Mobile Communications for Medical Care

a study of current and future healthcare and health promotion applications, and their use in China and elsewhere

Final Report
21 April 2011

UNIVERSITY OF CAMBRIDGE

中国移动通信 CHINA MOBILE

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Contents

Executive Summary

This report examines the use of mobile networks to enhance healthcare (so-called "mHealth"), as an example of how mobile communications can contribute to sustainable development. We define mHealth as *"a service or application that involves voice or data communication for health purposes between a central point and remote locations. It includes telehealth (or eHealth) applications if delivery over a mobile network adds utility to the application. It also includes the use of mobile phones and other devices as platforms for local health-related purposes as long as there is some use of a network."*

Innovative mHealth applications have the **potential to transform healthcare** in both the developing and the developed world. They can contribute to bringing healthcare to unserved or underserved populations; increasing the effectiveness and reducing the costs of healthcare delivery; improving the effectiveness of public health programmes and research; preventing illness (including through behaviour change); managing and treating chronic diseases; and keeping people out of hospital.

mHealth applications are **numerous and diverse**. They range across remote diagnostics and monitoring, self-diagnostics, management of long-term conditions, clinical information systems, targeted public health messaging, data gathering for public health, hospital administration, and supply chain management. They are emerging in response to **opportunities and needs** that are similarly diverse, including the threat of pandemics; globalisation and population mobility; an ageing and increasing population; rising income (leading to lifestyle changes); increased expectations of health provision; demands for the personalisation of healthcare; and a growing focus on behaviour change, disease prevention, and keeping people out of hospitals.

These applications are enabled by the **fundamental characteristics of mobile networks and devices**: near-ubiquitous, locatable, connected user interface devices, often personalised, delivering computing power at low cost, integrating a range of sensors and supporting mobility (essential in some applications but not all):

- In many developed countries, the coverage of mobile infrastructure is near-ubiquitous, and in many developing countries, it provides higher penetration of the population than fixed networks. In some places, it is the only ICT infrastructure, and mobiles are the only general-purpose computer available.
- The capabilities of mobile networks (particularly in terms of data-carrying) are increasing rapidly, extending the scope of applications that can be supported to include high-resolution images, video and large file exchange, which are required for some medical purposes.
- Basic phones with voice and text messaging already provide powerful tools; the new generation of "smartphones" offer greater computing power, data storage, the ability to interface with sensors, and intuitive user interfaces that can be used as the platform for sophisticated applications of many kinds.

Business models have emerged that encourage innovation in mHealth applications; many of these models are incremental (i.e. they do not require major infrastructure investment), although they may still rely on interaction with other service providers' components or platforms. Moreover, for many mHealth applications, deployment requires no intervention by policy-makers or the medical establishment. In such cases, normal market innovation, and consumers' willingness to pay, will drive deployment. But not all mHealth applications are like this: many will need to interact with established healthcare systems (and therefore be subject to the regulation of those systems). In these cases, development will play out very differently depending on the maturity of healthcare systems. At the same time, some of the greatest benefits of mHealth are unlikely to be delivered by the market in any environment. In particular, individual consumers are unlikely to pay for applications designed primarily to produce information from which **public goods** (such as better advance warning of the spread of epidemics) are derived. Such investments for the public good require funding by institutions if the potential benefits are to be realised.

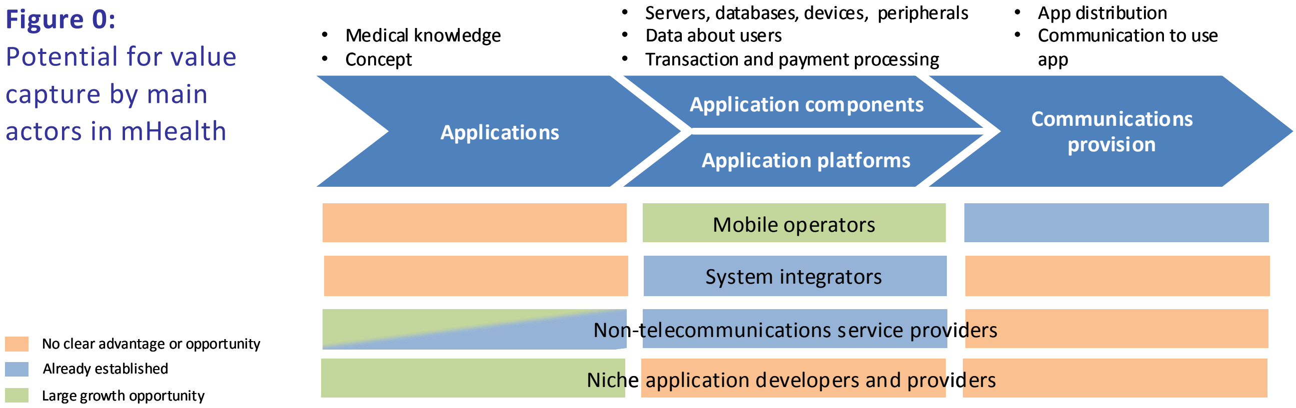
The nature and pace of development will vary between countries. In **developed economies**, the mobile will be used to collect, store, analyse and upload a wide spectrum of personal and environmental data, from vital signs (heart rate, body temperature, etc.) to location, motion, mood, ambient air temperature and pollution levels, and adherence to medication regimes. The ability of healthcare providers and carers to use this data in real time, and in aggregate form for research, will not only benefit individuals but will also lead to better forms of illness prevention and treatment, and earlier prediction of epidemics. Individuals' personal health records may come to be stored in electronic form, updatable from a mobile phone, and capable of being accessed with suitable permission anywhere in the world. Engaging applications will lead to better support for behaviour-change interventions and for treatments such as cognitive behavioural therapy in the area of mental health.

Over time, many of these applications will also reach **low-income economies**, though in the shorter term mHealth will help to put in place robust administrative systems for healthcare delivery that are taken for granted in developed countries. Increasingly powerful mobile phones will be in the hands of health workers, delivering technologies previously available only in larger population centres. Mobile phones will also deliver training to clinicians, and remote decision support using either automated analysis of data, or real-time contact with specialists. Medical staff will be enabled to diagnose and treat conditions locally without patients needing to travel large distances to specialist centres. Disease outbreaks will be handled more efficiently through better communication.

We expect applications to develop most rapidly in countries where healthcare delivery, and public services generally, are in transition from established to new structures (through market change, deregulation, other infrastructure change, or demographic change). Rapid development will also be encouraged where the population has rising expectations for healthcare, and where those involved in healthcare delivery are willing and able to experiment with new models. Such conditions may apply in any country, but are perhaps most likely to apply in **major emerging economies**.

In all parts of the world, the next phase of development and deployment will see **generic service platforms** playing a crucial role, providing processing power, storage, security, access control and other services to a wide range of mobile applications, including (but not limited to) mHealth. Until recently, an application that required "off-phone" services required dedicated servers that had to be dimensioned for the application, but the emergence of cloud computing is obviating this need. Few current mHealth applications use cloud-computing facilities; however, if these generic services were provided as publicly available platforms, like the mobile network and Internet themselves, the upfront investment required to deploy new applications would be decreased. The actors best placed to drive a move toward publicly available platforms include large network operators, as shown below:

Figure 0: Potential for value capture by main actors in mHealth



Investments in generic services have the potential to contribute to multiple applications, and not all of those applications have to succeed for the investment to be justified. This consideration is particularly true for the operator, where scale and brand allow a very effective spreading of financial risk; reputational risk is also decreased, because the operator need not enter the health sector application business at all, merely enable it. This both encourages sector-driven innovation, and allows applications to be developed which have too small a user base to be of interest to a large operator. It also separates any trust issues related to information privacy from the operator-provided infrastructure.

Our recommendations for the principal players in mHealth are presented below:

Players	Recommendations
Policy-makers (including governments, health NGOs, and regulators)	■ Policy-makers should ensure that policies and priorities for healthcare are complemented by financial incentives that reward those who deliver outcomes, particularly in disease prevention. ■ Policy-makers, healthcare agencies and professional healthcare bodies should provide guidance for assessing the healthcare and public financial benefits from emerging applications in a manner that can be understood by application providers, and create an expectation that such assessment should be an integral part of provision. ■ Public health authorities and agencies should engage in assessing the benefits and costs of acquiring information – whether as "by-products" or directly – from mobile applications, either to replace existing data gathering or to gain new knowledge. This requires clarity of ownership of, and access to, personal information. ■ Regulatory regimes and the medical establishment's guidance-setting need to strike an appropriate balance between the risks and benefits of specific mHealth applications, distinguishing between those apps for which a light touch or a market-based approach is appropriate (i.e. those that pose no risk to health and may be effective, and which typically have little or no interaction with the established health delivery system) and those which have the potential to bypass or substitute other healthcare systems (i.e. those that might pose a risk to health unless properly regulated, or which might need to be robustly evaluated if health system money is to be put into them). ■ Telecoms regulators should review any constraints that existing regulations may place on the deployment of mHealth applications. In particular they should consider allowing mobile operators to operate as micropayment banks, i.e. directly handling small financial transactions.
Telecommunications Operators	■ Operators should have clear strategies – which might be different in different markets – for how much of the value chain (basic services, generic platforms, application provision) they wish to operate, balancing investment, financial return, reputational risk and the presence/absence of other players operating parts of the value chain. ■ Mobile operators should promote their networks as platforms for innovation and small-scale application deployments, and should invest in the provision of generic service platforms for this purpose. They should facilitate the use of the platform for domain specific innovation (here healthcare, though the recommendation is more generally applicable) by third parties, recognising that, even if they choose to operate some applications directly, some applications will be too small (or present excessive risk) for the operator to provide.
System Integrators, Manufacturers and Technology Providers	■ Medical device manufacturers should exploit the power of the mobile handset as a computing and communications platform, even when the computation required to deliver a particular application cannot reside completely on the handset. The swiftest take-up will be of applications that rely only on voice, SMS and WAP. ■ There is an opportunity for technology providers to provide the tools for creating or running managed services related to mHealth, which will in turn enable operators to provide generic service platforms. Technology providers need to decide whether their strategy is (a) to build and sell or (b) to build, sell and operate, perhaps in direct competition with operators.
Healthcare Providers (including Insurers)	■ Healthcare providers should examine mHealth applications as a means of managing exposure to costs – e.g. through the use of in-home monitoring to avoid hospital or residential stays. This might allow reduced charges or premiums, or increased profits. ■ Healthcare providers should consider how they might use data generated by mHealth applications to monitor and optimise the healthcare delivery chain itself, e.g. by improving the management and efficiency of expensive assets, or by better understanding the patterns of use.

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Foreword
来自中国移动的卷首语

Mr. Wang Jianzhou, Chairman, China Mobile
中国移动通信集团公司 董事长 王建宙

The United Nations Millennium Development Goals specifically include the fight against diseases and the reduction of child mortality. By making full use of innovative technology and business models, we believe that it is possible to raise the level of healthcare in society, which is very important for promoting the sustainable development of the whole of mankind.

联合国千年发展目标中，明确提出了要降低儿童死亡率，并与疾病做斗争。充分运用创新的技术手段与商业模式，不断提升社会医疗保健水平，对于推动人类整体的可持续发展具有十分重要的意义。

As the world's largest telecommunications operator by customer base and network size, providing service to 600 million users, China Mobile believes that the use of mobile communications for healthcare is an important strategic development, integrating information and communications technology and the needs of the sustainable development of society. By the development of mHealth, we can, on the one hand, further enhance the real-time pertinence and convenience of healthcare services in urban areas, and on the other, provide a new way to make medical services available in remote areas.

作为服务于6亿用户的全球客户和网络规模最大的通信运营商，中国移动认为，移动医疗是将ICT技术与社会可持续发展需求相结合的一个重要战略性领域。发展移动医疗，一方面可以在技术和业务融合的背景下，进一步提升医疗服务的实时性、针对性与便捷性，另一方面也可为提升边远地区医疗服务的可获得性提供新的途径。

We at China Mobile have taken six years to extend our network and service to approximately 89 000 villages in the border and remote areas of China, meaning that our network now covers over 98% of the population; our services now reach the most remote areas of China and the vast majority of people in poverty. We now face the important issue of how to better leverage our network and services to contribute to the promotion of local sustainable development. Like our counterparts elsewhere in the world, we have trialled many innovative applications, including medical and health information services, mobile registration for appointments, remote visitation and diagnosis, and so forth.

中国移动用六年时间，为中国远边地区约89,000个村庄新开通了移动电话，使得我们网络的人口覆盖率达到了98%以上。我们的网络和服务已经可以到达中国最边远的地区和最贫困的人群。如何更好地发挥我们的网络和服务的影响，为推动当地可持续发展做出贡献，是我们面临的重要课题。和全球的同行一样，中国移动已经开展了包括医疗健康信息服务、移动预约挂号、远程探视和诊疗等创新的移动医疗应用尝试。

Next, we need to look carefully at the whole range of mobile medical applications, and (in line with changes in technology and need) identify and promote the best applications that can fully take advantage of mobile communications technology and meet social needs. This report, therefore, examines both existing applications and the most promising potential applications for the future.

下一步，我们需要共同来审视和梳理现有的移动医疗典型应用，根据技术的发展和需求的变化，识别和推动最能发挥移动通信技术特长并满足社会医疗信息化需求的应用，使移动医疗真正从一个好的概念变为切实可用的服务。而本报告，正是对于现有以及未来最有潜力的移动医疗相关应用进行了一番全面的审视。

In this regard, China Mobile has first-hand operational and practical experiences. By bringing this together with the professional and academic expertise of those consulted in the course of this project, we are convinced that our joint research presented here will further accelerate the development of mobile healthcare and make a significant contribution.

在这方面，中国移动拥有第一手的运营和实践经验。通过在此次联合研究项目过程中与相关专业人士和学术专家的紧密合作，我们相信此项联合研究项目将为进一步加快移动医疗的发展做出重要的贡献。

We are grateful to the project team at the University of Cambridge, and to all of those they have met and worked with during the project, for their commitment and for making their expertise available for this report. We look forward to an ongoing discussion in all the relevant global communities – development, telecommunications, and healthcare delivery – as the application of information and communication technologies to the world’s health needs gathers pace in the coming years.

非常感谢剑桥大学的项目团队以及在研究过程中接受访谈和参与项目研究的各位专家，正是他们的热情支持与专业参与，使得本报告得以呈现。我们期待在未来与全球相关业界专家就移动医疗的发展、通信技术的应用以及医疗保健的普及进行更加深入的交流，共同促进信息通信技术的应用、推动全球医疗卫生事业的更快发展。

王建宙

Mr. Wang Jianzhou, Chairman, China Mobile

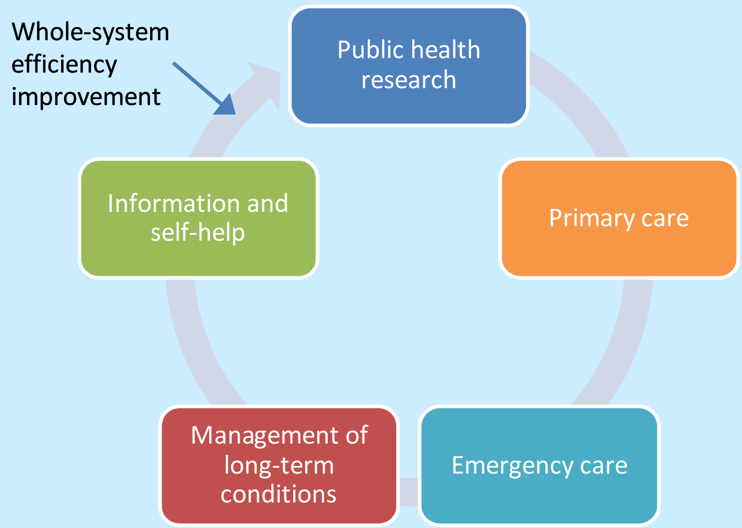
Chapter 1

Overview of the mHealth Market

This report sets out the results of a project conducted by the University of Cambridge and China Mobile on the application of mobile networks to healthcare (so-called "mHealth"), as an example of how mobile communications can contribute to global sustainable development.

Innovative mHealth applications have the potential to transform healthcare in both the developing and the developed world. They can contribute to bringing healthcare to unserved or underserved populations; increasing the effectiveness, and reducing the costs, of healthcare delivery; improving the effectiveness of public health programmes and research; preventing illness (for example through behaviour change); managing and treating chronic diseases; and keeping people out of hospital.

A very diverse range of applications is being developed and deployed in all parts of healthcare:



These mHealth applications are emerging in response to opportunities and needs that are similarly diverse, including the threat of pandemics; globalisation and population mobility; an ageing and increasing population; rising income (leading to lifestyle changes); increased expectations of health provision; demands for the personalisation of healthcare; and a growing focus on behaviour change, disease prevention, and keeping people out of hospitals.

These applications are being enabled by the fundamental characteristics of mobile networks and devices: locatable, near-ubiquitous, connected user interface devices, often personalised, delivering computing power at an affordable cost, integrating a range of sensors, and supporting mobility (which is essential in some applications but not all).

1 Objectives, Approach and Overview of the mHealth Market

This report sets out the results of a project – conducted jointly by the University of Cambridge and China Mobile – describing and forecasting the application of mobile networks to enhance healthcare and health promotion (so-called "mHealth") worldwide, as an example of how mobile communications can contribute to global sustainable development.

The University is grateful to China Mobile both for its sponsorship of the study, and for making available to the team information on its own operations in this area. The authors are also grateful to all those within and outside the University who so generously made their time and expertise available to support this research.

1.1 Objectives of the Project

mHealth applications have already been deployed in many markets, and many further developments will be enabled by smartphones, mobile broadband and the ever-increasing reach of mobile networks, including remote diagnosis, monitoring and care, emergency response, the tracking of the spread of infectious disease, the training of healthcare professionals and the targeted dissemination of public health information. Such applications have significant potential to contribute to major sustainable development goals, including the provision of universal access to safe, effective, convenient and affordable health services; improved maternal care and the reduction in child mortality; and the combating of disease.

By bringing together case studies provided by China Mobile, research into other emerging and developed markets, and the University's cross-disciplinary expertise in communications, healthcare and business, the project has been designed to:

- describe the opportunities and challenges typically presented by mHealth
- illustrate these through current mHealth applications in both the developed and developing world
- look forward to the most exciting potential applications (and the role they can play in improving the provision of healthcare)
- illustrate the costs and benefits to operators, healthcare providers, and society
- summarise the implications for operators (potential investments and returns) and for governments, NGOs and other policy-makers (regulatory action or intervention)
- identify areas for potential future research and studies.

For the purposes of this project we have defined "mHealth" as follows:

An mHealth service or application involves voice or data communication for health purposes between a central point and remote locations. It includes telehealth (or eHealth) applications if delivery over a mobile network adds utility to the application. It also includes the use of mobile phones and other devices as platforms for local health-related purposes as long as there is some use of a network.

This is a deliberately broad definition, as we were concerned not to exclude major developments in healthcare technology because of arguments over the relative importance of mobile communications in their delivery. Above all, we have been keen to consider whether mobile communications – combined with many other advances in information technology, sensors, and healthcare more broadly – can bring benefits to society in general, while also being affordable and making commercial sense for those businesses which will deliver them.

1.2 Approach

The project was undertaken between October 2010 and early February 2011 by a small team under the leadership of Professor Ian Leslie FREng (Professor of Computer Science at the University of Cambridge). The project principally involved a literature search and interviews conducted in the UK, fieldwork in China, and an expert workshop convened in Cambridge on 15 November 2010.

The literature search was designed to ensure that the project took account of the best existing research, by identifying examples of existing applications, and focusing on what mobile networks and devices deliver now that is already making a difference to the way health professionals and systems work. In particular, the authors would wish to acknowledge key sources such as the 2009 report by the United Nations (UN) and the Vodafone Foundation[1] and the publications of the mHealth Alliance.[2] Published sources were supplemented by access to current thinking and research generously provided by our interviewees.

The fieldwork in China was conducted by China Mobile staff, using an approach designed by the University team. Two members of that team visited Guangdong Province in the week of 22 November 2010, to discuss the findings of the field research and to interview a small number of managers who have direct involvement in, and responsibility for, the existing mHealth implementations and plans.

The Cambridge workshop brought together experts in clinical medicine, public health, healthcare delivery, technology, innovation, business and industry, and in China as a market, from both within and outside the University, to discuss applications likely to have the most significant impact on major areas of healthcare need. The primary purpose of the workshop and the interviews was to focus on future applications, addressing key questions including:

- What are the areas of greatest need and potential benefit which mHealth will address in the future?
- What kind of mHealth applications will have the biggest impact? Where, when, how and why?
- In practical terms, how can mHealth applications be evaluated for their impact on the health economy and society generally? What can be measured? What can be researched?
- How do developed/emerging economies differ? and urban/rural areas? What's special about China?
- What needs to happen for mHealth applications to be successfully introduced and effectively implemented on a wide scale?

