MAKING MHEALTH HAPPEN FOR HEALTH INFORMATION SYSTEMS IN LOW RESOURCE CONTEXTS

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Abstract: The paper offers a reference typology for large scale mHealth solutions in low-resource contexts. The proposed typology is produced through action research engagement with various mHealth initiatives within primary health care; including one fully deployed large-scale solution, medium-sized pilot studies and projects currently being implemented. Our investigations are informed by theoretical assumptions about the cultivation of health information infrastructures, through evolutionary strategies of installed base cultivation and local patchwork through bricolage. We view the extension of national Health Information Systems (HIS) through mobile phones to the community level as a socio-technical cultivation process shaped and determined by the availability of communication infrastructures, handset dispersion, telecom service provider schemes and tariffs, local politics & policies available skilled manpower and established work practices. Through the proposition of a reference typology for mHealth implementation strategies we aim to address the need for identification and cross-fertilization of appropriate mobile based approaches for extending digitized HISs to the community health facilities in a continuously changing development context.

Keywords: mHealth, Health Information Systems (HIS), Low-Resource Context
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1. INTRODUCTION

“It is not because countries are poor that they cannot afford good health information; it is because they are poor that they cannot afford to be without it” (AbouZahr & Boerma 2005).

At present, considerable efforts are made by international aid agencies (notably the World Health Organization - WHO) and the United Nations (UN) in addressing primary health care related human deprivations such as; poor health, rampant communicable diseases (e.g. HIV/AIDS, malaria, cholera), starvation, malnutrition and high rates of maternal & young child mortality. Wilson and Smith (1991 cited Wilson 2000) suggest that, “the creative use of microcomputer technology is one of the most promising means of improving the quality, timeliness, clarity, presentation, and use of relevant information for primary health care” (Wilson, 2000, p. 199). Similarly, Stansfield et al. (2006, p161) details that; “timely and accurate health information is required for strategic planning and the setting of priorities; clinical diagnosis and management of illness or injury; quality assurance and quality improvement for health services; and human resource management”. Despite many current difficulties, recent research experience finds that ICTs can play an important role in strengthening national Health Information Systems (HIS) in developing countries (Braa and Hedberg 2002, Lippeveld et al. 2000, Wilson 2000, AbouZahr & Boerma 2005), including important monitoring of Millennium Development Goals related to mother and child health1.

Unfortunately, the enabling infrastructures, skills and human capacity required for adopting and utilizing computers and landline Internet connectivity for routine HIS has been unavailable or unattainable to the majority of health information users in developing countries (Wilson 2000). Experiments with PDAs and low cost laptops have similarly met obstacles to realization in the public health care scenario in India (Ranjin & Sahay, 2005). In order to strengthen medical and primary health information systems at the grass-roots (i.e. local community), alternative strategies like mHealth are currently being explored (Mukherjee, Purkayastha & Sahay 2010, Braa, Purkayastha 2010, Braa, Purkayastha & Grisaw 2010).

In accordance with Germanakos, Mourlas, & Samaras (2005), we understand mHealth as the; “medical and public health practice supported through mobile devices for collecting community and clinical health data, delivery of healthcare information to practitioners, researchers, and beneficiaries, real-time monitoring of beneficiary vital signs, and direct provision of care”. Although mHealth encompasses all kinds of mobile devices from wireless chip-based solutions to portable computers, we advocate that low-end mobile phones bear some important characteristics that make them suited to large-scale deployment in low-resource primary health care scenarios; the extensive and swift rollout of mobile telecom infrastructures; widespread domestication of affordable and robust handsets; ease of mastery - leading to high levels of low-end mobile phone literacy; local competencies on servicing and repairing low-end handsets and; low consumption of scarce power.

