, and also makes it possible for a service to send messages across operators and even across national borders provided all the operators concerned have an agreement with the WASP.

Third-party services that need to receive incoming messages from end-users face a more complicated situation. As part of the GSM architecture, the sender’s SMSC is defined as being able to handle a special class of SMS addresses called shortcodes or short numbers, which are generally five or six digits long (for more on shortcodes see Brown et al., 2007). Shortcodes can be configured in the SMSC to forward messages to an external address, such as a WASP’s SMS gateway. Messages sent to shortcodes are charged either at normal SMS rates or at higher premium rates, with revenue from premium-rated SMSs being shared with the WASP and the third-party service provider. SMS donations, premium services such as horoscopes and competition entries are usually handled in this way (Vodafone UK, 2013).

The major drawback of shortcodes and other network-defined special numbers is that they are configured in a specific operator’s SMSC. Since only the sender’s SMSC is involved in message transmission, incoming SMSs to special numbers must be handled within the sender’s own network. This means that for a special number to work on multiple networks, it must be set up separately with each operator. A voluntary industry agreement has been established in many countries to overcome this technical issue, with operators agreeing on a shared system of common shortcodes available to third parties by application or through WASPs (Brown et al., 2007). Common international shortcodes would require similar agreements.

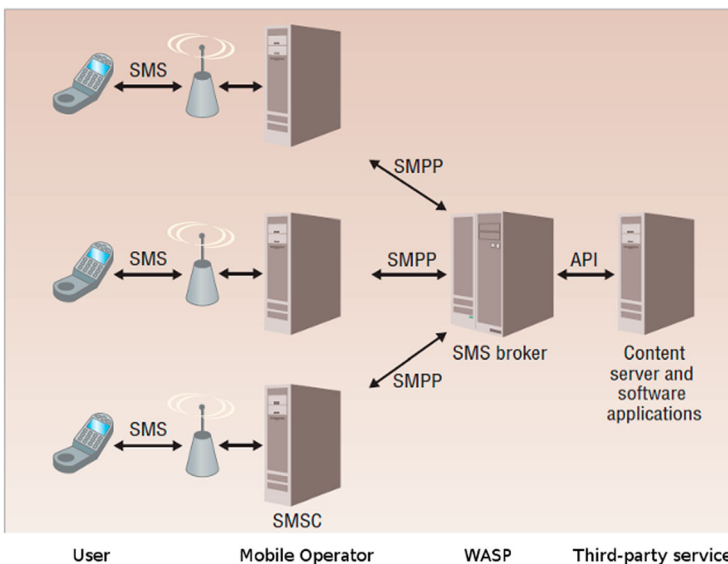


Figure 2. Third party – WASP – operator relationship. Adapted from Brown, Shipman and Vetter (2007, p. 108).

To mitigate the limitations of shortcodes, mobile operators in a few countries implement a specialized network component that mimics the message delivery infrastructure of the recipient's mobile network in the person-to-person case (Harris, 2010, p. 113). To the sending network, the "virtual mobile number" provided by this service appears to operate as a standard mobile number on the receiving operator's network. Operators can then rent the virtual numbers to WASPs and/or third-party service providers. Even in countries where shortcodes are supported by all operators, virtual numbers may be preferred for some purposes because they are internationally accessible (albeit at international rates for subscribers outside the country).

Issues receiving incoming messages are a common consideration for m4d apps and services. There are multiple African countries without any operator-independent options for mobile-originating messaging (Pottier, 2011). For services that require multi-country coverage, the problem is compounded by country-specific WASPs. WASPs need to maintain service agreements, payments and technical interoperability separately for each operator, and most have limited geographical coverage as a result. m4d apps and services requiring multi-country coverage will generally need to deal with several WASPs, applying and paying separately for shortcodes or virtual numbers in each country where they are available.

Operators and their partner WASPs also control the allocation and regulation of special numbers to third-party services. Requirements may include minimum usage levels, cost-to-user restrictions and restrictions on content deemed objectionable by the service provider. Unlike web-based services, where data transmission is content-neutral, content restrictions from mobile operators can be quite onerous (Brown et al., 2007). In the USA, for example, Verizon's terms and conditions for SMS services at one time prohibited not only adult content and profanity but information about organ transplants, adoption services and copyright protection circumvention, and speech that "trivializes historical events" (Lasar, 2008).

