Real Time Monitoring and the New Information Technologies[1]

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Abstract Debates as to the potential role of new Information and Communication Technologies (ICTs) in monitoring the wellbeing of vulnerable groups is often bedevilled by the failure of two principal actors – social researchers and technical experts – to address the other's concerns or even to use language that is comprehensible to the other side. The aim here is to unpick some of the technical language relevant in this context and provide a brief introductory guide to some aspects of the current, rapidly changing and highly diverse ICT environment.

1 Introduction

The astonishing speed at which new Information and Communication Technologies (ICTs), most obviously mobile telephones, have spread throughout even the resource-poor areas of the world, has clearly been one important driver of the recent focus on real-time monitoring. Partly driven by the parlous state of social sector routine data systems in the poorer developing countries and the consequent paucity of timely, reliable data, there have been many attempts to improve data collection procedures using ICTs.[2] As described below, many of these interventions have either delivered, or demonstrated a potential to deliver, substantial benefits in terms of data availability, timeliness and quality. Most obviously, the explosive growth of mobile phones has transformed the communications environment for service providers, in many instances freeing them from the relative isolation in which they previously had to function and dramatically improving their capacity not only to report the needs of their clients but to respond to those needs.

Given the widespread enthusiasm for ICT, it is of course important to note that the use of these technologies is not a 'magic bullet' that will guarantee the effectiveness of a poorly designed or poorly implemented monitoring and response system. As illustrated in this *IDS Bulletin*, there are many pathways to real-time monitoring which may involve no or marginal use of ICTs. Both face-to-face and paper-based information gathering and transmission systems have potential advantages, for example in terms of familiarity – to both service providers and their clients – and limited reliance on fallible technologies. In many cases they can be very effectively used in combination with ICT, providing opportunities to validate or complement findings.

There is a substantial body of evidence that demonstrates the risks of being beguiled by the superficial attractions of simply investing in 'technical fixes' to improve poorly performing and often inadequately understood information systems.[3] Special caution is required if this approach involves an intervention that entails substantial expenditure on either equipment or software. As one of the authors of this report has previously argued (Lucas 2008), the appeal of ICT innovations to providers and recipients of intervention funding and to the lower level staff who gain access to very attractive equipment is a very good reason to treat them with considerable care. This includes careful considerations concerning the potential for downplayed deficiencies and over-stated capacity of some ICT devices. In addition, though the cost of using mobile communications networks is falling, and the use of facilities such as the Short Message Service (SMS) may appear relatively inexpensive, it is still a potentially important barrier, especially considering the challenges often involved in shifting existing expenditures

Table 1 Types of communications network

Network	Basic capability	Extended capability
Manual	Physical media	
Radio	Voice – one-way transmission	Two-way transmission
Fixed line telephone	Voice, touch-tone[1]	Email, data, web, VoIP
Mobile phone networks	Voice, touch-tone, text	Email, data, internet, VoIP
Fixed line broadband	Email, data,[2] internet, VoIP[3]	
Mobile broadband	Email, data, internet, VoIP	
Satellite telephone	Voice, touch-tone, text	Email, internet
Satellite broadband	Voice, email, data, internet	

Notes (1) The use of the telephone key pad to send numeric codes – for example to trigger a menu system.
(2) Transfer of data files across the network. (3) 'Voice over Internet Protocol' is the use of the web to provide a low-cost telephone service.
Source Modified version of Ashar *et al.* (2010: 334).

towards new investments in potentially more cost-effective interventions and in allowing appropriate *recurrent* support to innovative interventions. These challenges underscore the importance of a careful, full cost-benefit analysis before undertaking ICT solutions and plans for scale and support. Many of the interventions described in Section 2 have received substantial concessions from private sector mobile service providers, either in terms of tariff reductions or free or subsidised 'short codes', which allow high-volume, high-frequency communications.

Nonetheless, a basic knowledge of the potential of the new technologies and the choices involved in their application has become an essential requirement for those involved in the implementation of monitoring systems, if only to understand their infrequently considered limitations. Many would argue for the inclusion of a specific requirement for such knowledge in relevant job descriptions. In this section we outline some key concepts and consider some of the alternative strategies that have been adopted.