The participants in the workshop and the interview programme are listed in Annex B below. As our discussions were conducted under the Chatham House Rule,[3] this report does not attribute any opinions specifically to any of the participants.

1.3 Overview of the mHealth Market

Among the reasons why mHealth has aroused such interest over the last few years is because the capabilities of mobile networks and devices address specific issues and needs in the provision of healthcare. The fundamentals of mobile telecoms – the way they drive ubiquitous connectivity, and support increasingly intelligent devices associated with individuals in specific locations – are now being extensively exploited in the medical and healthcare sector. For example:

- In many developed countries, mobile network coverage is near-ubiquitous, and in developing countries, the mobile infrastructure provides significantly higher penetration of the population than fixed telecoms networks, enabling communication with more people, even in remote areas. In some places, mobile infrastructure is the only information technology and communications infrastructure, and mobile handsets are the only general-purpose computer available.

- The capabilities of mobile networks (particularly in terms of data-carrying capacity) are increasing rapidly in many countries, extending the scope of applications that can be supported to include high-resolution images, video and large file exchange, which are required for some medical purposes, particularly diagnosis and the storage of medical records.

- As well as being already near-ubiquitous in many countries of the world, the mobile phone is generally a personal device that is nearly always on, connected, and locatable. This association of a device with an individual opens up significant opportunities for personalised communication; and, if privacy concerns are adequately addressed, large-scale data-gathering and (because the device is locatable) tracking.

- Where the mobile phone is not a personal device – for example, in developing countries in Africa – it is nonetheless a powerful tool for frontline healthcare workers, not least because its possession confers status on such individuals.

- Already today, basic phones with voice and text messaging provide powerful network-based flexibility for interaction with individuals. In addition, so-called "smartphones" (which are expected to be very widely used throughout the world within the next few years) offer significantly increased computing power, data storage, the ability to interface with sensors, and intuitive user interfaces that can be used as the platform for sophisticated applications of many kinds, both device-centric and network-enhanced (though differences between platforms present some challenges to deployment).

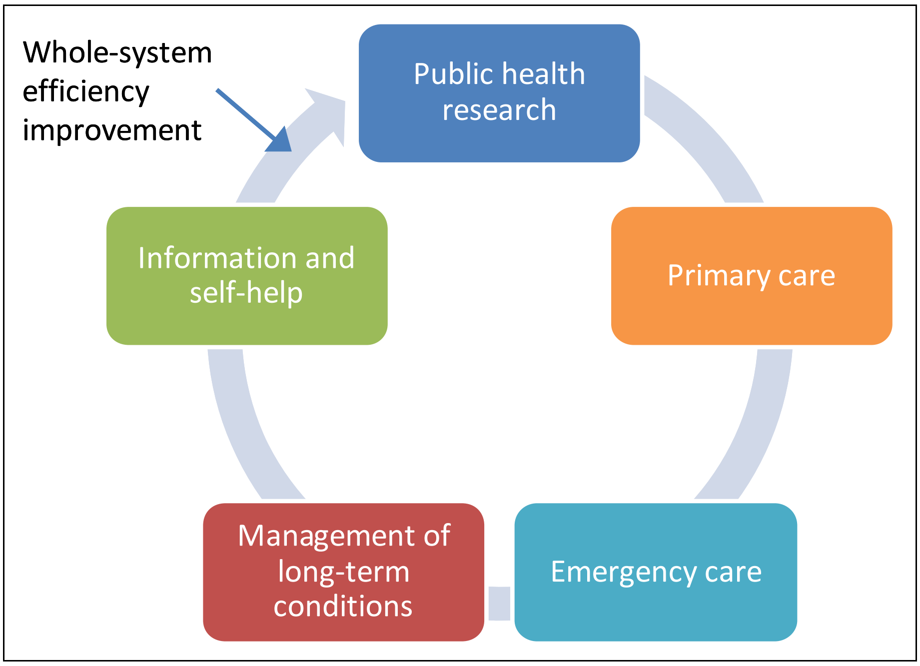
- Business models have emerged that encourage innovation, particularly in the area of apps for smartphones. Such apps can be directly related to health or healthcare, or can be combined to make healthcare apps more useful or appealing. Many (though not all) of these business models are incremental – that is, they do not require major infrastructure investment on top of the existing network and handset. As we will see, these apps fulfil key requirements for success in the current mHealth environment.

The development of mHealth is proceeding hand in hand with changes in the structure of health delivery. Individuals are taking greater responsibility for their own health – both because there are technologies and services that enable them to do this, and because the cost of system-based delivery of healthcare is increasing. The boundaries between the "healthcare system" and new providers of services is blurring as services and applications emerge to which individuals have direct access and which they want to use, independently of professionals in the healthcare system. Understanding of the possibilities that mHealth has to offer is contributing to this trend.

Despite this blurring of boundaries, the structure of healthcare systems remains useful in reviewing and classifying mHealth applications, and it is the one we have adopted in this report. Figure 1 shows six linked themes into which we have grouped applications, based on the primary purpose of the service or application (note, however, that an mHealth service or application can address more than one theme).

Each of these themes is described further below, with examples of services and applications that are either available now or are being trialled or developed as concepts. (Note that Annex A contains a longer list of example services and applications identified in the course of the project.) In Chapters 2 and 3 we then look in more detail at some specific current and future mHealth applications. Further detail on the Chinese case studies highlighted in Chapter 2 is provided in the "Special Feature" at the end of this report.

Figure 1:
Six "themes" into which mHealth applications can be grouped



Public Health Research

The first theme encompasses data-gathering for public health research programmes, including the tracking of disease outbreaks, epidemics and pandemics, both for the development of health policy and for the design of healthcare interventions. For example:

- The extension to mobile networks and devices of established surveillance and data-collection platforms for public health systems, such as DataDyne's web app Episurveyor,[4] which has been used for a wide range of data-collection applications in developing economies.
- Simple mobile-phone-based applications supporting maternity and neonatal health programmes, such as ChildCount+,[5] which uses SMS messages to coordinate the activities of local health workers in registering patients and reporting health status.
- A disease surveillance project (supported by Nokia) for Dengue Fever in Brazil, gathering data on reported outbreaks and mapping them, using questionnaires distributed to field health agents' mobiles. Health data and GPS location information are integrated to enable immediate analysis and identification of areas with high infection levels.[6]
- The use of private information in a suitably anonymised or authorised form for the public good – e.g. mining mobile-device-based eHealth records in order to design more effective interventions. Data-mining of eHealth records is already carried out by specialists such as IMS Health[7] and CVS Caremark[8] for health providers and pharmaceutical companies.

Primary Care

The primary care theme includes services and applications that support the diagnosis of medical conditions, and the provision of treatment by frontline local medical staff (including general practitioners), by clinic-based health workers, or indeed by itinerant health workers or those located in remote communities in developing economies or rural areas. Typical applications in this category are those where mobile networks are able to support the provision of services close to the patient in the community, and also where the capabilities of mobile devices can enhance local diagnosis or provide access to support from specialists in another location. For example:

- Breast cancer screening in Tasmania (provided by Telstra and Ericsson),[9] supported by a mobile broadband network which delivers image files to assessment centres, so that women in isolated areas are able to have a diagnosis without travelling long distances to specialist centres.
- The UK-based 3G Doctor mobile video consultation,[10] where patients use a 3G video call to consult with a doctor (at a cost of GBP35 per consultation), supported by online questionnaires. (See Section 4.4.2.)
- The Sana[11] app for Google Android phones (connecting rural health workers with doctors in urban areas), used to support remote diagnosis. Local health workers collect data including pictures and video and send them to a database. Data can be reviewed and diagnoses made, and these are then communicated to the health worker by SMS.

Emergency Care

This theme includes the enhancement of emergency care, in hospitals and elsewhere, through the deployment of mobile technologies. For example:

- Personal Emergency Response Systems – wireless devices aimed at the elderly or those suffering from conditions such as Alzheimer's, giving one-touch access to emergency services, sometimes with location-tracking built in – e.g. those produced by Wellcore[12] in the USA.
- Wireless fall-prevention devices that use accelerometers and pressure sensors connected to a mobile network to monitor a person's gait and warn carers or medical staff of imminent or actual falls.[13]
- Systems to ensure calls to health professionals reach an appropriate specialist through call distribution to groups of mobile phones, such as the Orange Smartnumbers[14] service in the UK.
- On a wider scale, rapidly deployed communications systems designed to support the response to natural disasters, such as those deployed after the Wenchuan earthquake in China's Sichuan Province in 2008, those deployed after the Haiti earthquake in 2010,[15] and the 40+ worldwide deployments of FrontlineSMS.[16]

Management of Long-Term Conditions

The management of long-term conditions was one of the earliest areas of application of telecare using fixed networks – supporting the provision of care for patients in their own homes, particularly those suffering from conditions such as diabetes, asthma, coronary heart disease, obstructive pulmonary disease and mental health problems. This theme relates to the enhancement of the concept using mobile networks (providing extension beyond the home), and to new applications enabled through the use of personal devices and ubiquitous networks. Examples include:

- Self-management of diabetes or cardiovascular illness using mobile devices and networks, such as the trial at Oxford University[17] of blood glucose test results and dietary information via mobile phones, which uses the graphical display on the phone to give the patient real-time feedback based on analysis of the data presented.

- Promotion of adherence to medication regimes through videophone-based Directly Observed Treatment (DOT), e.g. tuberculosis patients in Kenya[18] where daily videos are taken by carers to show patients taking their medication. Patients receive motivational texts following review of the video by health professionals. Simpler device-based calendars may also be used to help patients to remember to take their medicines.

- At the Murdoch Children's Research Institute in Australia, mobile phones have been used to track the mood of children and young people aged 14-24 with mental health problems.[19] A wide-ranging interactive questionnaire is used to ask participants how they feel, and the data is evaluated by a doctor who can determine appropriate treatment.

Information and Self-Help

This theme encompasses applications promoting wellness, and incentivising or encouraging individuals to improve their own health. This includes applications that provide information (either pushed to an individual, or requested by them) to end users and health workers. For example:

- "Medicine Link", a Chinese mobile information service on safe drug use and other healthy lifestyle issues, as well as a platform to disseminate public health information. Subscribers to the service can receive up to five public health messages per week on drug safety and healthy eating, along with policy updates and notifications of any currently known adverse reactions to food and drugs. (See Section S2.)

- The MiQuit SMS-based system for delivering personalised encouragement and support to pregnant smokers who want to stop smoking.[20] In an academic study, the system was shown to be capable of delivering valuable messages to individuals, and practical to implement.

- "Freedom HIV/AIDS", an awareness initiative using mobile phone games (and various "play and learn" methods), aimed at young people in remote regions without access to other information initiatives.[21]

- Mobile access to medical databases aimed at professionals, such as the Mobile Medline Plus service of the US Library of Medicine,[22] the Epocrates[23] database-driven apps for smartphones, and the drug information services provided by pharmaceutical companies.

Whole System Efficiency Improvement

Finally, some mobile health services and applications have an impact on the complete healthcare system – either by increasing the efficiency and effectiveness of existing processes, or by enabling new processes that have a broad impact on health and medical care. Examples include:

- Hospital appointment booking systems, such as the 12580 service in Guangdong, China. (See Sections 2.1 and S2.)

- Platforms to facilitate the efficient provision of information, consultations and feedback in rural areas, including systems for monitoring and streamlining the reimbursement of healthcare costs, such as those being developed in Guizhou Province in China. (See Section S3.)

- FrontlineSMS[24] – a free, open-source software platform for large-scale, two-way text messaging using a laptop, GSM modem and low-cost mobile phones. An extension of the platform (FrontlineSMS: Medic) provides access to other systems such as patient management, medical records, diagnostic tools, and mapping applications.

- The development of personal electronic health records, stored in, or accessed and updated through mobile devices and networks (e.g. the Sana[25] app mentioned earlier).

- Mobile-enhanced RFID-based tracking and certification of drugs through the supply chain, for example the Sproxil[26] SMS-based system being trialled in Nigeria. (See Section 2.2.)

1.4 Characteristics of mHealth Applications

As well as being associated with one or more of the major parts of the healthcare landscape as shown in Section 1.3 above, applications can also be assessed and described in terms of their technology and in terms of a number of human and market characteristics, as Figure 2 shows.

Figure 2: Some dimensions for characterising mHealth applications

Technology characteristics	Aggregated, networked	←→	Individual, P2P
	Multi-platform	←→	Single platform
	Sophisticated technology	←→	Simple technology
	One way, asynchronous	←→	Duplex, real-time
	Integral technology, software	←→	Platform+peripherals, hardware
Human characteristics	General distribution	←→	Controlled distribution
	Active, manual, engaged	←→	Autonomous, passive
Market/ business model characteristics	General population	←→	Health workers
	Developed world	←→	Developing world
	Consumer demand-led	←→	Healthcare-system led
	Private good	←→	Public good
	Integrated with back office	←→	Standalone

Each of these characteristics has an impact on the way the application is developed, trialled and deployed, how the business case can be built, and how implementation challenges can be addressed. We will return to these issues later in the report; firstly, in Chapters 2 and 3, we look in a little more detail at specific examples of current and potential future applications that we have identified as particularly significant.

Chapter 2

Existing Applications of mHealth

Many of the applications of mHealth already in use around the world today are technically simple (making use of voice and SMS rather than advanced features), meet an immediate need, and offer benefits that directly incentivise the owner of the mobile phone to use the application. Many of them extend existing eHealth applications to mobile networks, and have gained acceptance on the basis of a common-sense view of utility and risk. This Chapter looks in particular at:

- **Mobile-Enhanced Appointment Booking Systems**. Using the convenience of mobile voice and SMS to help make appointments with doctors and specialists. Such systems are widely applicable, and indeed have been widely deployed; they deliver utility and reduced costs for the healthcare provider, and ease-of-use benefits for the user.

- **Drug Authentication and Tracking.** Addressing counter-feiting and piracy by tracking drugs from the point of manufacture to the point of consumption, and authen-ticating provenance before use. Mobile networks allow tracking to be extended into remote regions, both to the point of sale and the point of use, and bring savings and brand benefits to manufacturers.

- **Remote Diagnosis.** mHealth applications can help a patient get a diagnosis without having to travel to a centre, using downloaded decision-support applications, remote access to decision-support databases and systems, or communic-ation with a specialist, via voice, messaging or video. They may connect a healthcare worker with a specialist, or connect the patient directly with a healthcare worker.

- **Well-being Applications.** Many mHealth applications that have emerged in the last few years have been developed as simple, lightweight apps for smartphones, aimed at increasing individuals' well-being. Some are based simply on the provision of information (either within the app, or entered by the user), while others make use of the more advanced functionality of the devices they are intended to run on, such as GPS positioning and accelerometers.

Such applications have shown that the use of a mobile network and connected device can help to extend cost-effective healthcare provision, particularly by allowing diagnosis to be performed closer to the patient without the need for travel to specialist centres (thus also reducing the risk of spreading epidemic disease). Moreover, data collected in this way, subject to appropriate consent and privacy regimes, can be of great value in research into disease transmission.

2 Overview of Existing Applications of mHealth

In this chapter we review a number of existing application types, drawing on examples from around the world, including China. We illustrate the current state of the field by focusing on four such types: mobile-enhanced appointment booking systems, drug authentication and tracking, well-being applications, and remote diagnosis. This is not intended as an exhaustive list, and indeed many existing applications shown in Annex A fall outside these types. They are, however, broadly illustrative of current mHealth applications, in that they typically:

- extend existing applications to mobile networks while adding utility
- are technically simple, generally making use of voice and text messaging rather than advanced features
- are acceptable to individuals and the healthcare sector on the basis of a common-sense view of utility and risk (without the need for lengthy academic or clinical trials or ethical review)
- meet an immediate need, have a clear business case (often outside the healthcare system), and offer benefits that directly incentivise the owner of the mobile phone to use the application.

This last point is related to the concept of the "public good" in mHealth introduced in Figure 2. Our research has also identified applications which have the potential to significantly improve the health of populations, and to deliver benefits for society in general, but for which it is difficult to identify a clear commercial business case with rapid payback on investment from commercial parties, and a clear reason why a particular individual would pay for the service. These include, for example, applications that facilitate mass immunisation programmes, or that enable the more effective modelling of disease transmission and the design of better healthcare interventions. The questions arise "who will pay in order to realise these benefits?" and "what are the ethical and privacy issues?" – we look at these in Section 3.4.

As the structure of economies and healthcare systems varies widely around the world, some current applications work better in some countries than others. Different countries' healthcare systems and societies have different "absorptive capacities" (that is, differing abilities to assimilate new information, technologies or ways of doing things). In countries where health systems have been established for a long time, for instance, and formal processes are required in order to introduce a new medical intervention, it can prove difficult (or at least time-consuming) for innovative applications to reach the point of clinical deployment; while in countries where mobile phones are near-ubiquitous but other ICT infrastructure is lacking, concepts such as SMS-based administrative systems may be more readily accepted.

2.1 Mobile-Enhanced Appointment Booking Systems

Systems to allow patients to make appointments to see doctors in primary care or hospital settings extend naturally to mobile networks. Patients can use a mobile phone or mobile-connected device to access existing systems without significant modification, using voice calls or text messages, or mobile access to websites. This type of application enhances whole-system efficiency, particularly in primary care.

Multi-channel booking systems are already used, for example, in the primary care sector in the UK. Some systems encompass digital interactive TV as well as fixed and mobile telephony, email and web interfaces. This functionality is typically a component of, or add-on to, more comprehensive practice support or clinical software (also encompassing records systems, diagnostic support and financial systems); providers include EMIS,[27] which provides over half of GP practices in England with IT systems, and INPS Vision.[28] Mobility can enhance the scope of such systems, for instance, by enabling more effective "push" of information related to the appointment to be sent to the patient. Studies have shown the effectiveness of this form of simple mHealth application:

- Systems for sending SMS reminders of appointments are used in many health systems. In Melbourne, Australia, an assessment of the effectiveness of SMS reminders for over 20 000 patients at the Royal Children's Hospital found that "Did Not Attend" rates were significantly reduced when a SMS reminder was sent.[29] The study concluded that the cost of sending the SMS messages was outweighed by the increase in revenues and other benefits.

- The iPLATO SMS platform is used in the UK to complement more traditional ways of encouraging attendance at primary care clinics and GP surgeries for breast cancer screening, seasonal influenza vaccination and child immunisation.[30]

- A randomised controlled trial of SMS text messaging and mobile phone reminders at a health promotion centre in Zhejiang, China, showed that both methods of reminding patients were effective – and that there was no difference between the two methods in terms of effectiveness (though the cost of the SMS reminder was lower than the cost of telephone call reminders).[31]

Box 1: The "12580" Hospital Booking System

In China's Guangdong Province, the "12580" system provides multiple patient contact services, at the heart of which is a hospital appointment reservation service, provided as a managed service to hospitals. 93 hospitals in nine cities in Guangdong use the service. (Note that in China hospitals fulfil the role of primary care provider as well as specialist treatment centre.)

The system is designed to help overcome several challenges facing those needing access to healthcare in China: on the one hand, the length of time they have to spend to get an appointment, to pay for a hospital consultation or treatment, and to get medication, and (on the other) the shortness of the time they get face-to-face with the doctor in the consultation itself. These challenges arise as a result of a shortage of healthcare personnel, and an uneven distribution of personnel between rural and urban areas. By enabling remote booking and payment for services, patients can get care more quickly at hospitals.

A patient calls 12580 from his or her mobile phone and speaks to a member of the call centre staff, who makes a reservation appropriate to the patient's requirements and the availability of doctors. Agents can use the system to make the best appointment at one of several nearby hospitals. Appointments can be made between one and seven days in advance. Hospital appointment fees can be paid in advance using the mobile payments facility, which saves the patient from having to queue to pay at the hospital. There is no additional charge (over and above the standard charge for the voice call) for making the reservation using the mobile phone. The system generates a number, transmitted to the user by SMS, which is entered on a self-service terminal on arrival at the hospital. A 2D matrix barcode is printed out that confirms the appointment at the relevant clinic. There are system-based and ID-based checks to prevent abuse (such as sale of the appointment codes).

Although it is difficult to measure the savings attributable to the service at any given hospital because it is intrinsically bound up with other related services, adoption has been significant: it is estimated that at the Chinese Medicine Hospital, covering seven sites in Guangdong, the system handled 300 000 patient calls using 36 call-centre seats over a three-month period. Overall, the system has served 4.25 million patients.

As part of the 12580 service, China Mobile has also developed a medical information service around the booking system, delivered via SMS and providing navigation assistance (location of and directions to hospitals) and information on hospitals, doctors, departments, opening times, and medical policy. A health-related e-magazine is also provided for an additional charge.