SMS services targeting low-income users in developing countries – particularly in the pilot phase – are sensitive to the financial and time cost of the shortcode or virtual number application process, as well as geographical coverage limitations and possible usage minimums. Two alternative strategies for receiving incoming messages are popular in the m4d community. Both involve procuring a SIM card for one or more mobile networks in the country where the service will operate, which is used to send and receive messages directly rather than dealing with a WASP.

In one strategy, popularized by desktop applications such as FrontlineSMS, the SIM card is inserted into a phone or a specialized hardware device called a GSM modem, which is connected via a data cable to a computer that processes messages. A more recent variant involves receiving and processing messages on an Android smartphone. The advantage of both approaches is that they require no operator or WASP involvement, and can be set up quickly and cheaply. However, both work only for low message volumes, as SMS throughput is low on phones and only slightly higher on GSM modems. Some operators also technically prohibit (but seldom shut down) automated devices that send and receive messages on their network.

Another strategy, used when no local WASP is available in a particular country but high throughput, reliability and a local number are required, involves procuring a local SIM card that is enabled for international roaming and then housed in an international WASP's data center. End-users sending messages to this number pay local rates, but the service operator pays for hosting in the data center as well as additional roaming charges.

5.2. Billing

Issues related to SMS billing – specifically, managing the cost of messages to end-users – also particularly affect m4d services. SMS billing options vary between mobile networks. Mobile-originated billing (the end-user pays to send an SMS) and mobile-terminated billing (the end-

user pays to receive an SMS) are commonly available and widely used commercially. Numbers that use so-called reverse billing, or other options for free-to-user SMS with the cost assumed by the receiving third-party service provider, are much harder to find. Where they do exist, they must be negotiated and configured per operator. There are also unresolved concerns around abuse of reverse-billed numbers. WASPs in South Africa are still hesitant to offer reverse billing despite its being introduced by Vodacom in 2012, as the WASP through which the reverse-billed SMS number is provisioned also has to accept responsibility for all SMSs sent to the number (Muller, 2012).

Difficulties with reverse billing and other free-to-user options are part of a general history of ad-hoc arrangements for SMS billing. Once mobile operators realized that person-to-person messaging was becoming popular and profitable, it became necessary to establish technical interoperability and billing procedures. Technical interoperability was achieved using an existing messaging infrastructure designed to handle roaming users (Holley, 2010, p. 94). Billing procedures were based on the realization that only the SMS sender's network had sufficient information to bill for the message since the sender's SMSC delivers to the recipient directly (Harris, 2010, p. 112).

Agreements among operators to deliver messages from other networks might take the form of a monthly reckoning (Le Bodic, 2005, p. 58), or (as was until recently the case in South Africa) an agreement not to charge for delivering messages from other networks since person-to-person traffic is roughly symmetrical (McLeod, 2013). Application-to-person traffic is not symmetrical, however, and operators may either opt to only deliver application-to-person messages to their own subscribers, or they may attempt to identify and charge a fee to other operators for application-to-person traffic terminating in their network. The first scenario is most common, and again leads us to the likelihood that users on different networks will require separate negotiations and technical accommodations for third-party access, particularly where a special request, such as reverse billing, needs to be entertained.

The low commercial priority of free-to-user SMS makes sense because outside of m4d, there are few business models where the cost of sending a text is a barrier to use for the intended market. WASPs concentrate on standard and premium-rated SMS, attracting third-party services whose users are either indifferent to the cost of an SMS or willing to pay premium rates for a service (or as a donation). m4d services, on the other hand, often need to solicit information from prepaid users with little or no airtime and significant price sensitivity. They are forced to negotiate free-to-user SMS numbers with operators individually, and frequently fail to obtain them.

One alternative, generally found in SMS data collection projects, is to arrange to automatically reimburse senders for the airtime they use to submit data. This depends on third-party services being able to access an operator's online credit purchase mechanism in an automated way. Another strategy is to provide a pre-defined amount of airtime to service users earmarked to send messages to the service (ict4chw, 2010). Neither strategy solves the problem of providing access to the service for users with no airtime credit. Additionally, neither is really scalable beyond a pre-defined group of service users who have an ongoing relationship with the service, usually as part of their job.