2 ICT options

One problem facing those who seek to implement monitoring procedures that include ICTs is the apparent absence of clear guidelines as to how design decisions might be addressed. For example, a recent review of applications in the health sector (DeRenzi *et al.* 2011) supports the view that mobile phone-based technologies

can 'address challenges in monitoring and supervising a large number of geographically distributed health workers'. However, it suggests that selection of the most appropriate approach for a given context is extremely difficult because of the absence of any coherent framework within which to make such assessments. The article then attempts to initiate the development of such a framework by identifying six key functions that health systems must perform where the use of mobile technology might prove most advantageous: data collection, training, communication, job aids and decision support, supervision and health promotion. The use of this framework is then illustrated by comparing existing applications relevant to community health workers.

Ashar *et al.* (2010: 333) similarly argue that the existing systems designed to collect data from remote areas 'suggest that no single ICT can satisfy every setting's data capture needs, but rather that different combinations of ICTs may work best in different settings'. It assesses these technologies in terms of three essential components: communications networks; send and receive devices (hardware); and applications (software), which determine how the user interacts with a device and how the data are transmitted over the network. Any given combination of these three components defines the structure ('architecture') of the system, though obviously only a limited number of

combinations are feasible. Eight commonly used types of network are identified (see Table 1).

Note that the first row of Table 1 is intended to act as a reminder that resource-constrained local authorities and civil society groups have often devised effective, affordable methods to send and receive information on paper using local postal or transport services. Delivery trucks and motorcycle taxis will often be the means by which health records or examination scripts travel from remote poor rural areas to the relevant authorities in urban centres. A basic principle should be that where such mechanisms for the communication of information are effective, they should not be discarded until there is a clearly better and *sustainable* alternative. The second and third columns of the table indicate that the services which can be provided by a given type of network may vary considerably, depending both on the specific characteristics of that network and the hardware and software used to access those services. Note that even where a service is technically possible, the reliability and speed of access may seriously impact its functionality.

These networks can be used by multiple devices, the most relevant of which include:

- Basic and Java-enabled mobile phones
- Smartphones/Personal Digital Assistants (PDAs)
- Laptops (standard)
- Laptops (basic)
- Netbooks.

Standard laptops will tend to be most powerful in standalone mode, with the processing capacity to run the largest range of software applications and the internal storage capacity to hold the largest amount of data. They will also probably be the most flexible in terms of the types of network to which they can connect, possibly with additional communications hardware. A range of inexpensive[4] 'basic' laptops have appeared in recent years, some in tablet or touch-screen format, targeted mainly to resource-poor and environmentally challenging contexts. A number have been developed specifically for children, the best known of which are the Intel Classmate PC[5] and the One Laptop per Child XO.[6] They have limited processing and storage capacity but can usually connect to a local network and may have

the capacity to access the web with additional components. Netbooks have recently become very popular in regions with good internet access. By using the web to provide both software applications and storage, an approach usually designated 'cloud computing',[7] these devices can be highly portable and relatively inexpensive, similar in price to basic laptops. However, they are typically designed for visual appeal, not for durability. PDAs appeared in the late 1980s and were often described as 'hand-held' or palm computers. They generally had an inbuilt mobile communications facility and in recent times have become indistinguishable from the latest smartphones, given that both types of device have the capacity to access the internet and run relatively sophisticated applications software. Basic and Java-enabled mobile phones are by far the most widely used devices and are discussed in detail below.

3 Open Source software as a driver for innovation
'Open Source' software is licensed under terms that support its free use, modification and distribution. The source code, that is, the full detailed set of instructions written in a standard programming language that constitute the software, is available for anyone to review and change without the need to pay the high licence fees typically demanded for proprietary software development. This can lower costs substantially, allowing programmers to adapt software to the specific needs of their users, including translating it in different languages and making it work seamlessly with other programs on a variety of devices. This is particularly important in pro-poor development, where one-size-fits-all solutions are often either unfeasible or problematic, and where there is little or no incentive for software companies to address the needs of small and under-privileged groups. This was an issue specifically addressed by UNICEF and partners in the development of RapidSMS, which is discussed in Section 4. This is an Open Source programming framework that was designed to facilitate adaptation of a flexible SMS communications system, typically with the support from a large development community, to meet local objectives and circumstances.