While the core booking system is not uniquely a mobile-based solution (the reservation system can be accessed online as well as through the 12580 service), the use of mobile phones has simplified the process by allowing for the reservation fee to be charged to the user's phone account. As mobile phones become the default way of contacting individuals and organisations, the capability of unified systems to integrate multiple functionality for the patient will increase. For example, automatic push of hospital location maps, SMS reminders and other information could be tightly integrated with the booking system. (For more details see Section S2 below.)

Mobile-enabled booking and reminder systems represent simple applications of mobile technology to enhance existing processes. They are widely applicable, and indeed have been widely deployed; in China such systems have been deployed in Niemenggu, Tianjin and Zhejiang, as well as Guangdong. They deliver utility and reduced costs for the healthcare provider, and ease-of-use benefits for the user. Reminders delivered to personal devices that users carry with them (and keep turned on) at all times, including on arrival at hospital, are both cheap and effective. Such systems could also be integrated with payment handling and electronic records systems, where permitted by regulation. This type of application is a "quick win" for mHealth that could be deployed around the world in many different healthcare delivery systems.

2.2 Drug Authentication and Tracking

Applications for drug authentication and tracking can contribute to increased efficiency in the healthcare system; in some countries, where the distribution system for drugs is poorly developed, they could address fundamental difficulties with counterfeiting and piracy.

Technology for tracking drugs through the supply chain from the point of manufacture to the point of consumption, and for authenticating drug provenance before use, has been developed over several years by IT services providers and pharmaceutical companies. Examples include Avery Dennison's solution for US pharmacy chain Walgreen,[32] or Odin Technologies' RFID-based ePedigree solution.[33] Such applications typically have benefits in terms of stock control and inventory efficiency, as well as providing authentication of provenance. Drug tracking using mobile networks enables this established process to be extended into regions where only mobile networks can provide connectivity to central drug pedigree databases, and also to the point of sale and the point of use. In addition, simpler applications have been developed so that those involved in the delivery of healthcare at any stage along the supply chain – right up to the point of use – can quickly check the authenticity of the drugs they are using.

- In Nigeria, Sproxil Inc.[34] has developed an SMS-based authentication service to address challenges of drug counterfeiting – working with mobile network operators, drugs companies and the Nigerian medical authorities on a three-month trial, completed in April 2010, to prove the concept. (See Box 2.)

- The Epothecary[35] system, developed at New York University, uses 2D matrix barcodes on drug cartons and mid-level phones with cameras (and GPS modules if available), together with SMS-based or GPRS mobile-data-based communication, for authentication and track/trace applications. The system enables the location of consignments to be known whenever the 2D code is scanned or photographed; this information can be compared with database records of buyers and sellers within the supply chain.

- In Guangdong in China, a "smart drug regulation" system is being established for piracy prevention. A single central database holds information on the provenance of medicines. Each package is coded with both an RFID tag and a 2D barcode. Fixed or mobile networks can be used to access the central database and authenticate a package. The aim of the system is to establish a regulated standard that central government agencies and manufacturers can adopt.

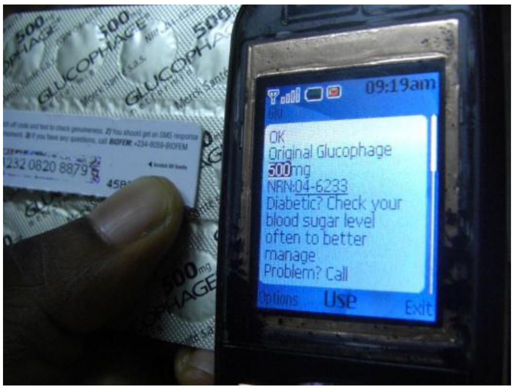
In some countries where supply chains can be interrupted – for instance because of a lack of secure health systems, logistics systems and other civil structures – drug authentication applications can provide an important end-to-end check. Existing examples of the use of mobile platforms to deliver such applications are not yet beyond the advanced trial stage, but the business case for doing so commercially should be relatively straightforward to make: such applications would use only cheap network services, and drug companies have a commercial interest in ensuring that their products are trusted, so should be willing to cover at least part of the costs involved in deployment.

Box 2: Nigerian Drug Authentication Trial[36]

The Nigerian National Agency for Food and Drug Administration and Control (NAFDAC) has trialled a Mobile Authentication Service (MAS) for one specific drug (BIOFEM's Glucophage) used in diabetes treatment. The MAS enables consumers to confirm the authenticity of the drug by scratching a label on the drug packaging to reveal a code number, and sending this number by SMS – in encrypted form and for free – to a database server. An immediate text reply confirms whether the drug is genuine or a fake (or if the secure PIN has already been used or is not recognised), and also contains an always-available helpline number.

The technology is provided by Sproxil; mobile network support is provided by Nigerian mobile operators MTN, Airtel, Etisalat and Globalcom, who have provided a uniform SMS number across all networks.

During the trial, which ran in three major cities (Lagos, Abuja and Port Harcourt) and covered 125 participating pharmacies who displayed point-of-sale promotional material, 735 000 blister packs of the drug were labelled, over 22 000 SMSs were sent, and 67 612 unique customers were served. The costs of the trial were borne by the drug company.



The trial showed that pack design was an important factor in encouraging take-up, and that the systems put in place were robust enough to deliver very high levels of service uptime, with only two outgoing SMSs not delivered. The study concluded that the costs of the trial were less than the benefits to the pharmaceutical company through sales recovery and brand retention. Plans are in place to scale up the system.

One issue that has emerged in some academic studies is the security of the tracking systems – particularly whether simple and easy-to-use systems can be made suitably secure. Systems based on two-way communication (whether over mobile or fixed networks) are inherently more secure than packaging tags and local readers, but may still be vulnerable to some fraud.

The potential for mobile-based tracking applications extends beyond drug supply chain logistics. Equipment, staff and patients could be tagged and tracked to improve resource efficiency. The tracking of drugs could also be combined with other data from trials and epidemiological studies to provide useful data to public health departments and pharmaceutical companies on the effectiveness of distribution and clinical efficacy. It is even possible that the actual taking of the drugs by patients could be monitored by such means, though this is still in the future (see Section 3.5).

2.3 Remote Diagnosis

mHealth applications for remote diagnosis fit within the primary care theme in our schema. They are characterised by the use of the device and/or network to help health workers to make a diagnosis without the patient having to travel to a centre. This may involve the use of databases and decision-support applications downloaded on to a mobile device; remote access to decision-support databases and systems; or communication with a specialist, via voice, messaging or video services.

Some of these applications use the network to *connect a healthcare worker with a specialist*, for example mobile teledermoscopy, the capture and transmission of images of moles and skin lesions for expert evaluation (which has proved effective in the triage and diagnosis of melanoma),[37] and more generally the Sana[38] app for Google Android phones (which connects rural health workers with specialist doctors to enable better diagnoses to be made, enabling text, images and video to be sent to a specialist who can reply with a diagnosis by text). The latter has been used in Mexico, India, the Philippines and in Africa.

Other applications, more typically in developed countries, are used to *connect an individual in the general population with a healthcare worker*, as in the case of the UK's 3G Doctor service, discussed in more detail in Section 4.4.2 below.[39]

Box 3: Remote Consultation and Diagnosis in China

China Mobile is developing several projects offering remote consultation and diagnosis services. For instance in Guangdong and Guizhou Provinces, it is working with partners to provide rural areas with medical services and information through intelligent self-service terminals connected via fixed and 3G/GPRS mobile networks. (In Guangdong terminals are initially connected via fixed networks, though it is planned to extend to rural areas using mobile networks; in Guizhou the services use a fixed network to reach larger towns, and GPRS-enabled terminals to reach village clinics).

The self-service terminal systems have been introduced to address a shortfall in medical resources, particularly in rural areas; the vast majority of both provinces' healthcare resources are concentrated in cities. Hundreds of terminals are already in use across the two projects, helping to spread healthcare knowledge among people in remote rural areas, and providing a healthcare consultation platform and service acquisition channels. Services are currently free, to encourage use, though it is expected that subscription charges will be introduced for some services. The services are expected to recover investment costs within only a few years, while at the same time improving the delivery of healthcare.

For users of the Guangdong "Intelligent Health Management Self-Service" terminal, the service consists of six interrelated modules covering all aspects of healthcare, including information on healthy living, information for pregnant women and mothers, health in the workplace and public health information updates. Two of the modules – the "One Stop Medical Report" and "Self-Service Disease Recovery" – constitute a remote health consultation application. (Note, however, that personal medical consultation is not possible at this stage because provision of personal medical consultations is strictly regulated.)

Using the One Stop Medical Report, users can input values for examination items such as routine blood test, blood lipid test, or tumour immunoassay. The terminal reports back reference values and the clinical significance of the patient's own values, along with a health assessment and advice on actions to maintain or improve health. For example, the terminal might indicate possible diseases, suggest that a hospital diagnosis is required, and facilitate appointment booking through the 12580 service. Alternatively users can make appointments with experts in traditional Chinese medicine via the "VIP Member Service" in the terminals.

Using the Self-Service Disease Recovery module, users can browse information, written by medical experts and professionals from within Guangdong Province, on more than 80 common diseases. Information is presented on symptoms, diagnosis, preventive measures, taboos and misunderstandings, diet advice and folk remedies. The application is designed to help users prevent illness, or to recognise symptoms and begin treatment early. Users can also use the terminal to subscribe to China Mobile's related Medical Link service (see Section S2) if they want to access information about less common diseases, with information being sent to user terminals via SMS.

In Guizhou the terminals provide similar services, enabling enquiries about treatment, family accounts, and medicine price lists; allowing the printing of documents; and providing access to outpatient statistics.

The terminals provide a valuable service not easily accessible in other ways. Due to the scarcity of medical resources, people do not usually get the chance to discuss the results of tests with doctors unless it transpires that they have serious medical conditions. Also, those living in rural areas may not have the time or money to return to the doctor to discuss results. This system enables people to receive an examination at a hospital, and then go to the terminal to find more detailed information and receive healthcare suggestions.

Another remote consultation service in Guangdong is provided by China Mobile's partner company Yihe. Subscribers to China Mobile's Medical Link service can send health-related questions (via the village terminals or mobile phones) to Yihe's background platform using SMS, MMS, or China Mobile's 12580 call centre service. Yihe's network of 30 professional general practitioners reply to the questions within five business days, charging only regular information fees for the consultation. They currently process 2000 messages per day, and the service has over 1.89 million registered users.

Figure 3:
The opening screen of the Intelligent Health Management Self-Service terminal (the two top left icons indicate the "One Stop Medical Report" and "Self-Service Disease Recovery" diagnostic and consultation modules)

2.4 Well-being Applications

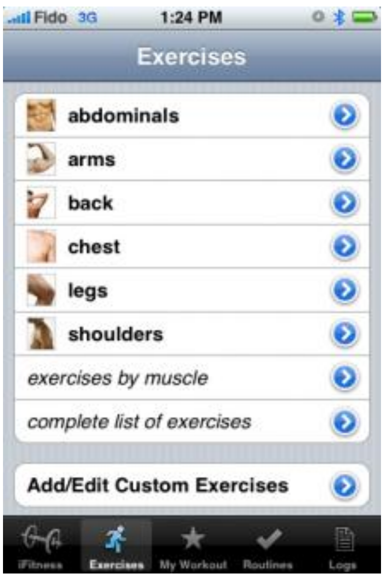
Among the most interesting of the mHealth applications that have emerged in the last two to three years are those that have been developed as simple, lightweight apps for smartphones, aimed at increasing individuals' well-being. A recent 3000-person US survey of usage of these types of mHealth apps found that some 9% of US adults had such apps on their phones, and 17% had used a mobile device to look up information relating to health.[40] The research, by Pew Internet Project, showed that younger users and urban-based users were more likely to use these apps; we expect similar patterns of usage to apply in most markets where smartphone penetration is high. While some are based simply on the provision of information (either within the app, or entered by the user), some make use of the more advanced functionality of the devices they are intended to run on, such as GPS positioning and accelerometers. For example:

- RunKeeper[41] for iPhone, a free app that uses the GPS capabilities of the device to measure speed and distance of runs (and also calculates calories burned). Data can be uploaded to a website so that the exercise history can be stored.

- iFitness[42] for iPhone and iPod Touch (illustrated alongside), an app that provides training programmes to suit different fitness regimes working different muscle groups. Programmes can be customised, and the app allows goals to be set and progress to be monitored.

- iQuit[43] for iPhone, a free application that provides multiple smoking cessation routines from which users can choose.

- SymptomMD[44] for iPhone, a low-cost app providing an interactive guide that aims to help users "make appropriate decisions on what level of care (if any) is needed and how to relieve symptoms of minor illnesses and injuries [they] can manage on [their] own".



Box 4: Drinks Tracker iPhone App[45]

The UK NHS's Drinks Tracker iPhone app, launched in 2009 before Christmas (traditionally a time of year when many people drink more heavily than usual), enables users to calculate the number of "units" of alcohol they have consumed, to log this over a period of weeks or months, and to receive personalised feedback. A cut-down version of the app is available for use with any mobile phone with Internet connection. The app also provides contact information for local NHS support services.

Each time a user drinks alcohol, they tap one of four icons on the screen and adjust the data on alcoholic strength if required. The app keeps track of the total consumed, and can be personalised to offer alternative views. Drinks consumed can be saved to the Tracker for each particular day, and it displays a running total for the week. Users can tap on a feedback button to receive information and advice about their consumption over the previous seven days, based on the UK government's guidelines.

The app – which cost the NHS around GBP10 000 to develop (according to news reports) – is part of a range of public health initiatives to reduce the harm caused by excessive alcohol intake, which also includes an online self-assessment tool and a desktop-based version of the Drinks Tracker app.

These applications are significant because they illustrate the most immediate utility of smartphones for mHealth, both in developed and developing countries. The combination of onboard computing power and connectivity offers something that individuals want to use and in many cases are prepared to pay for (though the cost of the paid-for apps cited above is typically less than USD1).

In addition, healthcare systems can make use of this approach by providing apps that support public health messages and encourage people to apply them to themselves, as in the case of the Drinks Tracker highlighted above. Research in public health has shown that the combination of "fear appeals" and "self efficacy" (i.e. frightening people about a risk to their health but at the same time giving them something they can do about it) is a powerful way of bringing about behaviour change.

2.5 The mHealth Opportunity

Existing applications have shown that the use of a mobile network and connected device can greatly extend the reach of healthcare provision, and the potential for further development is very large. In particular:

- The development of more sophisticated or lower-cost sensors as peripherals for smartphones is allowing better diagnosis to be performed closer to the patient without the need for referral or travel to specialist centres (we look at this in more detail in Section 3.1).

- During outbreaks of infectious disease, remote diagnosis can enable affected individuals to receive medical help without the need to travel (which would risk spreading the disease).

- Remote diagnosis could be extended to include prescription if the concerns that exist in some markets about the need for face-to-face consultation can be suitably addressed; at present, many countries do not permit prescription on the basis of remote consultation. There may be scope to use simple SMS-based authentication of prescriptions, for instance adapting solutions developed for other forms of drug tracking (as described in Section 2.2 above).

- Data collected from remote diagnosis can, subject to appropriate consent and privacy regimes being in place, be combined with data collected from conventional face-to-face diagnosis to augment epidemiological research into disease transmission.

In Chapter 3 we look at those applications that, although not so well developed commercially, or so widely deployed clinically, have what we believe to be the greatest potential to improve health worldwide, and for which a business case could be developed with careful consideration of the application design and deployment issues.

Chapter 3

Potential Next-Generation Applications of mHealth

The greatest potential of mHealth lies not in today's applications, but in the future benefits of applications currently at concept or trial stage. Many of these innovative applications make fuller use of the intrinsic qualities of mobility, ubiquity and computing power offered by mobile networks. This Chapter looks at four promising areas:

- **Sensor-Based Applications.** Using the computing power and standardised interfaces of the mobile phone together with high-resolution cameras, accelerometers, and specialised devices (e.g. to measure peak flow, blood glucose or oxygen levels, to diagnose eye conditions, or to assess emotional or mental states).

- **Mobile-Enabled Telecare.** Support for assisted living, connecting carers and those being cared for, can improve care delivered to the patient while minimising demand on expensive resources. Applications include cardiac monitors, motion sensors, and fall detectors, coupled with systems to alert carers and doctors when alarm conditions are met.

- **Intelligent Public Health Messaging.** Targeted messaging is applicable to sufferers from HIV, tuberculosis, diabetes etc. (aimed at improving adherence to medication regimes); to preventing illness by promoting risk awareness and lifestyle change; and to supporting communities and response teams in the event of a disease outbreak.

- **Aggregated Private Data for Public Health Benefit**. Population-level data has long been used in healthcare research, but mHealth opens up many new possibilities, including the tracking of individuals' movements and contacts. Many beneficial applications exist (e.g. epidemic prevention and understanding disease processes), but funding remains a challenge.

The pace of innovation will vary. **In developed economies**, the mobile will be used to collect, store, analyse and upload a wide range of data, from vital signs to location, motion, mood, and adherence to medication regimes. Healthcare providers and carers will use this data in real time, and in aggregate form for research, benefiting individuals and leading to better forms of illness prevention and treatment.

Over time, such applications will also reach **low-income economies**, though in the shorter term mHealth will help to put in place robust administrative systems for healthcare delivery that are taken for granted in developed countries. Increasingly powerful mobile phones will be in the hands of health workers, delivering technologies previously available only in larger population centres.

3 Overview of Potential Next-Generation Applications of mHealth

In Chapter 2 we have seen that mHealth applications are already well established in some fields. Much of the excitement in the subject, however, originates from the future benefits potentially resulting from implementation of services and applications that are at present only at the stage of concept or trial; in this chapter, therefore, we review some of the mHealth applications which show most promise for use in the developing and developed world, and in Chapter 5 we go on to look at the issues surrounding the appropriate measurement of their potential benefits, and the ways in which mHealth applications and services can and should be assessed.

As we saw in Chapter 2, "quick wins" for mHealth include introducing a mobile capability into existing processes and systems; but many of the applications that show promise are innovative, and make more of the intrinsic qualities of mobility, ubiquitous devices and portable computing power. Our review of the applications being developed suggests that the factors driving innovation in mHealth can be summarised as:

- commercial opportunity (most notably in the area of smartphone apps)
- innovation in social policy
- altruism
- intellectual curiosity (pure and applied R&D in academia, undertaken for its own sake and not with a view to profit or commercialisation)

and it is therefore unsurprising that organisations undertaking and funding R&D work include:

- technology vendors (mobile network and device equipment vendors, software vendors and providers of other mHealth enabling technologies)
- mobile operators
- healthcare providers and sponsors (both public-sector and commercial)
- national governments
- charities and charitable foundations
- international organisations such as branches of the UN
- universities and other academic institutions.

Many developments and trials are funded by joint ventures or partnerships between such organisations. (Organisations active in innovation can be found in the delegate lists for international conferences such as the mHealth Summit,[46] or the membership lists of trade alliances such as the mHealth Alliance.[47])

Since the groundbreaking work published by the UN Foundation and Vodafone Foundation[48] on the opportunity for mHealth in the developing world in early 2009, there has continued to be significant innovation, particularly in the areas of sensors and peripherals for mobile devices and in the use of data collected from devices. Our research suggests that some innovative mHealth applications have the potential to transform healthcare in both the developing and the developed world, particularly in areas such as:

- bringing healthcare to unserved or underserved populations
- increasing the effectiveness and reducing the costs of healthcare delivery
- improving the effectiveness of public health programmes (including research) and preventing illness (including through behaviour change)
- treating chronic diseases, and keeping people out of hospital.

For the innovative applications to be deployed, though, a number of barriers need to be overcome, as shown in the table on the following page.