Within the primary health care domain, mobile phones show promise in filling the digitization gap at the grass-root levels and assist in capturing routine health data even during Community Health Workers (CHWs) interaction with beneficiaries. Mobile data collection and reporting can help reduce errors associated with manual aggregation of routine health data. In addition, it promises to address issues of untimely or unreported data due to transportation of paper reports by foot, bike or

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1 The official United Nations site for the Millennium Development Goals Indicators including child and maternal mortality can be inspected at http://unstats.un.org/unsd/mdg/Default.aspx

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vehicle over long distances on poor or climatically challenged roads. Thirdly, the on-the-spot digitalization promises to free up time currently spent on monotonous tasks of manually transferring data from paper to paper and into the digitized HIS for aggregation and analysis at higher organizational levels. Finally, the early digitalization of data allows for data sharing and integration between currently isolated HISs that do not communicate across multiple coexistent health programs (WHO 1994). In short, mobiles are believed to assist in improving data quality and affect efficiency in reporting and sharing of data.

Through the proposition of a reference typology for mHealth implementation strategies, this paper aims to address the need to identify, cross-fertilize and maneuver in the space of appropriate mobile based approaches to extending digitized HISs to the community health facilities in a dynamic development context.

In the following section we disclose our theoretical assumptions about the cultivation of health information infrastructures. In section three we report on our networks of action approach to research. Next, we present the case of a large scale mHealth implementation, involving 5000 low-end handsets, in the Indian state of Punjab. Based on the presented case and our involvement with various other mHealth implementations we propose the reference typology for mHealth implementation strategies in section five. Finally, in section six we suggest some directions for future work on the typology and elaborate on the contribution this paper offers.

2. SUSTAINABLE HEALTH INFORMATION INFRASTRUCTURES IN LOW-RESOURCE CONTEXTS

A World Bank report by McNamara, McNamara & Kerry S. (2003) suggests that many ICT development initiatives are seeded as short-term donor funded pilots without regard to scalability and sustainability, which implies that the anticipated impact and benefits of the projects deteriorate as soon as pilot funding is discontinued or key activists resign from the projects. Similarly, attempts to computerize HISs have too often produced only pilot systems or systems that fail to exist after donor-based funding has ceased (Heeks and Baark 1999). The projects that actually aim for large scale intervention may be forced to go for a single “big bang” implementation due to short donor driven time schedules and attention spans (Cain, 2001). Kimaro and Nhampossab (2005) suggests that scalability is hampered due to the inability to mobilize long term national support, the focus on top-down strategies as opposed to a focus on local needs and the lack of focus on building local competencies to maintain and integrate the HIS interventions.

The political vision of equity in access to health services further intensify the need for scalable and sustainable approaches to the utilization of mHealth for extending digitized HISs to the community health facilities in low resource contexts. This has been characterized by Braa, Monteiro, Sahay (2004) as the all or nothing problem of HISs intervention within primary health care. Here we refer to it as the issue of full scalability, implying that local success is not sufficient as the mHealth solution has to scale to whole regions and whole nations in order to be of practical value. Existing research into the topic of how sustainable mobile HISs can be effectively deployed and scaled is limited (Donner, 2008), and hence this topic lies in the frontiers of health information systems research. Similarly, Rashid & Elder (2009) review of IDRC-supported mobile phone driven development projects conclude that there is a “dearth of research exploring mobile phone’s role in health”. To address this gap in research we explore the utilization of low-end mobile phones in HISs in low resource contexts through the notion of health information infrastructures.

With the term low-resource context we refer to the lack or instability of enabling infrastructures (e.g. roads, public transport, power-supply, and electronic communication networks), shortages in human capacity and skill (i.e. primary health and technology competence), as well as an inherent

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2 IDRC is a Canadian Crown corporation that works in close collaboration with researchers from the developing world in their search for the means to support growth and development.
price sensitivity in addressing these and other shortcomings. By health information infrastructure we refer to the complex socio-technical and socio-political ensemble of communication networks, information systems, and work practices that constitute the primary health information scenario.