In addition to its low cost, extensibility and adaptability, Open Source software is often characterised by a collaborative model of development. Improvements and new features

contributed by programmers and suggestions made by users can provide the basis for generating quickly improved versions and new spin-off programs. For example, the code of FrontLineSMS has been used as the basis for MedicMobile,[8] an SMS aggregation programme specifically adapted to the needs of the medical community. The licence terms and the collaborative development model can also support capacity building. The ability to enhance and customise the source code and exchange ideas with others can help hone the skills of programmers in developing countries and assist organisations with few resources to become self-sufficient in producing and maintaining their own customised software solutions (Soo Hoe 2006; Weerawarana and Weeratunga 2004).

Open Source software can also provide a means of engaging different communities of experts and practitioners in the innovation process, and can support lateral thinking and cross-fertilisation of ideas without the need for monetary incentives. In the aftermath of the Haitian earthquake, experts from Ushahidi and OpenStreetMap communities worked together with other programmers to develop mechanisms and standards for different programs to talk to each other. In principle, organisations using and developing Open Source software can tap into the experience and expertise of an extended community of developers if they can persuade those developers that a proposed initiative is interesting and useful (Weber 2004).

However, these benefits can sometimes be hard to realise given that Open Source software may in practice pose similar problems to those associated with proprietary offerings:

● Open Source programs may also be insufficiently documented, or constructed in a way that inhibits modification. Availability of the source code is often a necessary but not sufficient condition for effective development. Some programs are designed from the start to be adaptable and extensible, whereas others require substantial revisions to incorporate modifications easily. Programmers typically require considerable additional guidance to understand how software was constructed, which can be provided in the form of documentation and through one-to-one support via mailing lists and online forums.

Developing these resources and conditions can require significant investments on the part of the software custodians (Berdou 2011).

● Participation in Open Source software development typically requires not only a high level of technical expertise and proficiency in the English language but an understanding of the social norms that underlie Open Source collaboration. These include the importance ascribed to transparency and the free-flow of information and self-sufficiency in learning. Developing these skills could be an important barrier to participation for many organisations and programmers in developing countries, even for those with access to expertise in the development of proprietary software (*ibid.*).

● A program may be released under a free/ Open Source software licence but fail to attract a large community of external developers (Krishnamurthy 2002). A solution may simply not be deemed interesting, useful or mature enough for people to decide to contribute to it on a volunteer basis, or a similar Open Source program may exist which is regarded as having superior features.

3.1 Current debates

One ongoing discussion in the literature, familiar from other ICT contexts, concerns the relative advantage of making best use of established technologies as compared to planning for advances that are expected to be available in the 'near' future. In terms of mobile phone applications, the debate is often constructed as a choice between investing in innovations that extend and improve the use of voice and text messaging based on existing, 'second-generation' (2G) networks and relatively low-cost basic phones, or developing new, potentially far more sophisticated, applications ('apps') for smartphones that rely on the 'third-generation' (3G) high-speed data networks required to access the internet (Selanikio 2010). In practice, the options are far more nuanced. The move from 2G to 3G networks had at least two intermediary steps which had the potential to deliver higher speeds and enhanced services.[9] A further complication is the development of an enormous variety of mobile phones that lack web browser capabilities but can be connected to laptop computers for data transfer and are able to run a range of useful software applications (e.g. using the keypad for completion of a stored survey questionnaire).[10] They are typically priced

somewhere between basic mobiles and smartphones.