Barriers to adoption of innovative mHealth apps	Impact, Mitigation
Cultural differences between ICT and medical professions; entrenched medical institutional structures	Technology companies claim that the medical profession's conservatism slows adoption of useful new approaches using existing technologies; medical bodies and regulatory authorities worry about the introduction of services and applications that are not proven to be effective, and are concerned that technology companies do not fully understand medical processes and structures. To mitigate this, regulatory regimes and the medical establishment's guidance-setting need to strike an appropriate balance between the risks and benefits of specific mHealth applications.
Device operating system fragmentation (e.g. for smartphones)	Fragmentation can result in practical difficulties in deploying applications: an application may need to be created to run on dozens of software stacks to achieve the penetration required to be effective or commercially successful. There is a danger that new, sophisticated apps have their own support layers dealing with security, privacy, storage and networked resources, and that the apps that succeed will not necessarily be those that are most effective, but those from developers with the most prevalent support layers. Use of apps using controlled fleets of devices – or using web apps, voice or SMS – can overcome system fragmentation in the short term; in the longer term, standardisation and interoperability between device manufacturers may help, and the commercial pressure for app portability will be strong.
Network availability (including frequencies, coverage, etc.)	For many mHealth applications and services, reliable network coverage is important; for some, high data rates are also required. This cannot always be guaranteed (e.g. in-building or rural coverage may be patchy, or networks may not deliver high-speed data). Applications and services must take note of the capability of the network available: in some cases, coverage issues may be addressed by using multiple networks (assuming commercial agreement can be reached or this can be mandated by regulators). For some mHealth apps, fixed networks and WiFi can complement mobile networks.
Cost of services and handsets/devices relative to income levels	Affordability of handsets that will run useful apps may restrict their use either to more wealthy individuals, or to healthcare workers only. At present, many innovative and potentially beneficial apps run on smartphone platforms only. Distribution of subsidised devices and adaptation of apps for lower-spec and more affordable phones can help. In the medium term, the cost of smartphones is expected to fall significantly.
Handset churn	Handsets are changed frequently: apps (and locally stored data) may not be persistent. Where persistence of data is required, apps should be designed for ease of transfer from device to device or reside elsewhere (such as web apps); data may also be stored in the network rather than on the device.
Literacy levels	Apps may not be usable by target populations in areas where literacy levels are low, if they are based on written words. Careful (visual) interface design, and development of voice-driven apps can overcome this, as can the use of intermediaries (literate community members trusted to use the app on others' behalf).
Regulation	Some mHealth apps require the organisations delivering them to extend the scope of their activities beyond their normal remits. For instance, health apps that involve a financial transaction might benefit from changes to regulations to allow a telecom operator to function in the financial services market. Careful, pragmatic assessment of changing markets is needed by regulatory authorities to allow some innovative apps to develop.
Security and privacy concerns	Some authorities and individuals may be unwilling to sanction the use of certain types of data for mHealth apps, restricting their viability – this applies particularly to those apps where data gathering from large populations is required. Issues of privacy need to be fully considered at an early stage of apps development; academic research into security and privacy is an active topic, and lobbying and marketing may be required in order to change established views.

However, it is not the case that all these barriers apply to all mHealth applications: the barriers to deployment of a remote diagnosis app, for example, are not necessarily the same as the barriers facing the development of a public health data-gathering app. In addition, because commercial organisations see potential for profit, and many agencies see the potential for healthcare improvement, there is a real appetite to overcome these barriers and realise the benefits. In the rest of this chapter we look at four particularly promising types of innovative applications: those based on the sensors which are now commonly built into mobile devices (or which can be straightforwardly connected to them); mobile-enabled telecare; intelligent public health messaging; and the use of aggregated private data for public health benefit (including mining data contained in electronic health records).

3.1 Sensors and Other Peripherals

The rapidly increasing computing power of the mobile phone, coupled with its ubiquity and the personalised nature of its ownership by many individuals, means that it provides a unique platform not only for software applications, but also for peripheral devices (and especially sensors). In addition to the ubiquitous microphone, some sensors are already "on board" modern high-end phones, particularly high-resolution cameras, and accelerometers which detect the tilt and turns in the position of the devices. Others can be easily connected via USB ports, Bluetooth or other means, such as devices to measure peak flow for asthma sufferers, blood glucose levels for diabetics, pulse and blood pressure, and so forth.

Not all of the mHealth applications we have identified necessarily involve the use of the network to which the device is attached as an intrinsic part of the application. For instance, an unconnected device is still a powerful low-cost computing platform with a rich user interface that can support on-the-spot analysis of readings produced by sensors, though most applications do make use of the network too. The device that "barefoot doctors" or other local health workers carry with them will become an increasingly significant part of their kitbag both in its own right, and as a means of communicating through the network.

Many of the most interesting applications in this category are at an early stage of development, and have not been trialled in the field, or if they have, trials are ongoing and effectiveness has not yet been proved:

- At the University of Cambridge, a team has developed EmotionSense,[49] a way of assessing individuals' emotional state by analysing data from the handset's microphone using a speech/tone analysis algorithm running on a smartphone; data can be combined with information from location and movement sensors also on board the phone. Trials show that the system is effective at detecting individuals' emotions, holding out the prospect of designing effective social psychology experiments without requiring obtrusive cameras or voice recording devices.

- A team from St George's Hospital at the University of London, UK, is leading a public-private consortium that will develop low-cost, self-test devices for sexually transmitted infections (STIs).[50] The devices will be plugged into a mobile phone for immediate analysis of the outputs and provision of diagnosis and recommended treatments (without the need to make appointments at clinics or interact with a doctor or other clinician). The project has received GBP5.7 million in funding.

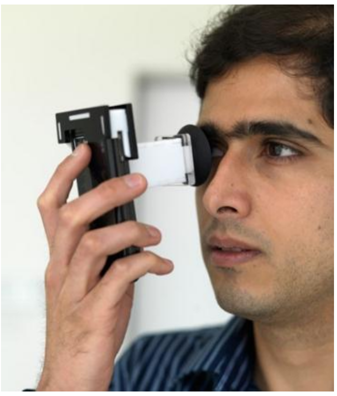
- At the University of Melbourne, Australia, a prototype low-cost (USD10) oximeter has been developed that makes use of widely available LEDs, based on the fact that absorption of red light by haemoglobin can be used to measure oxygen levels in the blood. The device is attached to a smartphone, and an app analyses the oximeter outputs to diagnose pneumonia in situations where no other diagnostic tools may be available. There are plans for a technical evaluation of the prototype in Mozambique and clinical trials in Melbourne. It may also be possible to develop a similar device for simpler phones.

- Researchers at Microsoft have been developing a minimally invasive method of measuring vital signs during sleep, using a soft cuff that fits around the neck and measures blood oximetry, three-axis position and movement of the head, and breathing sounds (e.g. silent, coughing, talking, snoring). The cuff transmits its data via Bluetooth to a mobile phone for immediate processing and use, or eventual secure transmission to the cloud. One of the main goals of data evaluation is to identify candidates for obstructive sleep apnoea; another is to gather "healthy" data for a population baseline.

Box 5: NETRA Low-Cost Mobile Phone Aberrometer for Eye Condition Diagnosis[51]

A team at the Media Lab of Massachusetts Institute of Technology (MIT) has developed an aberrometer for the diagnosis of eye conditions such as near- and far-sightedness and astigmatism. The device, which currently costs under USD2, is attached to the screen of a mobile phone, and has two key innovations: first, the use of an array of very small lenses – and a grid of pinholes generated by the mobile phone display – to display a pattern of lines and dots; and second, a software app on the phone that allows the patient to adjust the pattern being viewed to make it more sharply focused. The software can interpret the patient's actions as a prescription for corrective lenses. The patterns generated force the patient's eye to focus at different depths to enable the focusing ability of the eye to be measured.

In use, the patient uses the arrow keys on the phone to cause parallel sets of red and green lines to overlap, and repeats the process at different angles for each eye. The device can produce a corrective prescription within two minutes.



MIT says that preliminary testing with about 20 people has indicated that the device can achieve good results – accuracy within around 0.7 dioptres for focal range (near and far sight) – using the mobile phone display. During 2010 the team was preparing to undertake larger-scale field trials in the USA, Africa and India, in collaboration with various NGOs and healthcare providers. The MIT team also hopes that future work will enable the system to be developed to provide diagnosis of other eye conditions such as cataracts, retinal stray light and amblyopia (lazy eye).

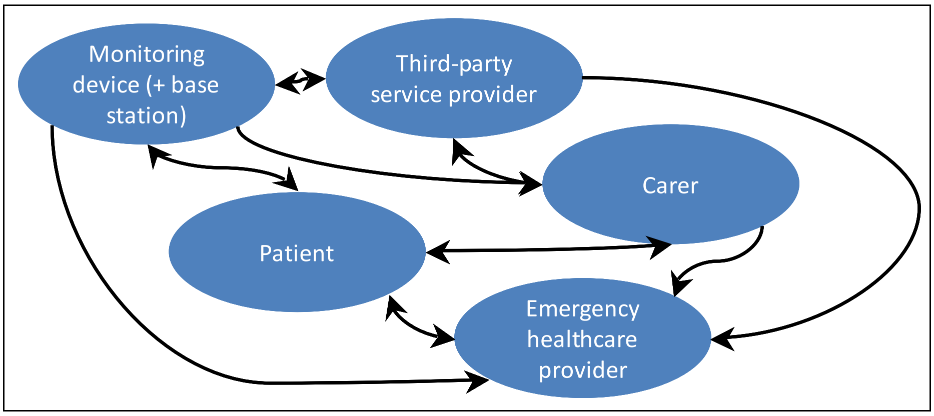
Mobile phones have already changed the ways in which individuals and societies communicate and live: their power as near-ubiquitous computing platforms can be leveraged to deliver some elements of healthcare at scale and remotely. The applications illustrated above show how the conventional processes for diagnosis of conditions can be radically changed (allowing earlier diagnosis of conditions, or simply diagnosis where none was possible before). This can be hugely beneficial for the individual and for the healthcare delivery system, assuming that the costs of the peripheral devices and associated applications can be kept low, and that issues of platform proliferation can be addressed.

3.2 Mobile Telecare

Mobile telecare – support for assisted living involving remote communications between carers and those being cared for – has the potential to reduce demands on healthcare resources such as doctors and hospitals. Such applications can involve healthcare professionals as well as family or other carers: the aim is to improve the care delivered to the patient while minimising the demand on expensive resources.

The commercial incentives for the deployment of telecare are greatest in systems where private organisations do much of the delivery of such care, because of these organisations' acute focus on efficiency and preparedness to embrace innovation. This has led, particularly in the USA, to a growth in telecare solutions. Mobile enablement of these solutions is one area of mHealth activity; others involve the creation of completely new ideas that build on attributes of mobile networks and always-on, portable devices. Many traditional telecare solutions have been based around equipment located in the home: mHealth apps in this area can be used in a complementary way with existing solutions, or as a replacement for them. As Figure 4 suggests, there are many links between actors in the provision in telecare that could be supported by improved communications and the transmission of information and alerts.

Figure 4:
Potential for mobile networks to support communications between the five basic nodes of the provision of telecare



The following examples show the range of innovative approaches being taken to develop applications aimed at supporting the care of individuals away from hospitals or care homes:

- The M-Link device for Medtronic's CareLink Patient Monitor[52] enables data stored in implanted cardiac devices to be transmitted to the patient's clinic using mobile networks as well as fixed networks. This extends the reach of the solution beyond the home. The device transmits notifications to the doctor when alert conditions are met.

- Smart slipper insoles are being jointly developed by telecoms operator AT&T, device maker 24Eight and Texas Tech University.[53] They use an accelerometer, pressure sensors and local wireless connectivity (using the ZigBee personal area connectivity protocol) to monitor a person's gait. Data can be sent via a mobile network to a doctor who can assess whether the user is at risk of, or has suffered, a fall. This application has the potential to be automated, and to alert carers as well as doctors.

- The iMonSys Verity[54] personal emergency response system measures an individual's vital signs (heart rate, skin temperature) and motion, using sensors embedded in a watch strap. The sensors communicate with a specially designed, voice-activated mobile phone. This also has an on-board voice/speech recognition system. If any of the monitored indicators fall outside threshold levels, the phone then asks the user whether he or she is OK before initiating a call to one or more of the user's nominated carers or the emergency medical services. The carer can be put directly in contact with the user.

These examples illustrate innovative, often sensor-based, applications of mobile technologies to the provision of care. Other forms of remote care based on monitoring of individuals by carers make use of existing technologies including video cameras, for instance in the case of the provision of video images from intensive care units in Guangdong, China, that can be viewed by patients' relatives either through fixed or mobile Internet connections.

Among the benefits that mHealth apps can deliver are: extending remote care beyond a few connected locations; the ability to reach carers with alarm messages wherever they are; and the relative ease of deployment compared with traditional wired solutions. As the cost of providing care in expensive, controlled environments grows (for instance, as the population of elderly people, or people with long-term conditions grows), we expect significant further innovation in this field, which is at an early stage of development.

3.3 Intelligent Public Health Messaging

Many examples of targeted messaging via mobile phones involve populations that are already being treated for specific conditions, such as HIV/AIDS, tuberculosis and diabetes – see, for instance, the work of Weltel in Kenya,[55] Diabediaro in Mexico[56] and WellDoc in the USA.[57] Such established applications seek to support patients with long-term conditions, for instance through improving adherence to medication regimes, either through “push messaging” or two-way communication.

The principle of targeted messaging can also extend to preventing illness by promoting lifestyle change, and other public health purposes such as supporting communities in the event of a disease outbreak. Such mHealth concepts can make use of low-tech systems to reach very large numbers of healthy people in order to prevent disease, or to support local health workers in their preventative public-health work.

Section 2.4 highlighted examples of public health authorities making use of personal smartphone apps to promote campaigns related to alcohol consumption. Other examples are emerging of the use of mobile-delivered messaging of other kinds for public health purposes:

- HIV/AIDS awareness in Africa – one element of the Project Masiluleke campaign[58] in South Africa reaches over 1 million people per day via SMS with public awareness and calls to action related to HIV infection. The campaign has tripled average daily call volumes to South Africa’s national AIDS helpline.
- In Cambodia, Rapid Response Teams (RRTs) under the control of the country’s Communicable Disease Control (CDC) Deputy Director receive information from central HQ about disease outbreaks very rapidly via mobile phones.[59] RRTs can engage in chats with each other about the outbreaks using InSTEDD’s open source GeoChat collaboration platform.
- In Tianjin Municipality in China, China Mobile is working with the local government to develop an Influenza Epidemic Prevention System. This uses mobile technology to enable the collection of data, as well as dissemination of advice. For more details see the case study in Section S4.

Box 6: iPLATO SMS Platform for Public Health Messaging

In Greenwich, a district of London, UK, 39 local primary (GP) practices have extended the scope of the iPLATO SMS platform from appointment reminders to the delivery of health promotion campaign messages, for instance those related to smoking cessation. The doctors are able to search their practice databases to identify a target group of patients, and then send an SMS message asking them, for instance, to confirm by text whether or not they smoke. Those that confirm they do smoke can be sent an additional message publicising available smoking cessation support and advice services. The local health service administration (NHS Greenwich) hopes that doctors will encourage patients to provide the surgeries with their mobile phone numbers to enable better communication.

The same platform has also been used elsewhere in London (Hammersmith and Fulham) to request details of patients’ weight in order to identify those at risk of obesity-related conditions, [60] and in Camden to advise patients on appropriate steps to take during an outbreak of H1N1 influenza. [61] At-risk groups of patients have also been sent “pushed” messages inviting them to attend a clinic for vaccination against seasonal influenza.

The suitability of similar, though more tailored, automated SMS-based behaviour-change programmes related to smoking cessation among pregnant women has been studied by a team at the University of Cambridge.[62] The findings of the study suggest that such systems are feasible and acceptable to patients, and have benefits in terms of effective reach; some people prefer the relative anonymity of contact that is not face-to-face for these purposes.

The use of mHealth apps for intelligent public health messaging – particularly those where messages are personalised or accurately targeted (for instance to geographical locations where there are disease outbreaks) – is at an early stage of development. However, the concept has significant potential, particularly when combined with new network-based ways to improve the quality of epidemiological research, and the careful use of more established mHealth applications to track disease outbreaks. A recent study[63] from Sri Lanka shows that systems using mobile-phone-based data collection and analysis need careful design in order to predict and prevent disease outbreaks in near real time, and those applications that rely on individuals answering health-related questions need to take into account the complex motivations that individuals have for responding.

Research into the effectiveness of mHealth in behaviour change is also at an early stage, and more academic work is needed before its long-term benefits can be properly assessed, though a literature research of studies undertaken to date found that 13 out of 14 relevant studies demonstrated a positive impact.[64] Research such as the Cambridge smoking cessation study referred to in Box 6 have shown that SMS-based apps are no less effective than conventional approaches, and are considered acceptable by users, opening up the possibility of low-cost, automated systems for the delivery of personalised messages to individuals on the basis of their medical history, or doctors' understanding of their conditions.

3.4 Using Aggregated Private Data for the Public Good

Data collected from the general population has been used for a long time in healthcare research and policy-making, but mobile networks and devices open up a number of new areas for innovation in public health and medical academic study. The potential of some of these applications, such as those using the power of mobile devices to track individuals' movements and contacts, is only starting to be fully understood. Some similar approaches based on "crowd-sourced" data already exist in the health field, but the use of the data for research purposes is still at an early stage. One example is Google Flu Trends,[65] which uses search terms to map the intensity of influenza activity using the Google Trend engine – of particular interest as a very public demonstration of the power of search-engine-based, crowd-sourced data for health purposes.

There are two uses of this type of mHealth development. First, various kinds of data from individuals, unrelated to their health or medical conditions, can be collected to form a data set that can be overlaid with other information for modelling purposes. For instance, standard *susceptible-(exposed)-infectious-recovered* simulation models of disease propagation using "virtual pathogens" can be built using the data, or real disease outbreaks can be tracked in real time. Second, data collected for health-related reasons (such as that collected by doctors, or directly, during disease outbreaks) can be used in medical research.

In modelling work, it is the quality of the basic data collected that is of most importance to epidemiologists; for real-time disease tracking, it is the timeliness of the tracking data that is most useful. Both of these considerations require careful attention to be paid to the design of the application, and the choice of underlying technologies and the human processes.

Mining of individuals' healthcare records is also a dynamic field of activity. As health records become increasingly electronic – even in developing countries without a well-bedded-down structure of physical paper records – and as those records are increasingly complemented by, or merge with, data held on individuals' PCs or mobile phones, the potential for mining aggregated data to build predictive models for individuals or populations becomes significant. This work is already starting on a small scale in developed countries where private organisations are responsible for the delivery of healthcare, such as in the USA. Those providers have a commercial incentive to understand how to deliver the most effective treatment most efficiently, and with fewest errors, and papers have described how this can be achieved.[66]

However, the use of private data raises significant questions of confidentiality and security of data, and so-called “differential privacy”, the purpose of which is to maximise the accuracy of queries from statistical databases while minimising the chances of identifying its records. As work carried out by IBM and at the University of Texas at Dallas and at Haifa University in Israel [67] has shown, it is possible to analyse apparently anonymous data sets and identify individuals; a suitable risk framework therefore needs to be developed if this potential health application is to be taken forward.

Despite these challenges, there are promising R&D projects underway examining the use of private data for the development of evidence-based health policy development and public health research. Particularly noteworthy are the work of OpenMRS[68] in developing an open medical record platform for use in developing countries, and of Sana Mobile[69] in building OpenMRS-compatible, mobile-phone-based tools and platforms for deployment in the field (for instance for data collection). These projects demonstrate the importance of the development of central dictionaries of concepts, user authentication and privilege-based access to data, and localisation to suit specific languages and cultures. Another project – the mapping of human contact and the spread of influenza in a population using a smartphone app and GPS location (Box 7) – demonstrates the potential of the mobile phone for collecting data for epidemiological research.

Box 7: FluPhone: Behavioural Response Mapping for Infectious Diseases

The FluPhone study[70] at the University of Cambridge has used mobile phones to collect data on the frequency and location of contact between individuals, in order to assist in the building of models of close-contact infection spread, giving public health authorities the information needed to develop mechanisms that could reduce the scale or length of epidemics.

The voluntary study, which took place during May and June 2010, involved participants downloading a Java app to GPS-enabled Nokia Series 40 and Series 60 mobile phones to record how often participants are in close proximity to each other. The app uses the phone’s GPS module to track location, and asks participants to enter details of any flu symptoms using an intuitive interface. Future studies will extend the range of supported phones to include Android and iPhone smartphones.

One of the project partners, the London School of Hygiene and Tropical Medicine, is working to establish a trial of the technology on a village population level in Malawi. The research team at Cambridge also sees potential use for the approach in targeting public health messages better (as discussed in Section 3.3 above) and measuring the effectiveness of public health messaging – something that is traditionally very difficult to do because of the delays in gathering data using traditional methods that involve surveys through primary care providers.

The research identified some challenges to deployment relating to operating system fragmentation (the app requires high-end smartphones and high levels of penetration to be effective) and ethical concerns about privacy (the trial took six months to gain approval from the relevant ethics committees).

While on a small scale there are specific benefits in mining existing, well-structured data, it is harder to perceive the incentive for individuals, commercial organisations and healthcare providers to pay the costs of very large-scale research, development and deployment of large systems (such as standardising meta-level healthcare record structures, or building very large national or international databases and contact maps). Such investments for the public good require funding by institutions – probably at national government level – in order for the significant potential benefits to be realised. Those benefits would include greater understanding of disease transmission, leading to better preparedness for outbreaks; the opportunity to test new treatments using more accurate simulation models; a greater understanding of how healthcare is delivered so that systems can be improved; and ultimately, more effective illness prevention and treatment for individuals and whole populations, in developing and developed countries.