Hanseth (2002) emphasize installed base cultivation as the most feasible ICT intervention strategy for complex socio-technical information infrastructures. Installed base refers broadly to whatever is already in place. In our case, this includes health workers and their paper registers at the community health facilities; computers and data analysts at the district levels; the servers and monitoring & evaluation officers at the state level; in addition to basic infrastructures required to support mobile phone use; charging facilities, maintenance support and network coverage. The installed base cultivation strategy acknowledges the lack of control any one stakeholder have over the full ensemble and sees the opportunities and choices of the present as shaped and determined by the materiality and institutionalization of previously stabilized alignments. Thus, addressing the shortcoming of more traditional top-down enterprise architecture strategies where work practices and infrastructures are supposed to be redesigned and implemented in one fell swoop.

Although subscribing to this evolutionary view on ICT intervention, we find that cultivation as an information infrastructure design strategy fails to guide the fine grained and nitty-gritty patchwork and problem solving happening on the ground in low-resource contexts. We therefore draw on the concept of bricolage to describe the constant trying out and re-ordering of people and resources. Bricolage (lat. bricola catapult) means “tinkering through the combination of resources at hand” as “[t]hese resources become the tools and they define in situ the heuristics to solve the problem” (original emphasis, Ciborra, 2002 p 49). The power of bricolage is that it is highly situated and exploits the local context and resources at hand, while often pre-planned ways of intervening appear to be less effective because they do not fit with the contingencies of the moment. Bricolage “tend to include an added element of ingenuity, experience and skill belonging to the individual and their community (of practice)” (ibid, p50).

3. RESEARCH APPROACH

The study presented in this paper is guided by a network of action research approach. The approach is aimed at to tackling the issue of sustainability in research driven interventions by recognizing that local intervention needs to be part of a larger network in order to achieve robustness. In short, the approach sees scalability as a prerequisite – not a luxury – for sustainability of local action. The network creates opportunities for sharing of experience, knowledge, technology, and value through multiple sites of action and use (Braa, Monteiro, Sahay, 2004). Hence, the emphasis on scale through a focus on networks is not so much about size as facilitating the necessary learning processes for sustainability (Elden and Chisholm 1993, p. 293). The focus on full scale and sustainability challenges the tendency of designing and reporting on action research as well-defined phases. Susman and Evered’s (1978) classic model outlines five such phases: diagnosing, action planning, action taking, evaluating, and specifying learning. While these cycles are implicit and ongoing in our interventions, we cannot categorize them neatly into different phases with a clear start and end.

Both authors are involved with the Health Information System Programme (HISP); an international research network doing open source development and implementation of District Health Information Systems (DHIS2) in more than 15 countries in Africa and Asia. DHIS2 is implemented in 20 states in India for intrastate HMIS reporting. The DHIS software is developed, customized and used for reporting, analysis and presentation of aggregated health data while catering for various health programs (HIV, ANC, Malaria, EPI etc).

This study draws its empirical material from mHealth implementations aimed at seamlessly integrating and extending DHIS to the community level; where there are no computers, no Internet and often unstable power supply. The suite of applications are referred to as DHIS-Mobile and address both capturing of aggregated routine data (facility reporting), as well as tracking
beneficiaries throughout the duration of the health program they are enrolled in such as ANC, child immunization and HIV/AIDS (name-based). One of the authors manages the DHIS-Mobile project (Author 1), while the other author is a Ph.D. student (Author 2) enrolled in the project since August 2010.

3.1. mHealth implementations
The authors have been involved in the iterative development of various solutions for DHIS-Mobile (Table 1); ranging from design, implementation, training, project coordination, and evaluation activities. In the following, we describe the different projects informing this study and the roles of the authors in the various projects.