One argument often used in favour of developing systems which can be used by the most basic devices is the enormous existing investment in 2G mobiles, even in some of the poorest countries. For example, the 'penetration' ratio (subscriptions per 100 people) is over 40 in Nigeria and over 30 in Tanzania and Zambia.[11] Coverage of 2G networks is over 50 per cent for Africa as a whole and over 40 per cent even in rural areas. With the notable exception of South Africa, internet access in many African countries is limited to less (and in some case considerably less) than 5 per cent of the population (UNCTAD 2009). Moreover, the communication infrastructure investment required to radically change this situation is almost certainly not affordable by many governments and not commercially attractive to private companies.[12]

A recent report on the use of mobiles in development commissioned by UNICEF (Boakye *et al.* 2010) highlights another key issue, the limited engagement, in spite of frequent claims to the contrary, with the private sector. The report argues that when major companies are involved, such engagement is typically with a small Corporate Social Responsibility department which have 'small budgets and limited decision-making power' (p2). Many operators are willing to collaborate only if there is a clear potential for the development, possibly over an extended period, of a service that will provide a return on investment comparable to that available elsewhere.

4 Some illustrative examples

The rapid pace of change in this area is a serious problem in terms of learning from previous experience. In the limited number of cases where systematic evaluations are undertaken, they usually appear some years after the full implementation of the intervention. By that time, the technology will probably have moved on, possibly to the extent that many of the technical findings may have limited practical application. However, such evaluations can often provide useful insights into the potential pitfalls that even well-designed interventions may encounter over the medium term, when initial enthusiasm has been tempered by experience. A good example is provided by one of the earliest

and best documented attempts to improve routine data systems using mobile devices. It was undertaken by the non-profit organisation, Satellife.[13] In 2003, with support from the International Development Research Centre (IDRC) it launched the Uganda Health Information Network (UHIN) Project based at Makerere University (Satellife 2005). Health workers in two districts were provided with PDAs which could be linked to connection points installed at health facilities, allowing data communications via the local mobile telephone network to a central computer in Kampala.

The project can claim some successes. Evaluations, both internal and independent, were generally favourable both in terms of data quality and cost (UHIN 2004). By the time it ended, in 2010, it had provided 700 health workers in five districts (Rakai, Mbale, Lyantonde, Bududa and Manafwa) with PDAs, and the government stated its intention to absorb the system into the Ministry of Health (MoH).[14] On the other hand, the exercise does seem to provide a classic example of a donor-driven intervention, which relied heavily on the willingness of that donor to supply additional funding as and when needed to maintain the system, and on the long-term *ad hoc* involvement of external consultants. There does seem to have been a tendency, which seems common to many ICT projects, to downplay potential problems and allow very little margin for error. Thus, the project agreed to accept a requirement by the MoH that the new system would provide for the compilation and transmission of their existing routine data forms. Within the first year it became apparent that the complexity of these forms had not been fully appreciated, entailing a complete replacement of the system software. Similarly, the facility-based connection points proved inadequate and had to be replaced with more advanced and considerably more expensive models; the life of the PDA batteries was shorter than expected and a series of exercises were required to experiment with alternative recharging mechanisms; and the cost of using the existing mobile telephone network for data transfers was substantially higher than planned.

Alongside the 2010 agreement to absorb the UHIN project, it is worth noting that in November 2009 the Ugandan MoH introduced a pilot Malaria Monitoring Platform that allowed

clinics to submit weekly disease and malaria data using the UNICEF supported software discussed below, RapidSMS, and basic mobile phones (Asiimwe *et al.* 2011). Contrary to the example above, this involved replacing the existing MoH form with a version that could be sent via SMS to a central computer. A display accessible over the internet then provides an overview of the disease burden, including specific malaria treatment and diagnosis data alongside ACT (artemisinin-based combination therapy) drug levels to allow a rapid response to potential or actual stock outs. This initiative, which has since been renamed mTrac, is being rolled out nationwide and is on track to cover all 5,000 health facilities in the country by March 2013.

In terms of mobile phone-based systems, five broad (but not mutually exclusive) approaches to real-time data collection can be distinguished: voice, touch-tone, text messaging, mobile phone applications and the internet. Voice-based systems may seem to be the only practical option for self-completion surveys where a substantial proportion of respondents are illiterate. However, there is some evidence from the Global Network for Disaster Reduction (GNDR) that such respondents will often simply call on the assistance of family members or friends. Similarly, the highly successful M-Pesa mobile money transfer system in Kenya (Mbiti and Weil 2011), which relies on menu systems, reports that they have many illiterate users, typically older people who rely on their children to operate the phones.[15] On the other hand, the corresponding system in Afghanistan (M-Paisa) found that a voice-operated system was necessary. There is some evidence that voice-based data collection systems may result in greater accuracy (Patnaik 2009), clearly an important factor where critical data, for example on health care, is being collected.