For larger groups of unknown or once-off users, free-to-user channels such as USSD or "please-call-me" messages sometimes replaces the mobile-originating SMS as a means for the user to initiate contact. Services with this configuration reply by SMS, but simplify the billing problem by sending rather than receiving SMSs. The Mobile Alliance for Maternal Action (MAMA), a service that provides health pregnancy tips via SMS to pregnant women who sign up for the service via a USSD code, is one example of this model (Praekelt Foundation, 2013). At least in South Africa, where the MAMA SMS project operates, simple USSD codes

and “please-call-me” messages are relatively well-used even by mobile users who do not send SMSs (Velge, 2013), making them a cheap and accessible way for users to initiate contact without incurring SMS costs.

5.3. *Message content*

Text encoding for short messages was based on an alphabet designed to provide a regional paging system for Europe. The encoding makes provision for a basic 7-bit Latin alphabet and the most common extension characters in major European languages, with the latter replacing control characters in the base character set (Trosby, 2010). This choice, combined with the maximum message size possible in the selected SMS transport protocol (MAP), gave a message length of 160 characters. Unicode was by that time the standard approach in information technology, but Holley (2010, p. 94) notes there existed “very little exchange between telecommunications and information technology experts,” which partly explains the unusual choice for the original encoding.

With several countries in Asia and the Middle East becoming significant GSM users, provision for Unicode support was added to GSM in 1996 (Hillebrand et al., 2013). Non-Latin alphabets were accommodated using a 16-bit Unicode character set. Since each character now required double the number of bits to encode, messages in non-Latin alphabets are restricted to 70 characters. This problem is partially ameliorated by SMS concatenation standards, which make it possible to send a message over several SMSs (Hillebrand et al., 2013).

Mobile device support for regional languages varies by device and by region. While most phones sold in a particular region should support major regional languages, “gray market” phones and older phones may not. In India, phonetic equivalents in the Latin SMS alphabet are so common that Vodafone India offers a “vernacular SMS” service. Users send the phonetic equivalent of the message and the language they require to a shortcode, and receive the Hindi, Gujarati or Marati equivalent as a picture message to forward to their chosen recipient (Vodafone India, 2013). SMS services operating in countries where a regional language uses non-Latin alphabets still need to decide whether to choose a non-Latin alphabet and risk some recipients not being able to read the message, or to attempt a phonetic equivalent. Dodson et al. (2013) document multiple issues with language support, gray-market phones and basic difficulty with SMS symbols and abbreviations among low-income users in Morocco. They conclude that in communities outside the narrow linguistic paradigm of the mobile network infrastructure, users “are acutely aware that simple phones are not simple to use.”

5.4. *Security*

Third-party services using SMS must consider that the technical specification of SMS makes no provision for message encryption once the message reaches the sender’s SMSC. The message passes through the sender’s network and the recipient’s in plain text, and can be intercepted or filtered in real time by an adversary with access (authorized or unauthorized) to mobile operators’ systems. Most commonly access is established within operators’ networks, but for many years communication between operators over the Signalling System 7 (SS7) network was unsecured except for the assumption that only legitimate operators would be able to obtain the required hardware and software to access the network. Once Internet connectivity became a cheaper and more reliable option than specialized networks, SS7 over IP (Internet Protocol, essentially SS7 over the Internet) became the preferred mode of telecommunications interconnectivity, opening the vulnerable SS7 network to exploitation in principle by anyone with an Internet connection (National Communications System, 2003).

SMS filtering under repressive regimes has been reported in several countries, and confirmed in Syria in 2012 (Elgin & Silver, 2012). The filtering tools involved in the Syrian case are technically identical to those commonly employed by operators to reject unauthorized messages and filter SMS spam coming into the SMSC, blurring the line between legitimate and contested use.