3.5 The Longer-Term Future for mHealth

The pace of development in some areas of mHealth (particularly smartphone apps that bypass or complement healthcare delivery systems, and the development of prototype peripheral devices designed to leverage the computing power of the mobile phone) is very fast. At the same time, in areas such as data collection and remote diagnosis, there have been many trials – though as yet only relatively small-scale deployments. Nevertheless, if the demonstrated potential of mobile devices and networks can be realised, business cases proved, and barriers to adoption overcome, mHealth promises significant, positive changes for the health of populations.

In low-income countries:

- The ability of the mobile network to deliver ICT infrastructure will help to put in place robust administrative systems for healthcare delivery that are currently taken for granted in developed countries and regions, but which are still lacking elsewhere. In developing economies, a completely new, mobile-centric healthcare delivery structure may emerge, free from the constraints of highly structured systems currently in place in developed countries.

- The health of the population will be better known to planning authorities; it will be possible to target resources at locations and populations on the basis of an understanding of local needs, and medical staff will be enabled to diagnose and treat conditions locally without patients needing to travel large distances to specialist centres. Disease outbreaks will be handled more efficiently through better communication with local workers, and because the evaluation of what works best (supported by the aggregation of data) will lead to better intervention design. Adoption of mHealth apps will be spurred by innovative coupling of the app with other ways of using a mobile phone – for instance the use of mobile credit as a cash replacement, or for mobile banking.

- Increasingly powerful mobile phones will be in the hands of health workers (and individuals), enabling them to use on-board apps and low-cost peripheral devices for information and (self-) diagnosis. Devices will evolve to become essential components of compact "field clinics", delivering technologies (from thermometers and stethoscopes to blood testing devices and detectors of dermatological disorders) that previously have been available only in larger population centres. Mobile phones will also deliver training to clinicians, and remote decision support using either automated analysis of data, or real-time (or near-real-time) contact with specialist doctors.

In developed economies, and (ultimately) most economies:

- The mobile phone will be used – with individuals' express consent – to *unobtrusively and passively* collect, store, analyse and upload data on a wide spectrum of personal and environmental variables, from vital signs (heart rate, body temperature, etc.) to location, motion, ambient air temperature and pollution levels, conversational patterns, interaction with other people, and even (through the use of RFID-enabled "smart pills") adherence to medication regimes. As well as generating data for research, this comprehensive monitoring capability will lead to applications of immediate personal benefit, such as "virtual guide dogs", sleep apnoea monitoring, warnings of pollution risks for asthma sufferers, and mobile-phone-based drug dosing controllers for long-term conditions such as diabetes.

- At the same time, with more *conscious and active* engagement of individuals, more information – for instance related to individuals' medical conditions and treatments – can be monitored and collected. The ability of healthcare providers, carers (friends and family), public health authorities and pharmaceutical companies to use this data in real time, and in aggregate form for research, will not only benefit individuals but will also lead to the development of better forms of illness prevention and treatment, through the design of suitable experiments using very large populations.

- Individuals' personal health records may be stored in electronic form, updatable from a mobile phone, and capable of being accessed with suitable permission by healthcare systems anywhere in the world. The full realisation of this would require an extension of approaches already beginning in some areas (such as Hong Kong) to standardise the most significant aspects of health record meta-data and formats. If this is successful, it would lead to better healthcare for individuals (because doctors will have access to up-to-date and comprehensive records wherever the individual is travelling, and will be able to interpret them consistently); it will also provide large-scale databases of information in standardised form, a valuable resource for researchers.

- Better understanding of disease transmission, and of the effectiveness of drugs or other interventions, through technologies such as personal tracking and tracking of drugs beyond the point of consumption (using RFID-enabled "smart pills"), will lead to earlier prediction of epidemics, better treatments for serious illness, and better (because more personalised) preventative public health campaigns.

- The development of engaging applications (perhaps games based, and using avatars) for mobile phones will lead to better support for behaviour-change interventions (e.g. for stopping smoking, promotion of healthy exercise regimes, or reducing dependence on alcohol and drugs) and for treatments such as cognitive behavioural therapy in the area of mental health.

While we expect the above pattern of deployment of mHealth to be followed, we also expect that the most rapid development of interesting applications will be seen in countries where:

- a transition is currently underway in healthcare delivery (or in public services more generally) from an established structure to a new structure – either through significant market change, deregulation, other infrastructure change, or major population demographic change;
- the population has rising expectations for healthcare that must be managed by healthcare delivery systems and governments; and
- those involved in healthcare delivery are willing and able to experiment with new models – for instance in response to changing budgets.

Such conditions may apply in any country, but perhaps are most likely to apply in major emerging economies. Finally, if, as has been suggested by experts contributing to this report, everyone outside the lowest-income economies in Africa will have at least indirect access to a smartphone by 2020, there is every reason to believe that "blue sky" applications will be practical reality for the vast majority of the world's population within ten years. If this is so, many benefits will ensue, and many business opportunities will be created – as discussed in Chapters 4 and 5 below.

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Chapter 4

Illustrative Business Cases for mHealth Provision

Business models have emerged encouraging innovation in mHealth applications, many of which require no major infrastructure investment or intervention by the medical establishment. In such cases, market forces and consumers' willingness to pay will drive deployment. Not all mHealth applications are like this, however: many will need to interact with established healthcare systems or communications platforms. In these cases, development will play out very differently depending on the maturity of existing networks and systems.

This Chapter reviews the main drivers for investment by the major players in the mHealth value chain, including market penetration, brand benefits, commercial profit, risk reduction, cost savings, improved quality of care, and the public good. We illustrate the value chains and business cases for several sample applications:

- appointment booking and reminder services
- smartphone apps
- end-to-end drug monitoring
- enablement of remotely located healthcare professionals
- remote monitoring services.

These business cases show that there are mHealth applications with the potential to generate profits for suppliers and to save money for healthcare systems. In many cases returns can be made more attractive through "piggy-backing" – that is to say, by combining the provision of mHealth solutions with other services, such as remote concierge packages; using mobile devices to gather data for national statistics, taxation, or other purposes, allowing costs to be shared; or using smartphones to pay salaries (so-called "mCash"), thereby reducing processing costs.

The real value for mobile operators and the health industry at large will not be found in any individual application, but in developing a platform which makes it much simpler to build, launch and deliver mHealth services and solutions. What is more, opening up this value does not require enormous investment – operators have the opportunity to leverage their existing investments to target low-hanging fruit.

Some of the greatest potential benefits of mHealth, however, are unlikely to be delivered by the market. In particular, individual consumers are unlikely to pay for applications designed primarily to produce information from which public goods (such as better advance warning of the spread of epidemics) are derived. Such investments for the public good require funding by institutions.

4 Illustrative Business Cases for mHealth Provision

mHealth services have been widely discussed for many years, yet widespread deployment has yet to take place. There are two main reasons for this: one is the need to ensure that mHealth applications provide some form of clinical or social benefit (as discussed in Chapter 5 below); the other is the need for providers and investors to have a business case showing a return on their investment (the subject of this chapter).

Without evidence of either a health benefit or a business case, any idea for an mHealth service or application is highly unlikely to get off the drawing board, or (if it does) to be developed beyond an early-stage trial. An application might possibly get developed into a full commercial offering where there is a business case but limited empirical evidence of a health benefit; it might also get developed where there is evidence of a strong medical benefit, but little clear business case, although under such a scenario the investment costs must be borne by the state, or by a charitable donor, as a public good. It is mHealth services and applications that demonstrate both health benefits and a business case that are most likely to see the light of day. Once there is a clear business case, private investment and intellectual capital can be harnessed to help develop an idea, and to commercialise a service or application.

In this chapter we review the main drivers for investment by the major private sector players in the mHealth value chain (network operators, infrastructure and handset vendors, IT companies, and others), before going on to consider the business cases for a number of applications discussed in previous chapters, including appointment booking and reminder services, smartphone apps, end-to-end drug monitoring, enablement of remotely located healthcare professionals, and remote monitoring services. Finally, we briefly consider issues surrounding the mobile network as a platform for multiple services.

4.1 Players in the mHealth Value Chain

Many different types of organisations are interested in identifying ideas for mHealth applications and services that are underpinned by a strong business case. There may also be a variety of different potential drivers for investment:

- There are some “soft” benefits – for instance, the brand benefits of being seen to be delivering services of social utility (such as supporting remote carers). Many large organisations also set themselves corporate social responsibility targets and objectives, which can be met by pursuing initiatives that benefit sustainable development.

- Sometimes involvement in mHealth is obligatory. The ability to call emergency services (for instance by dialling 999 or 911) is the closest the world has yet come to providing a global mHealth app. Mobile operators are typically required to provide access to emergency services numbers as a condition of their operating licences.

- In most cases, however, the primary incentive for investment in mHealth is commercial. Shareholders – whether they are private individuals, fund managers or state shareholders – typically demand a viable business case to justify an interest in mHealth. In other words, there has to be a potential for profit or for cost savings.

- In the public sector, drivers for mHealth investment may include the desire to cut costs, the need to make budgets go further, or the fact that a technology is expected to deliver a public benefit.

These incentives can take a variety of forms for different players, as the following table shows:

Investor type	Driver for investment
Mobile network operators	Mobile network operators are seeking new ways to expand their markets, either by stimulating the usage of their networks and services, or by using their networks as platforms for delivering value-adding services that generate revenues.
Mobile network technology vendors	Mobile network technology vendors can benefit from involvement in mHealth by driving investment in private networks, and by positioning themselves as partners of choice for public mobile network operators or systems integrators seeking to commercialise mHealth solutions. Increasingly, such vendors offer managed service models, as well as equipment sales models. Where they can see the potential to generate ongoing service revenues, they may invest in development of platforms enabling mHealth service delivery (e.g. Alcatel-Lucent's LifeStat remote monitoring and health management platform[71] and TeleHealth manager.[72])
Mobile device manufacturers	Mobile device manufacturers are keen to drive sales of their kit; one way of doing this is to establish themselves as the technology providers of choice for particular usage scenarios. They want operators, medical institutions and the public to turn to them for the devices that will support healthcare delivery in the future. This encourages investment in device-centric platforms for third-party app developers to use (e.g. Nokia's support for the Entra Health diabetes app.[73]) The appeal of their devices may be less associated with the hardware components of the devices themselves than with the ecosystems of developers creating applications and operating systems for those devices. By getting involved in trials, manufacturers also generate ideas for new devices they can sell (e.g. Apple has filed patents related to baby monitors embedded in plasters, and wireless earbuds to track biometrics).[74]
IT companies (including hardware and software vendors, and systems integrators)	IT companies and systems integrators stand to gain if they are selected for large numbers of mHealth deployments worldwide, and if they can embed their technologies and methods as standards within mHealth delivery. As such they will invest in early trials, with a view to establishing relationships, seeding the ground for bigger investments, and proving their credibility and experience in advance of full commercial deployments. Like network technology vendors, many IT companies are complementing product sales models with service-orientated business models; and may invest in the development of mHealth services solutions that they can subsequently sell.
Financial investors – including VC and private equity firms	Financial investors seek opportunities to make investments that can deliver a financial return – typically over a period of only a few years. The involvement of such companies is evidence that viable financial business cases are emerging, as their criteria for investment are typically rigorous.
Insurance companies	There is a strong potential for insurance companies to become key buyers of and advocates for mHealth services and solutions – for instance as a means of limiting exposure to hospital and care bills (e.g. see Section 4.4.3 below for detail about how home-based sensor networks might be attractive to insurers).
Public health institutions	Public health institutions are potential investors in the supply chain. They will typically approach the business case from a different perspective from privately owned organisations, asking whether investment in mHealth can help them to save costs, or to achieve more with the funds they have, or to improve the quality of care (even if at an increased cost).
Banks and payment companies	Payment companies see the potential to extend their influence and increase their revenues by enabling people to buy access to healthcare using the mobile phone. Meanwhile, both banks and payment companies are fighting a defensive action against mobile phone companies, who want to promote the mobile phone as a platform for making payments. Indeed, many of the organisations advocating the mobile phone for health also advocate it for banking and financial transactions. Examples are the Grameen Foundation and the Bill and Melinda Gates Foundation. Vodafone, too, is active in both, with its mHealth work and investments in M-PESA.
Private medical institutions (including hospitals)	Privately owned medical institutions look for investments that can increase efficiency (cut out costs), increase productivity (deliver more from the same investment), or open up new revenue streams (provide new sources of revenue and profit).

The costs of developing mHealth solutions on a national scale can be enormous, so often ecosystems of suppliers may emerge to share the risks – and the potential benefits. Ecosystems of suppliers also emerge because complex licensing and regulatory structures may make it challenging or even impossible for technology vendors to deliver a complete mHealth solution. By joining forces with licensed experts, technology companies can open up new markets.

It is possible that publicly owned health organisations (or charities) may also invest in mHealth service development on the grounds of a clear business case. That business case may come in the form of cost savings (making public or charitable resources stretch further); but depending upon the regulatory environment in any given country there may be an opportunity for a health organisation to provide a service which generates profit, and hence generate money that can be re-invested elsewhere in the system.

4.2 Emerging Evidence of the Business Case For mHealth

In contrast to health benefits (which typically require large trials, conducted over many years), the financial benefits and the business case for deployment of some mHealth services or applications can be proven with relatively modest trials over relatively short periods of time. In recent years, the mHealth market has been characterised by a great deal of innovation, and a wide variety of technical and commercial trials. One result of this effort is that the business case for a number of mHealth applications and services is now becoming much more clear.

mHealth applications and services can broadly be divided into three groups. At one end of the spectrum are application or service ideas that are relatively quick, low in cost, and simple to introduce, and which have a clear revenue stream associated with them. The business case is obvious. At the other end are ideas which are highly complex to implement, expensive to implement, that have uncertain revenue streams (in some cases no revenues at all), and that are not guaranteed to save money either. We have already highlighted examples earlier in this report – for instance platforms for health records that support vaccination tracking, or the use of data collection from mobile devices to enable more effective disease modelling. The business case for these ideas is challenging to qualify. In the middle are ideas which may be expensive or complex to introduce, but for which it is reasonably easy to see revenue streams or cost savings.

In this chapter we initially highlight examples of business models which are clear, and go on to consider some of the middle-ground mHealth applications and services, where the business case is emerging but less obvious.

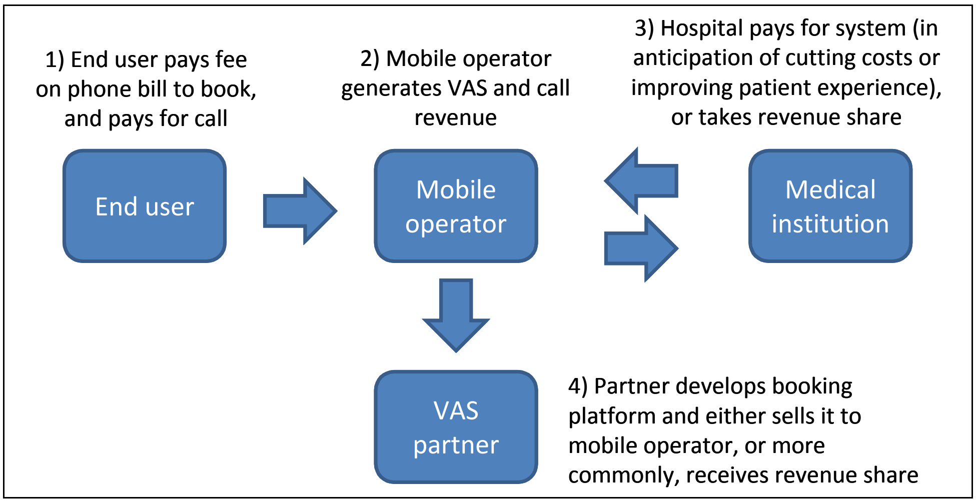
4.3 mHealth Applications with Established Business Models

Examples of applications with established business models include:

- Appointment booking systems
- Appointment reminder services
- Health-related information services
- Health- and fitness-related smartphone apps.

Appointment booking systems offering mobile SMS and voice booking capabilities – as discussed in Section 2.1 above – demonstrate potential financial benefits for mobile operators, hospitals, surgeries and clinics. The value chain is shown in Figure 5:

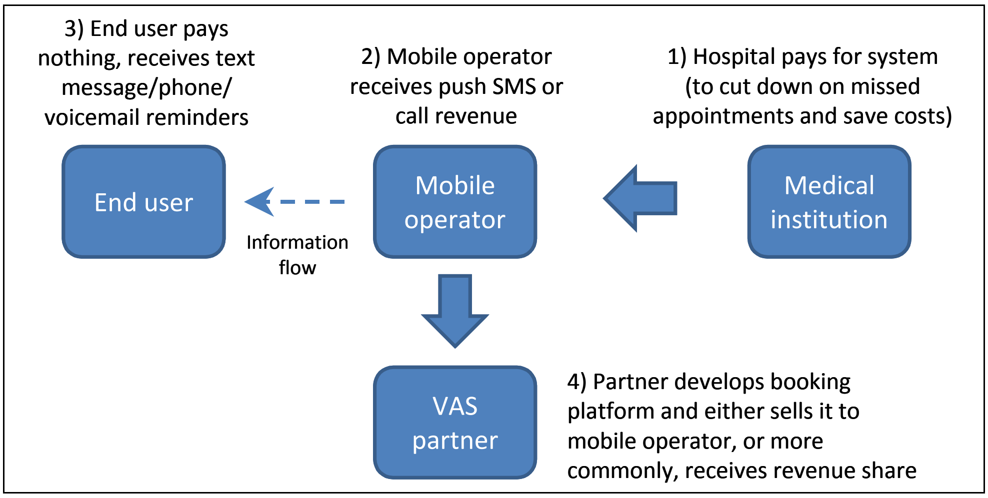
Figure 5:
Value chain for appointment booking systems



For example, as shown in Section 2.1, China Mobile and its value-added service (VAS) partners have implemented a system in Guangdong Province which shows the potential for booking service models, having now managed booking for over 4.5 million patients; see the featured case studies at the end of this report.

Appointment reminder services also have a simple business model, although the revenue flows in a different direction. Whereas for appointment bookings revenue flows from end user to network operator, and from there to VAS partners (with hospitals playing a variable role in funding the system), with reminders the medical institution typically funds the SMS messages, as fewer missed appointments means more patients seen, and – depending on the country – more costs saved and/or more revenue generated.

Figure 6:
Value chain for appointment reminder services



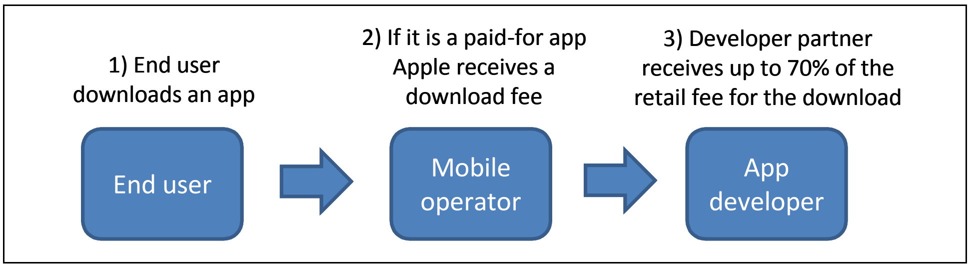
With these simple applications, the business model is relatively easy to justify. There comes a point at which sufficient traffic is being generated, or sufficient levels of booking fee are being captured, to pay for relatively small upfront investments; or the costs and inconvenience of managing bookings face-to-face become so high that a phone-based alternative saves time, and improves patient experience.

Health-related information services also have established business models. They take a variety of forms. **Premium information services** work on the assumption that there is a sufficient base of customers willing to pay for access; China Mobile, for instance, offers a variety of information services as part of its Medical Link offer in Guangdong (Section 2.3 above). It charges a fee for regular access to information about healthy lifestyles, and on specialist topics of interest to different groups of subscribers. Another example is mDhil in India,[75] which provides SMS-based and mobile web-based access to information; its SMS health text alert services cost Rs1 per day (minimum 10-day subscription), and provide information about health issues such as weight, diet, stress, skin and beauty, plus specific information geared to diabetes and tuberculosis patients. It has over 150 000 subscribing customers and is growing rapidly. Although premium services will typically be adopted by more affluent customers, services such as mDhil and Medical Link (which had nearly 1.4 million customers at the end of 2010) demonstrate that there is demand.