<table>
<thead>
<tr>
<th>Project Initiated</th>
<th>Current Stage</th>
<th>Application</th>
<th>Users Trained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Five state pilot (India)</td>
<td>May 2009</td>
<td>Pilot</td>
<td>Java / SMS</td>
</tr>
<tr>
<td>Nigeria</td>
<td>September 2009</td>
<td>Pilot</td>
<td>Java / SMS</td>
</tr>
<tr>
<td>Punjab</td>
<td>June 2010</td>
<td>Full-scale</td>
<td>Java / SMS</td>
</tr>
<tr>
<td>Name based</td>
<td>In startup</td>
<td>Pre-pilot</td>
<td>SMS/GPRS</td>
</tr>
</tbody>
</table>

Table 1. DHIS-Mobile Projects

Case study of IDSP pilot in Andhra Pradesh
In order to learn from an ongoing mHealth project in India a short case study of a SMS based reporting system for Integrated Disease Surveillance Project (IDSP) was conducted in February 2009 by Author 1 together with colleagues from HISP. The pilot was initiated in August 2008 and was implemented in six out of Andhra Pradesh’s 23 districts. The solution supports weekly reporting of data through plain SMS with alpha-numeric codes. Data of the prescribed IDSP formats is sent from the reporting units to a server at the state capital. To secure the confidential information being transmitted, the system identifies every reporting unit with a unique identification number and the SMSs are accepted only from pre-registered mobile numbers. The alpha-numeric codes include; facility ID, disease code, number of registered cases, deaths, etc. The system sends out automatic alerts to concerned officials whenever the frequency of particular events cross pre-set threshold levels.

The short case study served the purpose of learning about routine facility reporting, getting feedback on the facility reporting prototype for DHIS-Mobile and discussing possibilities for supporting Community Health Workers (CHWs) through mobile applications. A range of stakeholders involved in the pilot project were interviewed; including director of epidemics, district epidemic officer, district medical officer, data manager and the IDSP team. Three health facilities were visited and two monthly meetings were attended in order to discuss the experiences of 38 CHWs and 60 voluntary health workers.

Facility reporting Pilot in five Indian states
Simultaneously, facility reporting was initiated in five Indian states; Kerala, Rajasthan, Gujarat, Himachal Pradesh and Nagaland. CHWs were provided with an application on mobile phones to report routine outreach service data (e.g. ANC, immunization) to the district and state level. Over 250 people including CHWs and state/district/block-level medical officers were trained. The detailed findings of this study are reported in (Braa et al 2010, Mukherjee, Purkayastha, & Sahay 2010). The application was based on the national HIS form for CHWs coordinated by the National Rural Health Mission.

In February 2009 a pre testing of the prototype was performed among health workers in Andhra Pradesh (mentioned above) and Kerala. In Kerala Author 1 visited three health facilities and interviewed CHWs, block health administrative people and the village head. In July 2009 and April 2010 Author 1 was involved in the evaluation of the pilot in the two states Kerala and...
Rajasthan. Six community health facilities were visited and two focus groups were organized; with 15 facilities represented in each. A total of 30 CHWs were interviewed.

**Pilot in Nigeria**

Based on experience from of the IDSP pilot and the facility reporting solution, a pilot was initiated in the two Nigerian states Yobe and Katsina in September 2009. Health workers from 26 health facilities and 34 local government area Monitoring & Evaluation officers were involved, thus, covering the whole state of the Katsina and parts of Yobe. The Nigerian solution is very similar to the Indian pilots, although in Nigeria, the mobile application was developed based on the existing national HIS facility forms and implemented at the facility and district levels (Asangansi & Braa, 2010). Due to unstable power supply the pilot faced difficulties in maintaining server uptime and a power backup system was put into place. In order to receive all SMS’s, the modem had to be switched on at least daily as the mobile operator in Nigeria only store SMS for 24 hours. Author 1 was involved in the whole process from negotiating the pilot, designing the application, installing the application on handsets, training users and later evaluating the experience. Interviews were conducted with stakeholders from both states - including health and government administration.

**Full scale roll out in Punjab**

Based on the experience from the pilots a full scale mobile facility reporting implementation was rolled out in the state of Punjab. From late September 2010, Author 2 spent a total of six weeks following the implementation stages; visiting three health facilities to observe local work practice, attending one regular monthly meeting with about 40 CHWs, and participating in five mobile training sessions, also involving about 40 CHWs each. The fieldwork involved extensive interaction with representatives from the health organization; voluntary health workers, CHWs, medical officers, statistical assistants, and data analysts; the project HISP team; mobile trainers, application developers, technical support staff, project coordinators; and state officials/mangers. Secondary sources of data from studying the Punjab roll out include training manuals and official reports from mobile trainers, project coordinators, state level data analysts and state officials.