Text messaging may be appropriate where relatively simple responses to a small number of simple questions are required. The 'Birth to Twenty' longitudinal cohort study in South Africa (van Heerden *et al.* 2010) provides an interesting example in which mobile phones were provided to cohort members on reaching their fifteenth birthdays. They were then incentivised to continue responding to routine requests for information by offering them additional airtime. One of the main proponents of the use of SMS

has been Kiwanja.net,[16] a not-for-profit organisation that aims to facilitate innovative applications of mobile technology by NGOs. They have developed an Open Source software product (FrontlineSMS) that uses a standard laptop computer linked to one relatively expensive modem or mobile phone to create a standalone local network over which SMS messages can be sent and received by individuals or groups of individuals with the most basic mobile phones. There have been numerous applications in areas including training, mobile payment systems and legal services.

As indicated above, mTrac uses an alternative SMS-based approach, RapidSMS,[17] which was developed by UNICEF Uganda's Innovation Team. This was primarily intended to assist programmers in the development of customised applications intended to operate effectively, possibly with very large datasets, within a specific context. ChildCount, discussed at length in a later section, is probably the best known example. Another recent intervention of particular interest in the present context is the Community Vulnerability Surveillance Program in Uganda.[18] This is a pilot exercise but covers 300,000 to 400,000 people in two districts (Pader and Amuru) in which 500 members of Village Health Teams (VHT) will use RapidSMS on inexpensive mobile phones to collect and transmit data on disease outbreaks, household food security, WASH, births/deaths, and malnutrition. A related project, Integrated Community Case Management[19] (ICCM), in Mpigi district, aims to explore the possibilities for a range of mobile-based services that would improve the management of sick children of VHT members and incentivise them to submit data in a more reliable and timely manner.

The underlying code of RapidSMS is again Open Source, allowing access to programmers who wish to use and modify it to design their own data collection, management and analysis tools. A large user community has contributed a substantial library of routines that can be used to support new applications. One key principle has been to work strictly within the constraints of SMS, in order to retain compatibility with basic mobile phones. Working with the devices that are owned by and therefore familiar to the great majority of mobile phone users is seen as essential when the aim is to go to scale as quickly

as possible. Data collection involves the input of SMS 'forms' that consist of a keyword followed by one or more free-format fields. The compiled database is made available over the internet, allowing multiple users, from any location, to access the system remotely at the same time.

For more complex data, the use of mobile phone applications or phones that can link directly to the internet offer considerable advantages. This approach is not subject to the strict limits imposed by messaging systems, allowing a more user-friendly interface. In principle, it can also incorporate all of the techniques commonly adopted in traditional questionnaires or routine data returns, for example, skipping over questions that are not applicable to a given respondent or presenting follow-up questions to those identifying themselves as being in a category of particular interest. There is also a potential for improving data quality by specifying automatic checks to ensure that all questions have been answered, that values are within predetermined ranges and that they are consistent with previous responses. The major disadvantage is that basic mobile phones, by far the most widely used in resource-poor countries, are excluded. The type and quality of the mobile network will also play a major role in determining the feasibility and quality of such systems.

The FrontlineSMS system discussed above has been adapted to allow the use of data collection forms on mobile phones which can run application software. FrontlineForms[20] allows the downloading onto such phones of relatively simple questionnaire forms that can be completed and transmitted as SMS text. There is a particular focus on health care applications including MedicMobile,[21] which includes a potential for establishing electronic medical records. It is intended to extend this system to include remote diagnostics and mapping of services. Again, the Open Source software and support services are provided free of charge to organisations undertaking not-for-profit interventions and under contract to commercial enterprises.