In contrast, **publicly funded information services**, and services funded through public-private partnerships, are typically provided for free, because a public body or government (or special interest group) has decided that provision of the information will help to reduce incidences of illness, injury or death. Some have sponsors who assist with the costs of delivery. A good example of this model is Text4Baby,[76] a free SMS service providing information to pregnant mothers in the USA. Targeted at low-income communities, the texts provide reminders and information about immunisations, nutrition, oral health and child development, as well as toll-free numbers for health services. Text4Baby was formed as a public-private partnership, including government, corporations, academic institutions, professional associations, tribal agencies and non-profit organisations. Founding partners include the National Healthy Mothers, Healthy Babies Coalition, Voxiva, CTIA, The Wireless Foundation, and Grey Healthcare Group. Johnson & Johnson is the founding sponsor, giving what was described as a "multi-million dollar, multi-year" sponsorship package in November 2010; other sponsors include WellPoint, Pfizer, CareFirst BlueCross BlueShield, and MTV. Free messaging services are provided by participating wireless service providers. Launched in February 2010, it already has over 100 000 users, and it is hoped that it will reach over a million mothers by 2012.

The rise of **smartphone app** stores, and the use of ecosystems of developers to provide apps for mobile phone users have also made the business model for health-related mobile apps easier to justify. Apple broke all the rules when it launched its app store, giving developers a much greater slice of revenue generated by app downloads (up to 70%) as compared with the much smaller revenue share traditionally offered by mobile operators. This single move encouraged application developers to race to sell their apps through its platform. Apple benefited from a much wider range of applications for its device users, which increased the utility of its products and helped to drive sales. At the same time it generated some revenue from the sale of those apps, and cut the costs of developing them. Other handset and device manufacturers quickly followed Apple's lead; Google, for instance, also charges a 30% transaction fee on the sale of any app through its store. Meanwhile Nokia's Ovi store offers 70% revenue share for developers where customers pay by credit card, and 60% of the net revenue received by Nokia where the fee is paid through the mobile operator's bill.

Figure 7: Value chain for smartphone apps



Of all the hundreds of thousands of applications now available for download from app stores, over 5000 are health, medical or fitness-related,[77] more than 15% of which are free, with another 20% or so priced at less than USD1. Some professionally targeted apps, however, sell for between USD50 and USD300 per download. Where applications are provided for free, this is often designed to attract users; the developers then attempt to sell those users a value-added application which does cost a fee. For instance, CardioTrainer[78] is available as a free download; users are then offered several paid-for apps – such as Weight Loss Trainer.

Google has added an extra revenue model with its Android open operating system for mobile devices. Like Apple, it is exploiting an ecosystem of developers to spread the risk of app creation, and to increase the utility of its services. But in Google's case, it is not aiming to drive sales of handsets – it is aiming to drive adoption of its operating system, which in turn is intended to drive usage of its search engine. Search-related advertising is where the company makes the vast majority of its revenue.

4.4 mHealth Applications with Emerging Business Models

In considering the business case for the introduction of less obvious mHealth applications, there is a range of aspects to consider:

- Identification of users (who are the end users?)
- Drivers for end-user adoption (what is the value to the end users, and how does it make sense to monetise the application – subscription, fee per transaction, etc.?)
- Estimation of potential revenue streams (what is the scale of demand?)
- Identification of players in supply chain (what other players does the business case rely on?)
- Identification of costs for deployment and ongoing service delivery.

We illustrate this in respect of three mHealth applications with emerging business models: end-to-end drug monitoring; enabling the remotely located professional; and provision of remote monitoring services, e.g. for the elderly or infirm.

4.4.1 End-to-End Drug Monitoring Solutions

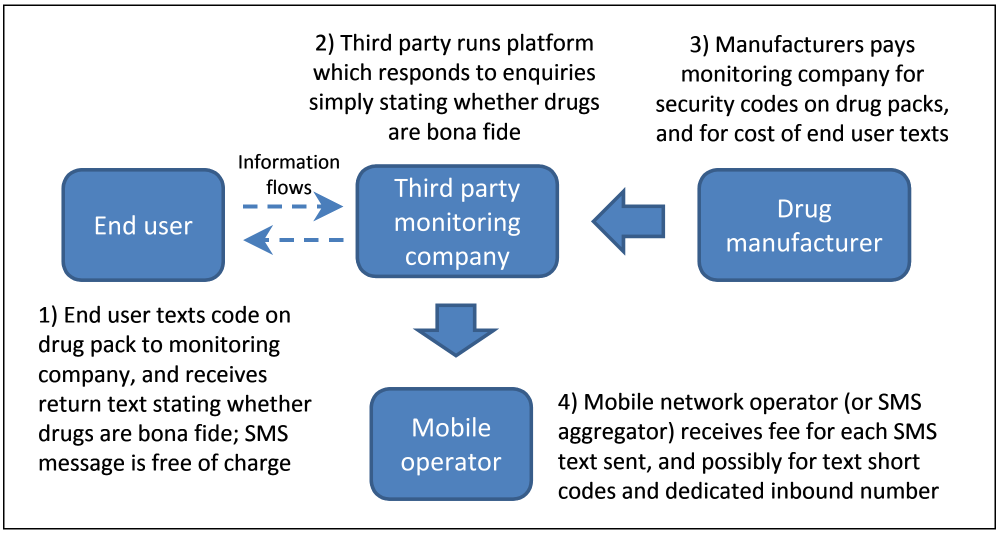
Our first example is taken from end-to-end drug monitoring, as described in Section 2.2 above. Such solutions have the potential to be highly sophisticated, but the business case described below focuses on a relatively low-tech solution, capable of delivering a service to any person with access to a mobile phone able to receive a text message. The business model has emerged in Africa, and although not yet deployed on a large scale, shows potential, not least because it addresses a major problem.

According to WHO,[79] counterfeit drugs may account for as much as 10% of the global drugs market. The problems are worst in developing economies, where counterfeit drugs account for 25% of the market (and in some countries this figure is as high as 50%); but the problem is not unknown in developed countries, where WHO estimates 1% of drugs to be counterfeit, even in developed market economies with strong regulatory and enforcement systems.[80] Drug manufacturer Pfizer has estimated that the counterfeit market is worth USD14 billion in Western Europe alone.[81]

Value Chain: In our example application, illustrated in Figure 8, the vendor of a drug pays a third party to provide a security code for each pack of drugs sold. When the consumer goes to buy (or use) the drugs, he or she can send the code in a text message (free of charge) to the third party, who sends back a text confirming whether or not the drugs are legitimate. The drug manufacturer also pays the third party for the cost of the SMS messages, and for the costs of a dedicated inbound number (which may be a short code to make calling as simple as possible for end users). In addition to generating revenues from the sale of the security codes (implemented in the form of a scratch-off strip of the packaging), the third-party monitoring company can also generate revenues from the sale of extra advertising on the confirmation texts which it sends out.

End users are motivated to use the service because they want to be assured that the drug they are about to buy or use has come through the appropriate supply chain, from a certified supplier; they want reassurance that the drug is genuine (and therefore likely to be effective) rather than counterfeit (and therefore likely to

Figure 8: Value chain for end-to-end drug monitoring



be ineffective or even actively harmful). The service costs the user nothing, so barriers to usage are low. The potential health benefits are significant – millions of people are believed to die every year as a result of counterfeit drugs. For instance Agenzia Fides, the missionary press agency of the Vatican, has estimated that 700 000 people die every year as a result of using counterfeit malaria and tuberculosis drugs alone.[82]

Drug manufacturers – who lose billions of dollars every year due to the sale of counterfeit products – stand to gain not only by reclaiming the market from the counterfeiters, but also from increased brand loyalty. In Nigeria, where Sproxil provides a service such as this (see Section 2.2), Merck enjoyed an increase in sales of more than 10% as a result of customers actively asking for its products with security codes.

Revenue and Cost Drivers: The table below shows illustrative revenues, costs and gross margins for a third party providing monitoring services over five years. There are several sources of revenue for the service provider, including fees for the security codes (providers charge a few cents for these – our model assumes USD0.05), and for the SMS messages (which vary by country – we have assumed a small mark-up on cost, at USD0.055). The third-party provider may charge for these whether or not the end user actually sends a text. A small amount of revenue may be achieved through advertising (USD0.05 per return message), but this delivers little upside, as the fee is only collected when drug buyers check the validity of a product. Costs of supply include sourcing the scratch-off strips for the drug packages (our model assumes USD0.035, rising by 5% per year because of the need to re-invent them and so stay ahead of counterfeiters); the messages that are sent (USD0.05); and the platform to manage the codes and the validation (assumed to be USD1 million to develop and USD150 000 per year to maintain). Costs are assumed for the short-code and inbound number (just over USD1000 per year combined), and for sales and marketing, staff and overheads.

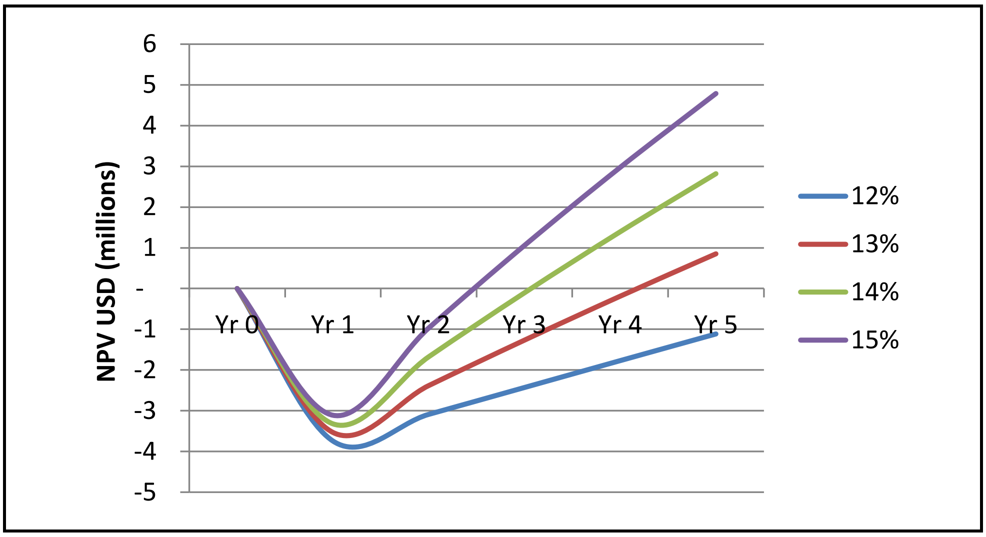
Figure 9: Revenues, costs and NPV for monitoring business

Year	1	2	3	4	5
Number of labelled packs sold	1 million	10 million	20 million	30 million	40 million
Revenue (USD)	161 500	1 617 500	3 240 000	4 867 500	6 500 000
Direct costs (USD)	219 232	733 652	1 182 902	1 726 658	2 322 861
Gross margin	-36%	55%	63%	65%	64%
SG&A	2 300 000	1 300 000	1 300 000	1 435 000	1 465 000
Cash flow (USD)	-2 357 732	-416 152	757 098	1 705 842	2 712 139
NPV (USD assuming WACC of 10%)	-2 143 393	-343 927	568 819	1 165 113	1 684 025

Our simple model illustrates that the key driver of revenue is the number of labelled packs sold to the manufacturer. Experience from real-world trials of such services shows that participation rates of up to 3% of all drug buyers are achievable in a short period of time. The model shows that achieving a profit is a function of scale – a service provider needs sales of 35 to 40 million security labels by year five to get a significant return on investment in that timescale. However, the model assumes a Western cost base; running the business from an economy with lower salary costs might enable a smaller-scale business to achieve a profit.

Return on Investment for the Manufacturer: for the drugs manufacturer, a return on investment may be delivered in two ways: by avoiding loss of sales to counterfeit drugs, and by growing market share at the expense of competitors because of the brand benefits. The manufacturer receives a benefit when the consumer chooses a pack with a security code over a pack without a code, provided that the pack without a code was either counterfeit, or was from another manufacturer. As already mentioned, early usage of Sproxil's system by Merck in Nigeria led to sales increases of more than 10%, driven by customers actively asking for its packs with the security codes. The greatest benefits, clearly, will be delivered in markets where the rate of counterfeiting is highest. In our illustrative model, as Figure 10 below shows, the payback on the investment is very sensitive to the level of market share increase, and a sales increase of at least 13% is required to see a return on investment within five years. The model, which shows the return on investment for a manufacturer selling an initial volume of 40 million packs of medicine per year (at an assumed USD3 cost per pack as shipped from the manufacturer), is also very sensitive to the ratio of the cost of the drug to the cost of the security solution.

Figure 10:
Net present value of benefit for drug manufacturer over five years, based on a sales increase of 12% to 15%



Market Potential: as discussed above, there is substantially more potential for a system such as this in developing markets than in developed markets, as the scale of the challenge from counterfeiting is so much greater. On the other hand, this business model is not especially sensitive to the degree of rurality, as it relies on a delivery mechanism that can be accessed in most areas. Given estimates of a drug counterfeiting market worth USD75–100 billion globally, the deployment of such systems, assuming they could deliver a 5% swing in usage back towards bona fide drugs, could deliver up to USD5 billion in extra revenues for the global drug manufacturing industry. Moreover, based on current estimates of the annual number of global deaths from use of counterfeit malaria and tuberculosis drugs, a similar sort of swing could save tens of thousands of lives per year.

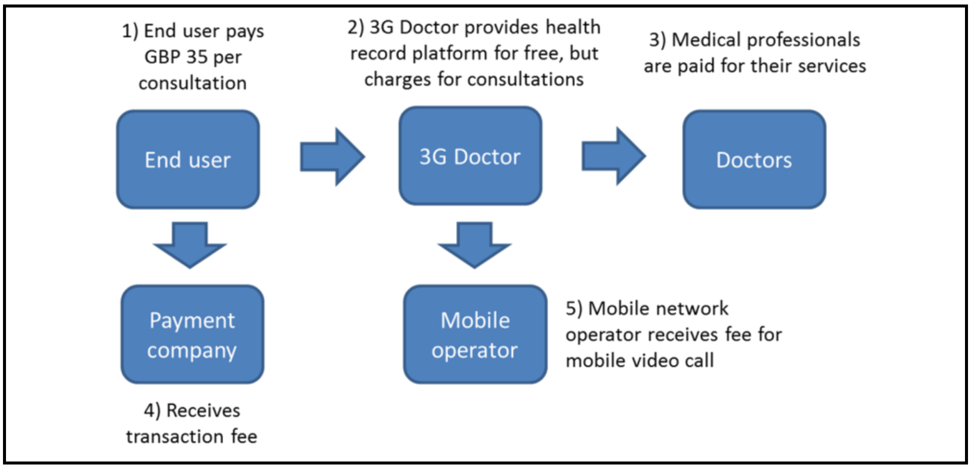
4.4.2 Enabling the Remote Professional

One emerging area of mHealth is the use of the mobile phone and mobile network services to enable the provision of remote health services – including remote consultation and diagnosis, and decision support.

This takes a number of forms, from remote 3G video consultations in developed countries to a modern equivalent of the "barefoot doctor" in low-income environments.[83]

Remote Consultation: Various examples of mobile video consultation have emerged around the world. These include 3G Doctor in the UK[84] (Figure 11), providing two services. The first allows users to create an online hosted personal health record which can be accessed using a PC or mobile phone, recording their medical history (including previous surgery, chronic illnesses, allergies, cholesterol levels, medications, etc.). There is no charge for this other than any data fee charged by a user's Internet access provider.

Figure 11: Value chain for "3G Doctor"



The second service provides access to a remote video consultation with a doctor, for a fee of GBP35. A request is made via 3G Doctor's website, and a doctor then makes a 3G video call direct to the customer (who therefore has no 3G call fee to pay). 3G Doctor pays its clinicians to participate. The service is positioned as a complement to face-to-face consultations with users' regular GPs, offering fast access to a consultation where one might otherwise not be possible. It does not offer booking systems to provide access to public health services in the UK.

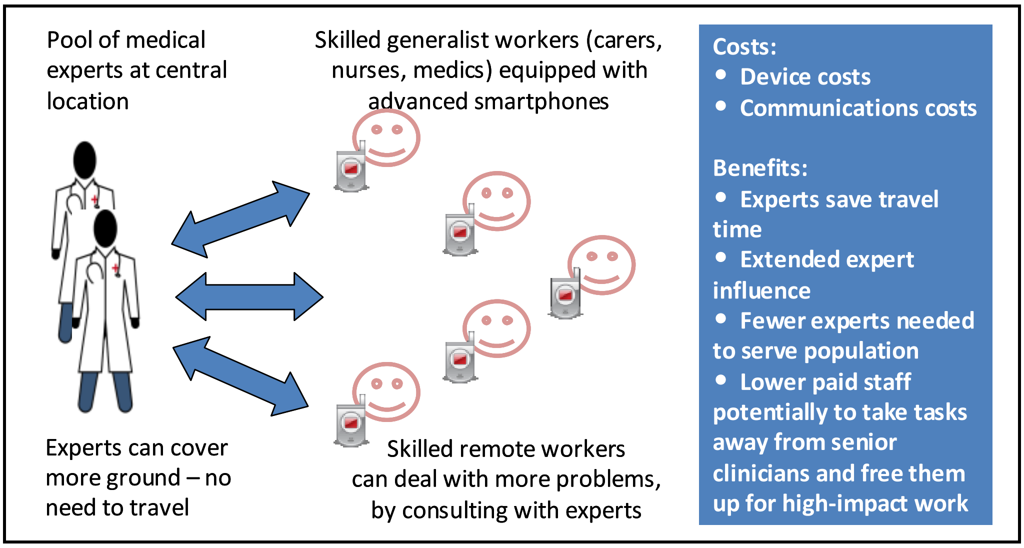
This service requires the end user to have a sophisticated mobile phone, with 3G network access and a camera to enable the video calling capability – a relatively high hurdle in emerging markets, limiting applicability of the service in this form. In other markets, however, examples have emerged of services that can operate with less expensive mobile technology. Yihe's remote consultation service in China, for instance, enables support using voice and text (see Section 2.3).

"Barefoot Doctor": Rather than relying on patients having mobile phones themselves, an alternative is to put advanced mobile devices into the hands of medics and care workers located within the community. By initiating a controlled distribution of devices (usually smartphones) to trained professionals, health organisations can facilitate better access to, and use of, expert resources. Clearly, there are costs involved in this, but the benefits (as listed in Figure 12) have the potential to significantly outweigh the upfront investment.

Return on Investment: Providing devices to skilled remote workers makes sense where there are insufficient specialist experts to treat the population in any given area; by providing appropriate devices to remote workers, the reach of the available experts can be extended, and the number of patients treated can be increased. To justify the investment, therefore, the increase in expenditure as a proportion of overall expenditure must be outweighed by the increase in number of patients that can be served.

How many extra patients might be served depends on a wide variety of local factors – the ability of experts to travel, the frequency of expert travel and time of travel (between appointments, or overnight), the

Figure 12: "Barefoot Doctor" – roles, costs and benefits



ability and willingness of patients to travel to experts (and their ability to find the right experts), and the number of remote consultations that experts can serve from a central location in addition to other responsibilities. Clearly, in reality, no two cases will be the same, but a simple illustrative model can indicate the level of productivity gain that might be required for the business case to make sense.

Cost Drivers: Figure 13 shows an illustrative scenario based on Pakistan. According to WHO statistics, the country has nearly 128 000 physicians (around 8 for every 1000 people) and nearly 66 000 community health workers. The cost of distributing a smartphone to each of these community workers, with call and data allowances, would be a very small fraction of the annual cost of employing the country's physicians.

Figure 13: Illustrative scenario for salary costs versus comms costs

Year	1	2	3	4	5
Cost to equip (PKR millions)					
Devices	2 970	144	140	2 711	131
Services	542	532	523	514	505
Total cost	3512	676	663	3225	636
Cumulative comms cost	3512	4188	4851	8076	8712
Salary costs					
Number of physicians	128 000	128 000	128 000	128 000	128 000
Average salary (PKR)	255 000	260 100	265 302	270 608	276 020
Total salary bill (PKR millions)	32 640	33 293	33 959	34 638	35 331
Cumulative salary bill (PKR millions)	32 640	65 933	99 891	134 529	169 860
Ratios					
Comms cost as % of annual salary	10.8%	2.0%	2.0%	9.3%	1.8%
Comms cost as % of cum. salary bill	10.8%	6.4%	4.9%	6.0%	5.1%

Model Assumptions: Salaries are assumed to increase 2% p.a., and comms and device costs to decline by 1% to 3% p.a. The number of workers is assumed to remain constant; in reality the number of experts would need to be adjusted over time to match demand. Device costs have been benchmarked against current prices for smartphones in Pakistan (PKR45 000); service costs of PKR8208 per year per device, enabling unlimited GPRS and MMS usage, 300 minutes of voice calls and 300 texts per month, have been benchmarked against current offers from mobile operators in Pakistan. The model assumes 5% device replacement each year, and 100% replacement in year 4. It assumes all community health workers are issued with a device – in practice this may not be necessary.