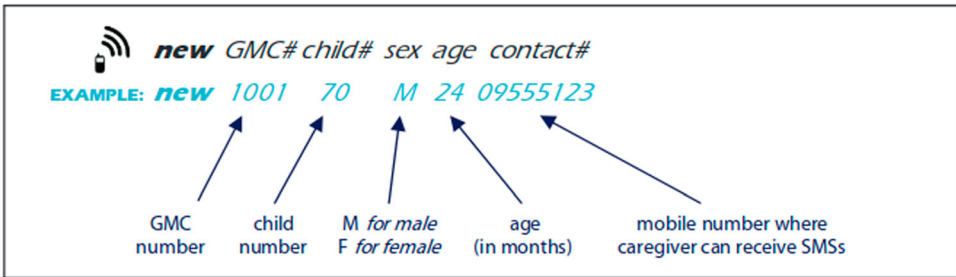
As well as intercepting and filtering, SMS services are vulnerable to impersonation. The GSM standard makes provision for senders to specify numeric and alphanumeric sender IDs as part of the message content. Third-party services routinely do this to identify themselves and provide a reply number. Third-party services are generally required to agree to a particular sender ID, but the message as displayed to the recipient (or the receiving network) provides no way to positively identify the sender.

For many m4d SMS services, security issues are a lower priority than access, and SMS is still an appropriate choice. However, the plain-text transmission of message content and the difficulty of verifying senders' identity may run afoul of legal requirements for certain operations, such as transmission of medical records or financial data. Given the possibility of government interception and filtering, services that solicit or deliver politically sensitive information may also choose to avoid SMS.

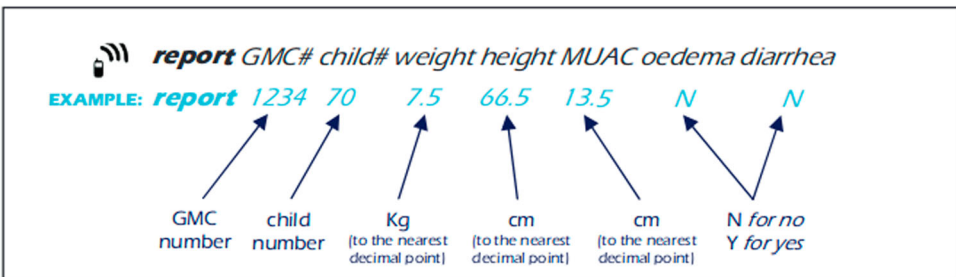
5.5. Structured data collection

Structured data collection applications using SMS have been a site of particular innovation in m4d services. Services that rely on automated data processing and aggregation, including mobile data collection, often require structured rather than free-text data. Because it is available on any phone, SMS has been a popular choice for structured data collection in m4d communities of practice. SMS polls, where users might text a word or a numeric choice to a shortcode, are a simple example.

For mobile data collection applications, multiple data points, such as a newborn's weight, sex, date of birth and location, can also be collected in a single message written in a predefined



Example of RapidSMS text message for registering a child



Example of RapidSMS text message for reporting child measurements

Figure 3. Structured SMS for data collection. Source: Blaschke et al. (2009).

format. The example in Figure 3 shows structured data collection for a nutrition program run by UNICEF in Malawi.

It is also possible to send several SMSs in sequence as a multiple-question “script.” However, SMS was designed as a “store-and-forward,” “best-effort” system without delivery guarantees. Data collection systems are vulnerable to problems with messages arriving out of order or not at all, which are most severe in places where mobile network coverage is inconsistent (Harris, 2010).

Structured data collection requires both basic literacy and keyboard dexterity on the part of the mobile user, as well as careful data entry every time a message is sent. User training and monitoring of SMS errors may improve accuracy among a pre-defined user group. Nevertheless, error rates for SMS data collection have been cited as cause for concern in two studies, both testing reporting of healthcare information by users in the developing world (Haberer, Kiwanuka, Nansera, Wilson, & Bangsberg, 2010; Patnaik, Brunskill, & Thies, 2009). In both cases, users reported using SMS for person-to-person communication, but struggled at times with structured data collection.