**Global Developers Workshop**

In November 2010 both authors participated in a two week global workshop for DHIS-Mobile developers in Kerala with 12 participants from India, Vietnam, Tanzania and Norway. The aim of the workshop was to design prototypes for DHIS-Mobile based on previous experiences and new requirements. In addition to improving the existing solutions, a prototype for the mobile name-based module of DHIS was developed. Three CHWs from different facilities tested the prototype and gave valuable feedback to the developers and implementers.

In order to structure the key experience and learning from engagement with previous implementations and navigate in the space of possible design solutions, different version of the reference typology for mHealth implementation strategies was presented by Author 1 and negotiated between the researchers and developers throughout the last week of the workshop. The negotiation during the workshop is just one example of how data collection and analysis has been highly interlinked in our study. The typology has been continuously re-negotiated as it has been presented by the authors to fellow researchers, students, and practitioners involved with HISP-Mobile. The typology has thus emerged, not from a well defined process of analysis, but from both authors’ engagement and interaction with the HISP-Mobile project. Both our own and others shared experiences have been conceptualized and synthesized through our theoretical assumptions about installed base cultivation of health information infrastructures while allowing room for improvisation and local patchwork through bricolage.

Although our proposed typology draws insights from engagement with all the mentioned implementations, we will, in the following data chapter describe in further detail the full scale mHealth implementation in the Indian state Punjab.
4. MOBILE REPORTING OF DAILY AND MONTHLY ROUTINE DATA IN PUNJAB

The bricks and mortar of the Punjabi public health system are the CHWs stationed at the community health facilities. There are 2948 such facilities in Punjab employing about 5000 CHWs, of which a large portion is middle aged women. The primary health organization of Punjab is divided into districts, blocks, primary health centers (PHCs), and community health facilities. Table 2 illustrates the availability of computers and Internet connectivity at the different hierarchical levels of the primary health organization.

<table>
<thead>
<tr>
<th>Reporting Units</th>
<th>Computers</th>
<th>Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>District</td>
<td>20</td>
<td>Yes</td>
</tr>
<tr>
<td>Block</td>
<td>118</td>
<td>Yes</td>
</tr>
<tr>
<td>Primary Health Centers</td>
<td>396</td>
<td>Rare</td>
</tr>
<tr>
<td>Community Health Facility</td>
<td>2948</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 2. Punjab Health Organization Units

During spring 2010, the state of Punjab decided to implement mobile phone based facility reporting from all community health facilities. An evaluation of the network signal strength in districts of Punjab led to the choice of basing the mobile data reporting on SMS rather than GPRS. All of the CHWs were provided with a SIM card and a Nokia 2330 Classic with a Java application for routine data reporting installed. The application allows CHWs to fill forms and send one daily (10 data elements) and two monthly (53 & 86 data elements) reports of routine health data (see Figure 1). A team of ten people manually installed the native Java mobile applications (*.jar files) to all 5000 handsets over a period of one month. The application utilizes only basic J2ME functionality which allows it to be installed and run on most Java enabled low-end handsets.

Training on mobile reporting and the data elements in the forms was given to all CHWs. Completed reports can be stored and retrieved locally on the mobile phone and forwarded when reception of the mobile network is sufficient. The report is sent as a compressed (70% compression rate) SMS to two GSM Modems integrated with the DHIS2 data warehouse. Block and higher facility personnel can access the reported data through the online DHIS2 software on computers (Figure 2).
Although Internet connections and computers are available at block level, Bluetooth is generally not. This has forced support staff to travel long distances in order to reinstall the Java applications to handsets in cases where CHWs have accidently deleted them. CHWs will continue paper reporting until the mobile based reporting stabilizes and consistency with paper reports can be confirmed.