As this simple illustration shows, even if we consider only base salary and ignore overheads, over five years physicians would only need to achieve a 5% increase in the number of consultations in order to recover the cost of the technology investment. (This rises to 15% if it is not possible to assume they already have access to mobiles or Internet-enabled PCs in the centres where they work.) Assuming all physicians participate, and an average consultation time of ten minutes (with ten minutes between consultations), that is an average of one extra consultation per physician per day. It is not difficult to imagine that this is achievable.

Market Potential and Future Benefits: Pakistan was selected as an example because it suffers from a lack of physicians and clinicians, but in this it is not untypical of low-income economies. The provision of the smartphones would enable picture messaging, SMS and voice conversations between community health workers and physicians; the health workers would also have ready access to online information resources over mobile Internet connections. Once 3G becomes available, mobile video consultations would add further value. It seems reasonable to assume that community health workers or nurses might be empowered by these means to undertake certain tasks in the field that might otherwise be undertaken by higher-paid physicians centrally, so freeing up the physicians' time for the additional consultation work.

The increased productivity of the physician workforce modelled above is just one of the benefits. Because smartphones are powerful computing devices that can be put to a variety of uses (through network access and the running of apps), the initial investment in the infrastructure opens the way to many extra benefits for only incremental costs. Possibilities include:

- collection of data on a wide scale (e.g. maternity and neonatal information, vaccination data)
- online health records
- non-health-related efficiencies such as videoconferencing, conference calling, or online conferencing instead of physical meetings, and easy inter-group messaging, email and large file transfer
- SMS messaging to push important news to professionals in the field
- providing professionals with access to information and training resources
- providing community workers with low-cost peripherals which can support diagnosis, e.g. attachments to enable eye tests (see Section 3.1 above), detection of skin cancer,[85] teleanaesthesia,[86] etc.

Where (as we assume in our example) healthcare authorities are buying devices in bulk, there is the potential for them to negotiate free access to devices in return for service spend commitments, or longer-term contracts. Mobile operators would benefit from large customers with certain revenue streams, and the opportunity to supply devices pre-loaded with value-added applications of interest to the medical community that could be accessed for extra fees. It might also be possible to explore entirely new business models, such as getting large corporations to sponsor the provision of the devices in return for advertising opportunities and the brand benefits which association with such a scheme could deliver.

In developed economies, it is harder to make the business case simply on the basis of the number of people treated, as patients are generally willing and able to travel to doctors and consultants. There are, however, instances where specialised resources are in short supply and patients often incapable of travel; e.g. the American Geriatrics Society has estimated that by 2030 the USA will have a geriatric population of nearly 71 million, and that there will be a shortfall of around 36 000 certified geriatricians. In such circumstances it is easy to see that enabling remote access to those specialists for consultations (or as support for community workers) would help resources to stretch further.

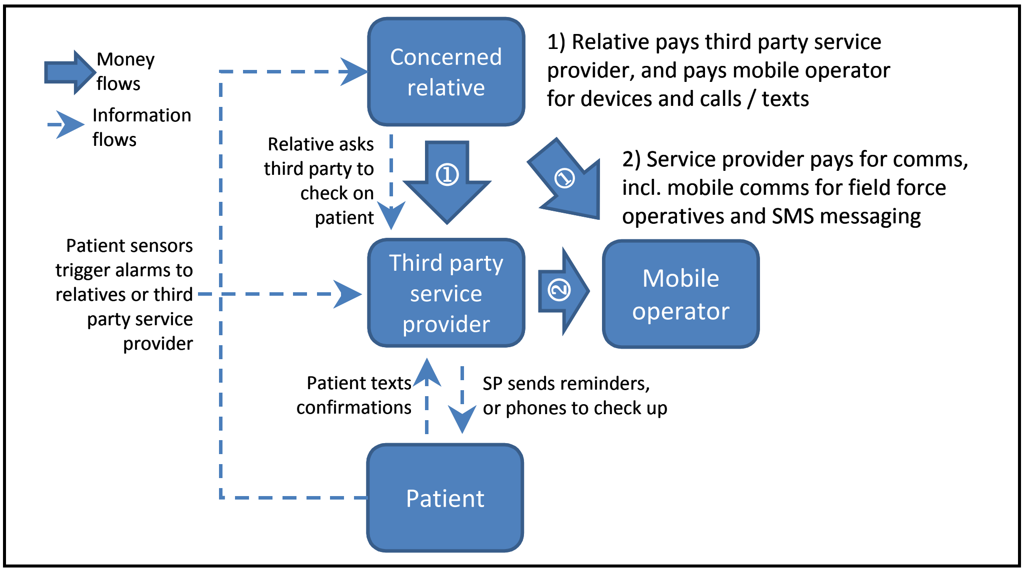
4.4.3 Provision of Remote Monitoring Services

Our final example considers the use of mobile communications for telecare, and specifically to support remote monitoring of the elderly or infirm in the home. A major challenge in developed economies is the rapidly ageing population, and the need to find effective, humane and efficient ways of caring for them; often the burden of care falls on relatives, but there are also major costs to the state-funded healthcare systems. In low-income and developing countries, remote monitoring is particularly applicable in an environment in which young professionals commonly leave rural areas to find work, leaving elderly relatives behind in villages.

As we saw in Section 3.2, there are various applications in this category; we have modelled those which fall under the heading of "assisted living", applications that use the mobile device as a sensor and help to make it possible for the elderly to live independently at home. Examples include ActiveCare's Personal Assistance Link,[87] which sends an alarm if the wearer falls (using accelerometer-type features) or wanders or gets lost (using location-tracking), and also includes one-touch dialling. Apps have emerged for the iPhone and for Android devices which provide some similar elements – for instance the iFall app for Android devices.[88]

Value Chain: It is possible to envisage differing value chains for the provision of remote monitoring services, as shown in Figures 14 and 15 below. Under one scenario, the services would be entirely funded by concerned relatives, perhaps supported by insurance plans taken out in advance. (Insurers might even decide to pay for this sort of service for some customer groups, if close monitoring could offset much higher hospital bills.)

Figure 14: Relative-funded model

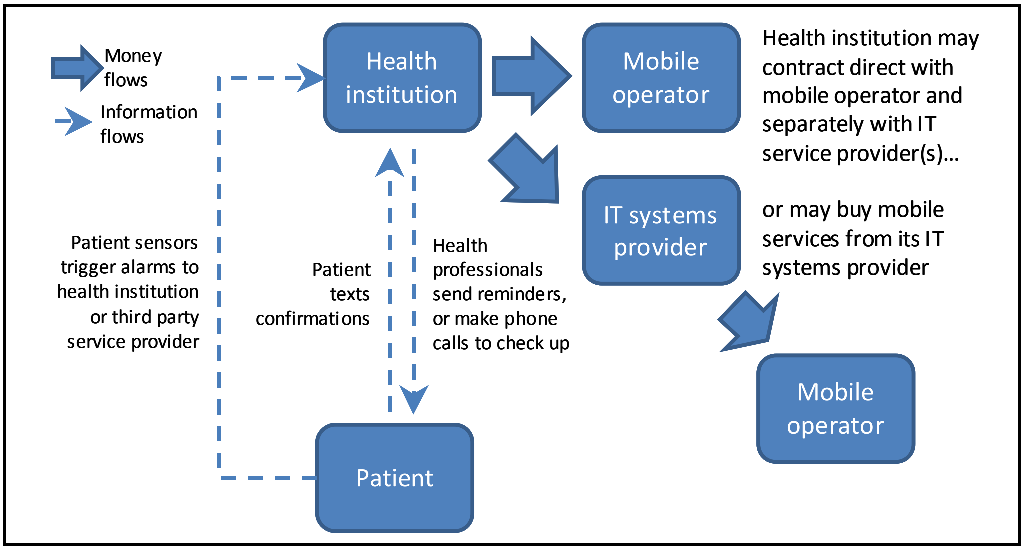


Under another scenario, it is possible to envisage a model in which the health institutions pay for such services in order to facilitate the provision of healthcare within the home. Studies have shown that under some circumstances it is less expensive to support someone in the home than it is to treat them in hospital. This might be done through a managed service model whereby the health institution pays a third party for complete delivery of remote monitoring service: the value chain for this would be as in Figure 14 above, with "health institution" substituted for "relative". Figure 15 in contrast shows an alternative model, where the hospital runs the services, and buys IT and comms components from suppliers.

Revenue and Cost Drivers: Sources of revenue for these various types of remote monitoring include:

- **Personal contribution** (i.e. subscription fees to third-party service providers for managed services; connection and traffic fees to mobile network operators; and possibly fees to purchase mobile devices). In these cases the driver of revenue is the number of patients using some kind of monitoring service. Private individuals are motivated to pay for this sort of service, for themselves or for relatives, because it provides them with peace of mind.

Figure 15:
In-house delivered model



- **Spending by health institutions** (investment in technology to facilitate monitoring, and potentially to pay for the cost of supporting services and personnel). Such spending might be motivated by the desire to reduce hospital admissions, increase patient satisfaction, or reduce the cost of providing healthcare services. In the case of privately operated health institutions, additional drivers might be the desire to differentiate services and attract more customers, or even to generate more revenue (for instance by charging for access to some services).

Cost drivers relate to the extent of monitoring required, location, and the desired degree of integration with existing IT systems. There is a range of mobile device and software technology options, including:

- use of simple low-cost handsets and SMS messaging – accessible to much of the global population
- use of high-end handsets with GPRS/3G (and eventually LTE) access, and video – accessible to far fewer people and more expensive, but offering greater utility
- use of mobile handsets plus peripherals – peripherals have to be supplied to end users, which reduces the potential user base further
- use of customised devices – increases cost substantially, but may potentially increase utility and integration with wider healthcare systems
- use of web-based open source apps – probably low-cost, less likely to integrate with existing systems
- use of bespoke technology platforms – higher cost, more likely to integrate with existing systems.

Unless the services to be delivered are simple web apps, the choice of device will be critical, as it will determine whether the service can take advantage of open platforms, and the widest possible community of developers; and whether it is accessible to billions, millions or just thousands of potential users.

Return on Investment: We have considered the potential costs and benefits accruing to healthcare providers from the deployment of remote monitoring in the home using phone-based sensor technology, where the costs of providing such a service are balanced against the costs saved by fewer people needing hospital treatment or residential care. A monthly fee is paid to a third-party provider for devices which monitor the wearer's health and location, and which use mobile technology to raise an alert if there is a problem. For the service provider, the major issues in successful commercial deployment have to with the costs of the device; a simple handset is of limited use, as it does not have the features (such as accelerometers) or the processing power required. The alternatives are:

- **Smartphones** are able to run the appropriate apps, but they are expensive, and are not ruggedised (and so cannot be used in the shower, and may not survive the fall they are designed to raise an alert about). Moreover, the elderly and infirm may not find such devices easy to use.

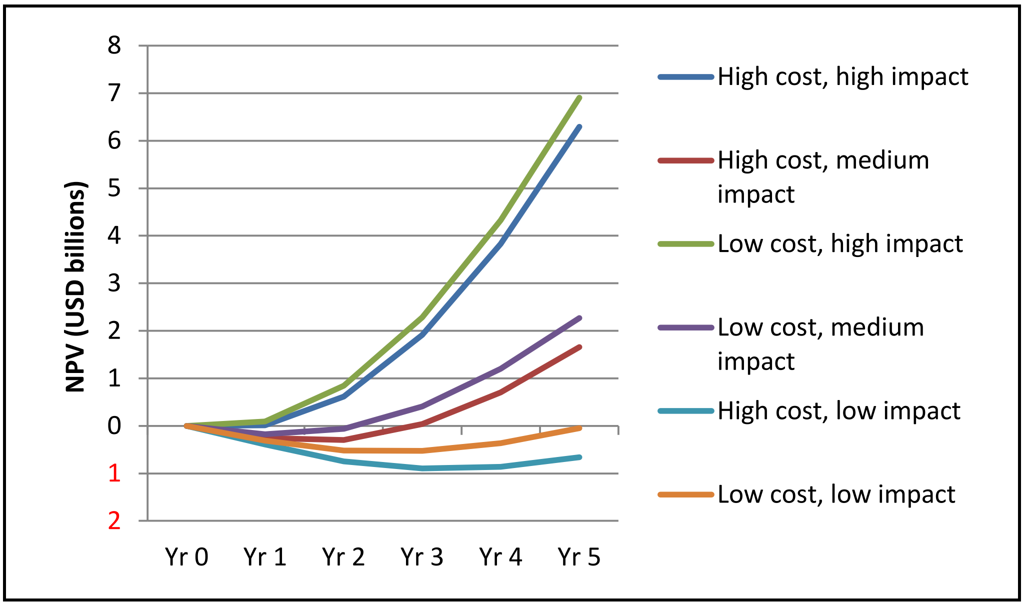
- Development of a **bespoke device** is very expensive. Real-world examples show that it costs tens of millions of dollars to develop and commercialise bespoke devices. At the rates customers are willing to pay on a monthly basis, very large numbers of customers are required. Companies such as ActiveCare are pursuing this model, but they are early in their development and have yet to reach profitability.

- The model might may be made to work with very cheap **passive sensors**, linking low-specification mobile handsets via Bluetooth or WiFi and using the mobile device simply to enable wide area connectivity (i.e. sending alerts). However, trials of this technology are at a very early stage.

At present, it would appear that the only way to commercialise such a service would be to develop and ship bespoke technology at low cost and high scale. This is most likely to be successful with the active involvement of a very large healthcare technology vendor, or where a publicly directed health service makes the decision to develop the technology at scale because of the benefits (primarily cost savings) arising from keeping people at home and avoiding hospitalisation. Two distinct benefit models are generally discussed in the industry: savings made from monitoring people at home and catching episodes of poor health before a person needs hospitalisation for acute treatment; and savings made from enabling people to live in their own home rather than in a nursing or care home.

We have considered the potential for mHealth technology in each of these two cases. Figure 16 illustrates the potential net present value of the cost impact over five years of deploying sensor technology in the home to **avoid hospitalisation episodes**. The assumptions modelled relate to the incidence and cost of hospitalisations after emergency admissions in the USA, based on 5% of the elderly population using a monitoring service by the end of the forecast period. Upfront costs include cost-benefit analysis, costs for making the appropriate technology choice, plus fees for a consultation with each new person considering (or being considered for) having the technology in their home. As this is a service model, subsequent changes are driven by the evolution of healthcare and remote monitoring service costs.

Figure 16: Net present value (NPV) of cost savings (for the healthcare provider/funder) from deployment of remote monitoring to prevent hospitalisation

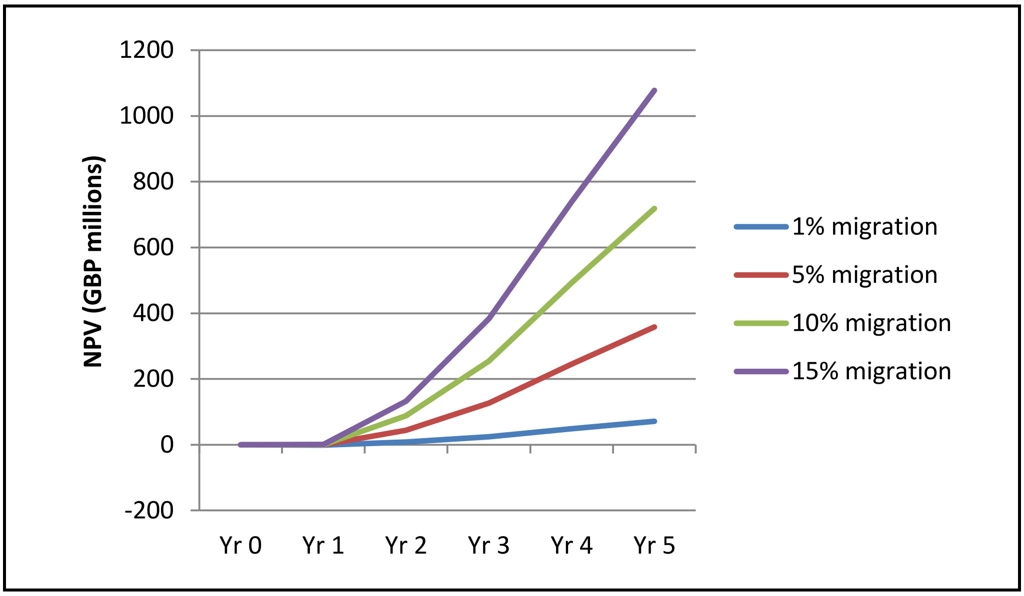


The graph shows the NPV of the cost savings achieved by preventing hospitalisations with this technology. Annual service costs, paid by the health service in the form of monthly fees to a third party, are assumed to be between USD700 ("low-cost scenario") and USD1200 ("high-cost scenario"), falling by 1% each year as technology costs fall. The "high-impact" case assumes that high-risk individuals can be identified, and that 20% of their hospitalisations are avoided because of the system; in the "medium impact" and "low impact" cases these figures are 10% and 5% respectively.

These figures illustrate the magnitude of hospitalisations prevented which would have to be achieved in order for the system to provide a net benefit – approaching 5% for the low-cost system, rising to nearly 10% for the high-cost system. Although much would depend on conditions and healthcare costs in a particular country, and it would be important to keep administrative costs (excluded from the model) low, it would appear that such systems could be cost-effective, and merit serious consideration.

It would also appear that there are potential cost savings to be gained by using **remote monitoring to keep people out of care homes**. Figure 17 illustrates the potential savings to be made in the UK from enabling selected people to say in their own homes instead of moving into residential care. It considers the benefits from keeping in their homes only those individuals for whom (because their care needs are less onerous) the cost of home care is low, but where (because of geographic, availability, and economic factors) the cost of local residential care support is high. It shows the output for five cases – reflecting assumptions about different proportions of the existing residential care population that might meet these criteria. That proportion is not reached immediately; a migration period of three years is assumed. These figures are based on the unit cost of health provision[89] and the numbers of people in residential care in the UK.[90] The benefit accruing to the healthcare provider is driven by the fact that the cost of the technology is relatively insignificant compared to the cost savings potentially achieved by keeping people in home care situations rather than residential care.

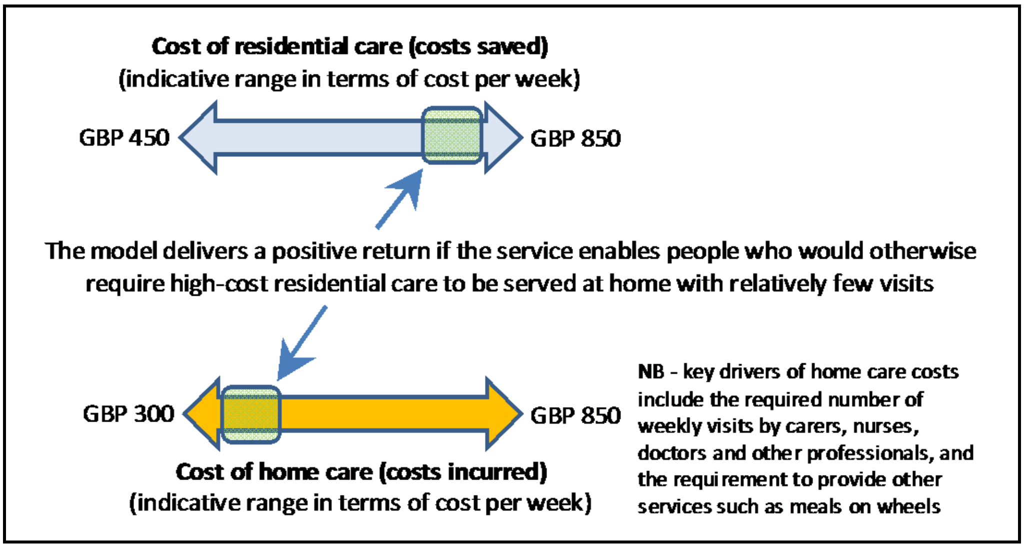
Figure 17: Net present value of the benefit (to the healthcare provider/funder) from deployment of remote monitoring to avoid the need for residential care



In this case the service costs are assumed to be higher than in the model for hospitalisation avoidance, as significant consultation would be needed to ensure a person could live at home; we have assumed a first-year consultation and personal system design cost of GBP6000 for each new user, plus ongoing service costs of GBP750 per year (consultation costs are assumed to rise, and the ongoing service costs to fall, over time). We have also assumed some project start-up costs (GBP1 million for cost-benefit analysis and system choice). But these costs are significantly outweighed by the savings that arise from the cost of home care being lower than the cost of residential care for the elderly. We assume that doctors are able to identify a proportion of the residents of care homes who, with the support of monitoring devices, can be cared for at home at a cost of GBP300 to GBP500 per week rather than in residential care at a cost of GBP550 to

GBP750 a week (as illustrated in Figure 18). Even if the proportion falling into this category is only 1%, the costs of the monitoring service are more than offset.