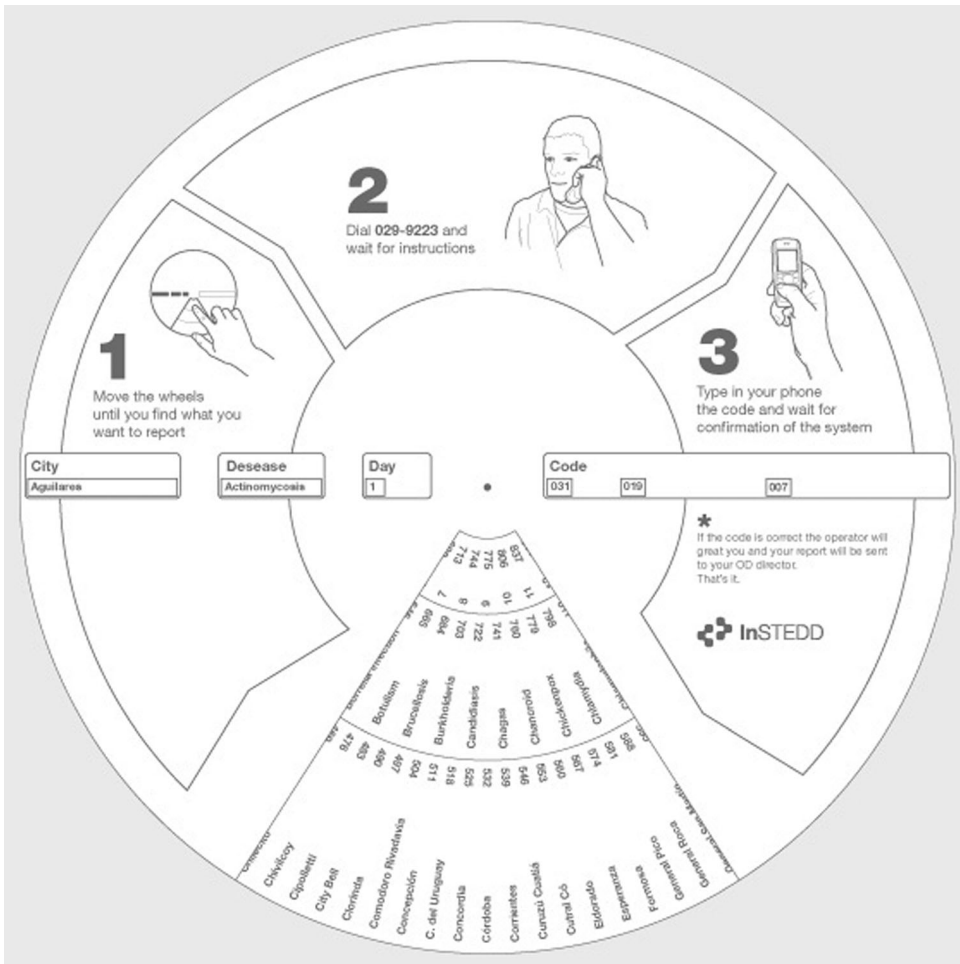


Figure 4. Reporting Wheel. Source: di Tada (2010).

Some projects have addressed accuracy issues by developing paper-based assistance tools such as logbooks, or in a more unusual example, a paper wheel that, when turned to display the correct date and other data points, produces the exact text for the SMS. The Reporting Wheel developed by InSTEDD is shown in [Figure 4](#). Developed for a project in Cambodia where users generally had phones that did not support Khmer or Thai characters (di Tada, 2010), this technique is also useful for countries where non-Latin alphabets are common. Innovations in structured data collection via SMS are important because they demonstrate the role of communities of practice – here specifically designers and implementers of m4d services – in shaping the technology platform beyond what was anticipated in its original design.

6. Discussion

The technical standards, historical evolution and relationships underlying SMS still shape how m4d apps and services are designed today. For apps and services that are conceptually similar to common commercial services, operator-specific integration is partially ameliorated by working through commercial WASPs. Alternative strategies developed by m4d SMS apps and services that have dissimilar requirements to commercial services expose important points of non-congruence. Such services may need multi-country coverage, or work in countries where the commercial WASP model is uncommon. Unlike commercial services, m4d apps and services also often need reverse-billing or other free-to-user options. It should also be noted that unlike the Internet, SMS data transmission is not content-neutral, and access to operators' SMS infrastructure may depend on operating in a domain that is not unpalatable to the WASP or the operator.

Mobile network operators loom large in the mobile services ecosystem. They were major players in the GSM standards processes that shaped SMS as it exists today and still act as technological and procedural gatekeepers of SMS as a platform for m4d apps and services. In some cases, such as with virtual mobile numbers, operators have taken active steps to build in support for third-party services. To the extent that the requirements of m4d and commercial services are similar, increased use of SMS by commercial third-party services benefits everyone on the platform.