4.1. Mobile Networks, handset and service provider schemes
The state of Punjab decided to purchase the 5000 handsets in one go, in order to get the best possible discount price of 1900Rs ($40), as opposed to the retail price of about 2700Rs ($60). A tender document was published in national newspapers and included the required cost and technical phone specifications for mobile phone companies and lowest rental plan with Closed User Group (CUG) for service providers. The Nokia 2330 Classic was chosen for the project implementation as it supported all the technical specifications within budgetary limitations. According to the requirements of a tariff plan, customer service and network coverage in rural areas of Punjab, a service provider was chosen, however a few CHWs have complained that the service provider does not have sufficient network coverage in their catchment area. The Indian pilot studies show that having unconstrained access to managers, medical officers and colleagues through the CUG are some of the most cherished and obvious benefits recognized by CHWs (Braa et al. 2010). Thus, the CUG was part of the implementation concept in the Punjab roll out and was negotiated to include free calls within the network for health workers and 100 free SMS every month.

5. MHEALTH IMPLEMENTATION STRATEGIES FOR LOW RESOURCE CONTEXTS
In this section we will present the reference typology for mHealth implementation strategies, with the aim of identification, cross-fertilization and maneuvering in the space of appropriate mobile based approaches to extending digitized HISs to the grass-root levels (Table 3). The typology address the need to cultivate the existing resources available (the installed base) as well as creating room for improvisation and bricolage in a dynamic development context. Our intention is to
unravel a solution space that can also cater for changes in implementation strategies according to infrastructure resources.

Although mobile network coverage can be found in low resource contexts where there is not even stable power supply and roads are underdeveloped, these networks are oftentimes unstable or have weak signal strength. Within primary health care, mHealth solutions need the robustness to cope with situations where no wireless communication is available (e.g. by storing data on the handset until connectivity is available). Thus, the mobile application was designed so that the facility reports can be saved on the phone until a place with better reception is reached. SMS data can be sent even where network coverage is marginal, as illustrated by a Nigerian health worker climbing a three in order to send the SMS report. Cost of data transfer can also be a factor influencing the mHealth solution and where sending SMS is costly; GPRS can be utilized for report sending whenever the network signal is strong enough.

In Punjab the applications on 5000 phones were installed manually and took a team of ten people almost a month. With a hybrid solution where the application can be downloaded via GPRS (i.e. during user training) while reports are still sent as compressed SMSs would reduce the manual workload. Similarly, a hybrid solution would allow for a link to be sent as an SMS while GPRS would be utilized to download a new version or reinstall a deleted application. Reinstallation or updating could then be performed during monthly CHWs meetings at block or PHC if GPRS is available there.

In contexts where GPRS network is good and cover the whole area a full GPRS solution where both downloading the application and sending the data through the GPRS network may be preferable. A new implementation to be tried out in Himachal Pradesh will most likely be a mix between GPRS hybrid and full GPRS solution due to fluctuating network quality.

However, more skill and experience is required in order to design and develop a hybrid solution. Thus, we see a trade-off between human resources for application development and solution deployment. The SMS based client solution with the Java manually installed on the phone was relatively easy and fast to develop but have required more human resources to maintain. To some extent, the lack of a robust application design can be compensated for by use of manual deployment labor.

In situations where handsets cannot run Java clients, have no browsers and GPRS network is unavailable, plain SMS based solutions like the IDSP pilot may be an option -although usability is a challenge. In the pilot, CHWs found it hard and cumbersome to enter all the required digits without making errors. Thus, they relied on super users to enter the data whenever coming to a meeting. Failures in data capturing were still reported as a problem.

All the DHIS-Mobile solutions reported in this paper are based on initial purchase, application installation and subsequent distribution of phones to the health workers. This strategy was chosen because the phones people already had were frequently not Java enabled. To provide phones will not always be possible due to lack of finances and different solutions need to be explored. We have seen that pure SMS based solutions may be chosen on the expense of usability, but if the handset has a browser web based solutions can be a viable option.