The mobile phone application approach is also used by EpiSurveyor. The development of this software, by the social enterprise company DataDyne, was supported by the United Nations Foundation, the Vodafone Foundation, and a World Bank Development Marketplace Grant.

The basic version is made freely available, subsidised by a very limited number of premium version commercial applications. Users with a basic knowledge of computing can design relatively complex surveys or routine data forms on the EpiSurveyor website. These can be downloaded to a suitable mobile phone, which then sequentially presents each section of the data collection form for completion and storage. The responses can later be uploaded to an online account or a laptop. The website provides basic analysis capabilities, allowing the generation of simple tables, graphs, charts and maps from data files which can also be exported to Microsoft Excel or Access. The survey data are stored in encrypted form to ensure confidentiality.

The developers claim widespread use of the software to conduct surveys and also cite the example of Kenya, where the Ministry of Health is using EpiSurveyor not only to collect data on notifiable diseases from rural clinics but to manage its drug supply chain (Economist Intelligence Unit 2011: 13). A recent nationally representative survey using a sample of 700 beneficiaries of a Conditional Cash Transfer Program in Guatemala was undertaken by the World Bank using EpiSurveyor. It found that 'Compared to its 2009 paper-based counterpart, the 2010 mobile-phone-based survey proved highly superior in terms of cost and showed notable improvements in quality control and the implementation speed of the survey' (Schuster and Perez Brito 2011: 3). They report that average cost per interview, allowing for the cost of data entry, was reduced by 71 per cent. Data quality improvements were linked to the ability of supervisors to monitor enumerator activities in real time, responding immediately to apparent data inconsistencies, and to a zero level of data loss, which can have a serious effect on traditional questionnaire surveys.

Perhaps the most important single observation that can be derived from the above discussion is that those designing information systems need to develop the habit of working at multiple levels. In computer systems design a commonly adopted strategy is to distinguish between the conceptual, logical (software) and physical (hardware) levels of analysis (Simsion and Witt 2004). Developers become very attached to their chosen hardware and software options. This can be a great advantage in terms of generating the level of

commitment often required to turn good ideas into practical field applications. However, there is a need to routinely step back from immediate technical challenges to allow for the possibility of adopting a radically new approach to a given problem, even if this sometimes involves abandoning the technological options with which we feel most comfortable.

Notes

1 This article is an edited extract from the Desk Review prepared during the first phase of the IDS-UNICEF project on Real Time Monitoring for the Most Vulnerable.
2 www.unglobalpulse.org/resources/mobile-phone-data-collection-inventory.
3 For example, both developing and developed countries have expended very substantial sums on IT projects intended to improve health information systems, often with very limited benefits (Halford *et al.* 2010; Bend 2004).
4 The target price tends to be around $100 though the Indian government is proposing a device that will cost around $35. See www.rnw.nl/english/article/indias-35-dollar-pc-simply-impossible.
5 www.intellearningseries.com/WhatIsILS.html.
6 http://laptop.org/en/laptop/hardware/index.shtml.
7 www.economist.com/node/14637206?story_id=14637206.
8 http://medic.frontlinesms.com/.
9 Generally described as GPRS (2.5G) and EDGE (2.75G) networks.
10 These are often written in the 'Java' programming language. Mobiles that can run applications written in Java are described as 'Java-enabled'. They are often described as 'feature phones'.
11 The penetration ratio is usually the number of subscriptions per 100 adults – the per cent of households with access may be much higher.
12 Though in Kenya mobile internet subscriptions are currently around 5 million (CCK 2011), compared to an adult population of less than 23 million, with growth at around 20 per cent per annum.
13 www.healthnet.org/.
14 www.healthnet.org/sites/default/files/UHIN%20Press%20Release%20-%205-26-2010.pdf.
15 Personal correspondence.
16 www.kiwanja.net.
17 www.rapidsms.org.
18 www.acted.org/en/writing-sms-can-save-lives-northern-uganda.
19 Integrated Community Case Management (ICCM) www.healthynewbornnetwork.org/sites/default/files/resources/SCiUG_assessment.pdf.
20 www.frontlinesms.com/resources/frontlineforms/.
21 http://medicmobile.org/.

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