However, m4d service models frequently diverge from commercial services, particularly in terms of business models and user base. Except in a few countries, reverse-billed SMS is available only as part of an ad-hoc agreement with an operator, making it difficult for services targeting low-income users to receive messages from users with little or no airtime. Unlike premium-rated shortcodes, reverse-billed lines have not been the subject of agreements between operators. This is both a technical and an administrative issue given concerns about abuse, but it also illustrates the challenges m4d apps and services face in working on a platform governed by commercial logic. With smartphones becoming more common among wealthier and better-connected residents of developing countries, fears that SMS will be left behind as a platform carry some weight.

The European origins of GSM and SMS are reflected in the complexities involved in developing services in languages with non-Latin character sets. While innovative alternatives such as picture messaging exist, SMS services can be expected to work least well for users who have basic phones with limited language support, low literacy levels in general or who are speakers of minority languages. In the particular case of structured data collection, the error rate of free-text typing demonstrates that while SMS may be an infrastructural technology for some users, this is certainly not the case for everyone that m4d apps and services aim to reach. The patterns of exclusion that are created – or, more often, perpetuated – should be carefully considered when SMS-based apps and services are evaluated.

This research has also documented a body of innovative strategies, technological and process, that have emerged to address some of the specific issues encountered by m4d apps and services. Knowledge-sharing in communities of practice that develop around software (such as SMS application frameworks as FrontlineSMS and RapidSMS) and particular application domains (such as m-Health) has played a key role in popularizing these alternative strategies. Some, such as the use of GSM modems, exist in a somewhat uneasy relationship to mobile operators. Yet they allow m4d apps and services greater design flexibility in critical areas of functionality, which are often not well-served by operators and other commercial players.

At the same time, innovative workarounds on the fringes of the mobile network infrastructure can be a double-edged sword for m4d apps and services. A pilot version of a service designed in a way that is inherently not scalable, whether for technological (SMS throughput limitations, short code availability) or process (training, billing/business model) reasons, relies on being able to transition to a more suitable design when the time comes to scale up a service. The structure and limitations of the “formal” infrastructure (Horst, 2013) render the “informal” infrastructure of user-driven innovations somewhat brittle. This factor may well contribute to the large number of non-scaling pilots for SMS services, and ICTD interventions more generally.

7. Conclusion: technology solutions to development problems?

The case of SMS as a platform for m4d apps and services illustrates the complicated relationship between the needs and logics of such services and those of the various players in the commercially oriented mobile ecosystem. On the one hand, SMS offers an unprecedented opportunity for two-way information and communication services to reach previously unserved users, and to develop services that meet their particular needs. Some services, such as m-Pesa, have done this very successfully. On the other hand, concerns about the scalability, sustainability and viability of m4d apps and services for low-income, older, less-educated or more rural users are not unfounded.

As this paper has shown, these concerns are as much related to the way the platform has developed and is encountered today as to how m4d apps and services are designed. Designers of m4d apps and services can employ various techniques to mitigate the limitations of the platform, and some services have done so creatively, innovatively and successfully. However, it is difficult to argue that these creative strategies, existing in an uneasy relationship to an operator-controlled platform, represent a stable basis for m4d apps and services, much less a claim about “serving the underserved through mobile” as made by the GSM association.

Technology studies approaches such as infrastructure studies and platform studies can provide a critical, historicized counterpoint to techno-utopian promises in ICT4D. As part of an ecosystems approach, they challenge us to augment pragmatic deployment of new technologies in the service of development with an understanding of the structural limitations faced by designers and users in the developing world. Intervention at the ecosystem level might involve supporting communities of practice as a source of innovation, but equally might identify and work with institutional gatekeepers.

While not negating a real potential contribution, the development promise of m4d apps and services functions as “discursive work” (Gillespie, 2010, p. 347) congruent with the interests of major players in the ICT ecosystem. Consensus around mobile technology as an aid to solving to development problems obscures the historically and socially contingent nature of the platform. The findings of this paper suggest that justifiable enthusiasm at the expansion of person-to-person communication and a few very successful m4d apps and services should be tempered

with the realization that the platform is far from neutral. Limitations resulting from design decisions taken long ago and far away affect the variety, sustainability, scalability and potential audience of m4d apps and services. Real gains notwithstanding, technology solutions to development problems operate within an infrastructural legacy of structural inequality, which can be both reinforced and challenged through technology design.

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Notes on contributor

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