In our reference typology (Table 3) the various mHealth implementation strategies are mapped according to the contextual parameters including network signal strength, handset availability and existing tariff plans, human capacity and user experience on low-end handsets. The reference
typology aims to support the navigation in the space of possible design solutions in low resource contexts and facilitate the cross-fertilization of synthesized experiences between different full scale and sustainable mHealth projects. The contextual parameters of the installed base are not stable, but will be subject to changes in resources availability such as network upgrades, better handsets and service provider competition.

<table>
<thead>
<tr>
<th>Technical Solution</th>
<th>Contextual Resources</th>
<th>Human Capacity</th>
<th>Application Use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Network</strong></td>
<td><strong>Handset</strong></td>
<td><strong>Tariff</strong></td>
</tr>
<tr>
<td><strong>SMS only</strong></td>
<td>Plain SMS</td>
<td>Works on all handsets</td>
<td>Cheap SMS</td>
</tr>
<tr>
<td><strong>SMS based client</strong></td>
<td>Sending compressed SMS</td>
<td>Java enabled phones</td>
<td>Cheap SMS, CUG</td>
</tr>
<tr>
<td><strong>SMS based client hybrid</strong></td>
<td>SMS client with GPRS sending</td>
<td>Java enabled phones</td>
<td>Cheap GPRS, CUG</td>
</tr>
<tr>
<td><strong>GPRS hybrid</strong></td>
<td>GPRS for downloading application and SMS data reporting</td>
<td>Java enabled phones</td>
<td>Cheap SMS, CUG</td>
</tr>
<tr>
<td><strong>GPRS</strong></td>
<td>GPRS for downloading application and data reporting</td>
<td>Java enabled phones</td>
<td>Low data tariff, CUG</td>
</tr>
</tbody>
</table>

Table 3 Reference typology for mHealth implementation strategies in low resource contexts

**Cultivating Health Information Infrastructure**

We find that the strengthening of existing HIS through mHealth solution is made feasibly by leveraging on the backbone system (i.e. the DHIS2) that is already shared in the current HIS setup and work practices. In order to extend the reach of digitized HIS we see that we need to cultivate the installed base of resources as technologies mature and contexts change. Cultivation occurs through the constant inclusion of local innovation based on currently available resources, while bricolage is the maneuvering on the ground in this landscape of making mHealth happen.

We see bricolage as a strategy for navigating within the typology as it addresses the fine-grained situated local problem solving of “gluing” the bricks together. From the trying out in different local contexts the network of action accumulates knowledge within the community and learns to avoid the pitfalls. Learning is produced through the sharing of experience from resource trade-offs, breakdowns and successful patchwork in the network. This needs to be an ongoing process due to continuous changes in infrastructures such as network and handset availability and resource availability, thus the experience and skill required to do bricolage is accumulated in the network.
6. CONCLUSION

In this paper we have presented a reference typology for mHealth implementation strategies for matching mobile solutions to low resource contexts. We find that the theoretical lens of installed base cultivation through bricolage is useful in understanding, describing and synthesizing the learning that emerges from our networks of action oriented involvement with various mHealth implementations.

The proposed reference typology is based on a limited set of implementations conducted within the same network of action over a three year period. Our findings suggest that extending national HIS with mHealth solutions, need to match with existing work practices, local contextual resources, service provider tariffs, existing communication infrastructures and integration with the backbone HIS. Thus, solutions need to be continuously cultivated with respect to the context they are embedded in. The typology is not cut in stone and will need to be expanded and improved in the future e.g. web-based solutions will be a viable option in some low resource contexts. In this study the main focus has been on utilizing the mobile phone in the primary health scenario for scalable and sustainable data reporting, with improved data quality and timeliness as key motives, yet the pilots revealed the use of the handsets for coordination tasks and social networking within a Closed User Group (CUG) was a much appreciated benefit to health workers. Further utilization of this effect as an engine for sustainable intervention needs to be explored. Finally, we suggest that low-end mobile phones offer opportunities for giving contextualized and localized feedback to CHWs directly on the handsets, the solution space offered from the typology needs to be explored further with feedback in mind.

7. REFERENCES AND CITATIONS


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