Figure 18: Situation where use of home monitoring might deliver a return on investment for healthcare providers/funders



Market Potential: The potential market for home-based monitoring solutions is very large indeed, as there are billions of ageing people worldwide, and the costs of hospitalisation and providing residential healthcare are enormous. However, as we have seen, the business case for such applications requires scale, and looks most viable where ultimately funded by institutions seeking to cut costs (i.e. where the sensor-based system can be shown to prevent the need for a stay in a hospital or residential home). Large publicly funded healthcare authorities are the most likely beneficiaries, and therefore most likely to consider such investments, though it is also possible to imagine privately operated healthcare companies, insurance companies and service providers coming together to achieve the scale needed to develop the potential of this market.

4.5 The Mobile Network as a Platform for Multiple Services

The business cases outlined in this chapter demonstrate there are mHealth applications which have the potential not only to deliver healthcare benefits, but to generate profits for suppliers, and to save money for players in the health value chain. The applications highlighted here are all examples in which mobile devices and networks significantly improve the accessibility and scalability of the services concerned; where the same services could also be delivered using fixed telecoms networks, usage would be lower, and fewer people would be able to access them.

The business cases we have outlined are relatively straightforward. In many cases there is also the potential to make them more attractive through “piggy-backing” – that is, the business cases may be altered for the better by combining the provision of mHealth solutions with the provision of other services. Examples of complementary activities include:

- provision of remote concierge packages (offering day-to-day non-health support from call centres set up to field health-related queries and alerts), making the service more attractive;
- using mobile devices for data-gathering for more than just health – e.g. for national statistics offices, or even tax offices – allowing costs to be shared; or
- using smartphones to pay salaries (so-called “mCash”) and reduce processing costs.

It is important to realise that the real value for mobile network operators, and the health industry at large will not be found in any individual application or service. The real value is in developing a platform to support a variety of mHealth services and applications, a platform which makes it much simpler to build, launch and deliver mHealth services and solutions. What is more, opening up this value does not require enormous investment – operators have the opportunity to leverage their existing investments to target low-hanging fruit. We consider these issues further in Chapter 6 below.

Chapter 5

Realising the Health Benefits to Society

In addition to commercial opportunities, mHealth offers significant benefits to society, addressing some of the major health challenges in all economies, from the most developed to the least (though perhaps most of all in economies where income, urbanisation, infrastructure and the systems for delivering healthcare are changing very fast). For example:

- In **low-income economies**, mHealth can improve access to services in areas that are hard to reach through conventional means of health delivery; disseminate information on medical advances and public health to professionals and the public; facilitate data gathering from remote areas during disease outbreaks, enabling better research and response planning; help secure the supply chain for drugs; and increase the effectiveness of treatments by supporting adherence to medication regimes.

- In **developed and developing economies**, mHealth can also address the challenges of ageing populations by replacing expensive resources with automated processes; provide support for carers outside the health system; improve the take-up of testing for socially stigmatised diseases; and support monitoring and self-help responses relevant to long-term conditions.

Such benefits have already been demonstrated in deployments and trials of applications as diverse as diabetes self-management, wearable monitors to promote weight loss, mobilising maternal health workers in rural areas, and appointment booking systems. The greatest potential benefits, however, could come from services contributing to public health. Such applications can be thought of as a public good in the same sense as sewerage services or the provision of clean water, delivering utility to individuals but with the greatest benefit being derived from their being universal.

Any application must demonstrate benefits to those that will use it and those that will pay for it. In many cases such benefits are self-evident, or can be left to the market to demonstrate; but in healthcare there are also complex financial and ethical considerations. Many countries fund healthcare from taxation, and so must ensure that the services they fund are safe and cost-effective. Policy-makers should provide guidance for assessing the healthcare and public benefits from emerging applications in a manner that can be understood by application providers, and create an expectation that such assessment should be an integral part of provision. Such evaluation should distinguish appropriately between applications to which the market-based principle might apply and those which have the potential to bypass or substitute health systems or regulators.

5 Realising the Health Benefits to Society

As we have seen in Chapters 1 to 3, mHealth applications range across a wide spectrum of healthcare. In this chapter we look at how the societal benefits of the applications and services should and can be assessed for effectiveness and efficiency, and also consider the potential of mHealth to address some of the big health challenges in all economies, from the most developed to the least.

It is not straightforward in this context to define "developed", "developing" and "low-income" economies, partly because the relevance of mHealth applications is not solely governed by any classification of this type; the degree of rurality or urbanisation, in particular, is also significant, and this does not map on to the economic development spectrum in a straightforward way. Moreover, there is a spectrum for each of the measures that could be chosen in defining the level of development. Nevertheless, it is instructive to consider that some economies are characterised by relatively high levels of disposable income per head; well-developed infrastructure for power, water and waste disposal, and fixed and mobile telecommunications; functioning and well-funded central, regional and local administration; and healthcare systems that deliver high levels of care to most of the population. These are what we refer to as "developed" countries in this report.

At the other end of the spectrum, there are countries where few of these situations apply – primarily driven by a relatively very low GDP per head over many years. These are what we refer to as "low-income" countries. Finally, there are also countries where the attributes listed above are changing very fast – these are the "developing" economies, including the well-known examples of Brazil, Russia, India and China, which from an mHealth perspective have much more in common with the developed countries than with the low-income economies, though all contain within them remote and rural areas which share the challenges faced by the low-income countries.

5.1 Macro Issues, Health Challenges and mHealth

Many macro-level factors and trends have an impact on health, although the nature of each factor, and its impact, varies from country to country. For *low-income economies,* in particular, the eight interrelated Millennium Development Goals (MDGs) – which all 191 UN Member States have agreed to try and achieve by 2015 – are relevant in the context of mHealth. Goals 3 to 6, in particular, could be addressed in part through deployment of mHealth services and applications, as summarised in the table below:

Goals	Potential applications of mHealth
To promote gender equality and empower women, to reduce child mortality, and to improve maternal health	mHealth can enable the provision of maternity, neonatal and women's health services in areas that are difficult to reach through conventional health delivery infrastructures (and many mHealth apps are designed specifically to achieve this).[91] Both data collection and support for local health workers can be enabled through mHealth apps.
To combat HIV/AIDS, malaria, and other diseases	Mobile communications can facilitate improved data gathering from remote areas (including during outbreaks), enabling better epidemiological research in the long term, and better short-term response planning and more effective local treatment and care (to prevent unnecessary migration of the population and spread of disease). mHealth apps can also help secure the supply chain for drugs, and increase the effectiveness of treatments by supporting adherence to medication regimes.

Some of these challenges may be less pressing in *developed and developing economies*, but there are nonetheless many macro-level factors and trends with an impact on health that might be addressed by mHealth in various ways:

Factors	Health-related impacts	Relevant mHealth applications
Increasing (and ageing) population	Increasing costs of providing care for individuals, in particular those suffering with the diseases of old age	• Applications that reduce cost (e.g. substituting expensive resources such as hospitals, medical professionals and manual processes with locally based, automated or remotely delivered processes) • Applications that support carers outside the health system
Rising income, dietary and lifestyle changes	Potential increase in long-term conditions associated with "Western" lifestyles, e.g. heart disease, diabetes, certain cancers, and smoking-related respiratory illness	• Information provision and self-help • Intelligent public health systems • Remote monitoring for treatment of long-term conditions
Advancement of medical technology and rising personal expectations	Supply-side push for the use of new equipment and services; growing demand for advanced (and more expensive) treatments; more "industrialisation" of health	• Information provision for health professionals and public • Applications that match resources to need more effectively
Antibiotic resistance of some bacteria	Reduction in effectiveness, and increase in costs, of established treatment	• Information provision for health professionals • Information gathering for monitoring of treatment effectiveness
Corruption, fraud, war	Risks to drug supply chain effectiveness (including counterfeit and possibly dangerous drugs) and cost; disruption of fundamental health delivery (administration, information, finance)	• Tracking applications • Point-of-sale security • Information systems • Applications that support distributed and local healthcare
Population mobility and globalisation	Increased risks of epidemics and global pandemics; migration to cities putting pressure on centralised health systems	• Applications supporting *local* healthcare • Increasing efficiency of healthcare systems, in hospitals, in the wide area and across the country • Data collection for epidemiological research

In both low-income and developing economies, one of the most significant of the benefits that mobile networks can bring is the ability to support delivery of healthcare in *rural and remote areas*, which are traditionally ill-served by conventional infrastructure and systems. There are, however, challenges relating to costs – both of handsets and of network deployment. For low-income economies, the promoters of mHealth apps designed for individuals need to take into account that expensive services and handsets will be unaffordable for most people. Apps that are aimed at healthcare workers, where low numbers of (expensive) devices can be justified, still need to take into account the fact that mobile operators' economic case for infrastructure deployment is based around serving large numbers of affluent consumers within small geographic areas: incentives, external funding or central direction will be needed in order that infrastructure is deployed. In wealthy countries, rural areas might still deliver revenue that makes deployment of high-speed networks a sound investment for operators; but in low-income countries mHealth applications for rural areas are likely to have to be designed to work on networks that are cheaper to deploy. Those apps that work well with voice, SMS or basic, low-bandwidth data are likely to be most appropriate and effective.

However, although an mHealth application (or set of applications) is highly unlikely of itself to justify the cost of deployment of new network infrastructure, the marginal cost of advanced handsets that make the most of that network is relatively small. The benefits of mHealth applications may be able to justify the subsidy (with appropriate controls to prevent resale or other abuse) of more advanced handsets in countries where the general population, or strategically located healthcare workers, might not be able to afford them otherwise.

5.2 Measuring the Benefits of mHealth

Any mobile health application, like any new idea, must demonstrate to those that will use it, and those that will pay for it, that there are benefits to adopting it. In many applications of technology such benefits can be considered almost self-evident, or it is acceptable to let a free market decide whether the benefits justify adoption. In the case of healthcare, however, there are more complex financial and ethical dimensions to be considered.

Many countries fund most or part of healthcare delivery from general taxation revenues, and therefore must be confident that all elements of such funded healthcare are delivering value – i.e. that they are cost-effective. In addition, governments must not fund care that is known to be unsafe. Even in systems where much healthcare delivery is delivered by a private market, there is always significant regulation related to the safety of treatments, processes and drugs.

As with any new technology or process, there are potential disbenefits of mHealth applications. Some applications may be dangerous. Some may be unreliable. Some may be useless, offering no benefits compared to established processes. Some may be clinically effective yet expensive to deploy, raising questions of relative value for money. Traditionally, these are the issues that rigorous clinical trials and scientific studies of healthcare interventions attempt to determine. Such analysis, however, is time-consuming and expensive – for example, the "Whole System Demonstrator" trials of telecare (including mobile delivery) for assisted living in the UK have cost around GBP31 million.[92] As well as being costly, traditional scientific trials also take a long time (which can act as a brake on innovation and deployment), and are themselves subject to scrutiny for their ethical dimension.

It could be argued that not all mHealth apps actually require such an approach to determine effectiveness and value; indeed, it is instructive to note that some of the technologies now taken for granted in medicine – such as the electrocardiogram – have never been subject to a detailed academic evaluation to measure their benefit, yet their benefit is not seriously questioned. On the other hand, some technology interventions can have unintended consequences: automated machines for blood pressure measurement are quick and accurate, yet their introduction means that medical staff no longer have the physical contact with patients' skin that enables other signs and symptoms to be observed, and in some hospitals, manual processes have been brought back to replace the mechanised ones.

5.3 Ethical Issues

The ethical dilemmas for those involved in mHealth are similar to other sectors of healthcare – particularly in relation to countries where even basic systems for healthcare provision are not in place, and where there appears to be a *prima facie* case for intervention. Questions include: Is it right to introduce an application with uncertain benefits on the basis that it could be "better than nothing"? Is it ever right to seek to deploy an mHealth service knowing that its effectiveness (or even safety) has not been proved or cannot be proved without significant expense and delay? On the other hand, is it right *not* to deploy the service or application because funding for appropriate studies cannot be found?

Discussion with experts consulted during the preparation of this report suggests that these are questions to which there are no absolute right answers, but for which some general principles can be proposed to guide the assessment of mHealth benefits:

- appropriate and measurable metrics must be found for the service or application
- appropriate evaluation programmes (academic trials, pilots/feasibility studies, etc.) must be designed
- compliance with national regulatory regimes must be ensured
- the risks of the study must be appropriately assessed
- appropriate funding for the evaluation should be sought, including (where this does not jeopardise any necessary independence) from those that will benefit from the application.

As we have argued in Chapter 2, what is appropriate in one country is not always appropriate in another, for reasons of system capacity and culture – the same principles apply to ethical considerations, and to the choice of metrics.

It is reasonable that there would generally be less rigorous control for some apps than for others – for example, personal well-being apps, and those promoting healthy diets, exercise and other lifestyle choices, might attract less demanding requirements for proving effectiveness. With these apps, the market-based principle might apply. Nevertheless, some applications for which there is an immediate business case have the potential to bypass or substitute health systems or regulators. Some apps – particularly those that enable diagnosis or treatment of conditions – could function as a replacement health system, substituting for existing provision in an inferior way. Similarly, in countries where there is an established healthcare system, mHealth could represent *potential bypass* of that system, and lead to aspects of a patient's medical history becoming more distributed. In some low-income economies, on the other hand, it may represent a new healthcare delivery system, possibly where none existed before. For these reasons, regulatory authorities need to make sure that mHealth does not grow up in a completely unregulated way, while ensuring its benefits are realised.

5.4 Design and Implementation Issues

In assessing the benefits of mHealth, it is important to take into account issues of design and implement-ation, particularly when apps are being designed for use in many countries, or in cultural environments very different from those in which the development has taken place. Studies have shown that there are significant differences in the acceptability of technology solutions between communities;[93] these subtle factors need to be understood by mHealth app designers. At a basic level, for instance, it is not appropriate to design apps that depend on reading text messages if literacy levels among the target groups are very low; in such situations, it will be appropriate to deploy voice-based services (including those which use voice-to-text and text-to-voice conversion, or voice recognition and synthesis). It goes without saying that users must also be able to communicate with application interfaces in their own language.

Interfaces can be "localised" to target users by ensuring that apps are designed within the country for which they are intended, but also by customisation and adaptation. One of the challenges facing mHealth developers is to design data and software structures in such a way that they can be customised while preserving sufficient structural consistency for analysis of meta-level information to be possible.

For reasons of cost saving or administrative efficiency, or for the purpose of extending healthcare to remote locations, mHealth applications often mediate the relationship between an individual and a health professional – by replacing face-to-face contact, or by providing automated processes without obvious clinician intervention. With some applications, care must be taken to avoid breaking necessary bonds of trust between the patients and the healthcare system, trust which arises naturally in face-to-face consultations. On the other hand, mediation can sometimes improve the effectiveness of diagnosis or treatment. For instance, the fact that a mobile device is always available means that an immediate, rather than a delayed, interaction is possible. Interacting with a device rather than a person might overcome the reluctance of people to talk face-to-face with a health professional perceived as judgemental. Among the areas where this mediation is valuable are mental health and behaviour applications, or the diagnosis of socially stigmatised conditions such as STIs.

Incentivising individuals (both within the general population and within the healthcare sector) to use an mHealth app is also a design challenge. For the benefits of the app to be fully realised, the factors that motivate adoption need to be thought through carefully: this is an area of active research – not just in mobile apps, but in other forms of health-oriented human-computer interaction, for instance in behaviour change, such as in relation to smoking cessation,[94] adherence to medication regimes, or mental health treatment.[95]

Another challenge to those developing and implementing some advanced mHealth apps is presented by the proliferation of device operating systems. There are, for example, several “branches” of the Google Android operating system in the installed base of mobiles worldwide; six versions have been released in under two years, with two more scheduled for 2011, differing in ways which developers must accommodate if their applications are to run on all devices even in this one operating system family. The problems are mitigated where devices are distributed in a controlled fashion – for instance, to relatively small numbers of health professionals, or community health workers or leaders. They can also be mitigated if the application is simple or makes use of a web browser interface only (with little intelligence or data processing in the device itself), though such compromises may reduce the utility of the application; or in markets where very large populations are served by mobile operators able to impose standards for device operating systems – such as may be the case with the OPhone in China.

5.5 Evidence of the Benefits of mHealth Applications

A number of the applications discussed in Chapters 2 and 3 above offer, as we have seen, actual or potential benefits for particular types of individuals or organisations (those suffering from chronic or acute disease, carers, healthcare workers, administrators, suppliers, or policy-makers):

- Mobile-enhanced appointment booking systems offer convenience for users and enhance whole-system efficiency in a cost-effective way by reducing non-attendance at appointments.
- Remote diagnosis applications can extend the reach of healthcare provision to remote and rural areas which are underserved by other means, and enable patients to receive medical help without the need to travel (potentially reducing the spread of disease).
- In future, mobile telecare applications may bring similar benefits in the management of long-term conditions, and leveraging the computing power of the mobile phone and its ability to integrate sensors may enable sophisticated diagnostic techniques to be used in locations far from specialist facilities.

- Applications for drug authentication and tracking can increase efficiency and address difficulties with counterfeiting, and in future may also provide useful public health data on clinical efficacy.

- The new generation of well-being applications can reinforce important health messages in a highly personalised way, and users may be willing to pay for them; in the future, intelligent, personalised public health messaging may improve the effectiveness of healthcare-system-driven campaigns.

- Aggregated private data collected from mHealth applications may be used for the public good to improve understanding of disease spread, and to design better responses to it, and to help in the development of novel health interventions.

It is not straightforward, however, to assess the effectiveness of mHealth applications from a rigorous academic standpoint, and therefore it is perhaps not surprising that relatively few clinical trials have been published. Moreover, while technology vendors do commission some academic studies, much of their assessment of mHealth apps is driven by commercial considerations and is either commercially confidential, or less robust and rigorous than that typically demanded by healthcare regulators.

Even in clinical trials and academic studies, the measures that are used may not be those that can prove either the clinical effectiveness or the commercial viability mHealth applications. Rather they might be chosen to determine whether the concept is technically feasible, or to establish a link to intermediate measures that have themselves been linked with outcomes: applications that might have an impact on clinical outcomes several years after the intervention can be more easily evaluated this way. Examples might include apps designed to promote behavioural change that could lead to a lower incidence of chronic disease in the future – all that may need to be proved is the effectiveness of the behaviour change.[96]

Among the trials and pilots that have been rigorously evaluated, either from an academic or a commercial perspective, the following examples demonstrate mHealth benefits in a robust way:

- Diabetes self-management using a mobile phone to transmit blood glucose measurements:[97] a randomised controlled trial demonstrating that glycaemic control improved through the use of mobile phone technology. Nurse support was found to be essential for patients to gain most benefit from the system and maintain compliance, but demands on nurse time were not found to be excessive.

- Mobilising and motivating maternal health workers in rural India:[98] a study measuring the effect of short videos delivered on mobile phones showed that they helped persuade village women to engage in dialogue with health workers, and motivated those health workers and key community influencers.

- Smartphones for communication between clinicians at Toronto General Hospital:[99] as a result of a trial using smartphones (in this case, the RIM BlackBerry), senior clinicians perceived an improvement in communications, and nurses perceived a reduction in the time taken to contact senior clinicians, though their perception of physician response time did not improve significantly.

- Wearable monitors to promote weight loss:[100] BodyMedia Armband technology was shown to be effective in combination with a lifestyle intervention programme in achieving better weight loss results in obese patients.

- The potential to use more advanced mobile technologies as the basis for existing mHealth applications in Ghana:[101] mobile technologies already used for consultation, administration, and emergency support present an opportunity to streamline data capture and reporting practices. While low-end networks and devices should be promoted, it was found that extension should be possible to 3G networks and smartphones.

- A literature search and discussion paper on the effectiveness of SMS in various health applications in the UK[102] concluded that substantial savings could be made through reducing the number of missed appointments.

Other researchers are also keen to collect together evidence: for example, researchers at the London School of Hygiene and Tropical Medicine[103] list “mobile phone text messaging to support management of diabetes, hypertension, asthma, eating disorders and HIV treatment … mobile phone text messaging and PDAs as aids to smoking cessation, body weight loss, reducing alcohol consumption, sexually transmitted infection prevention and testing; PDAs for data collection in healthcare and health research and to support medical education and clinical practice”, and note that “whilst the majority of mHealth interventions are reported from high-income countries, there is an emerging literature on the application of mobile technologies in low-income countries.”

There is, therefore, an emerging base of evidence on benefits, and there are also apps for which benefits are readily apparent, albeit possibly for only some of the agents in the system. For instance, a particular application might be profitable for the supplier and for the networks, and do no harm and possibly some good for the consumer; such applications are likely to be deployed quickly and without controversy. On the other hand, there are applications for which the benefits are harder to demonstrate, but where the benefits may nonetheless be profound, such as those applications relating to the provision of centralised information systems, or the very large-scale collection and analysis of data for public health purposes. It is widely understood that there are very large benefits – both in terms of the health of the population and in terms of healthcare provision costs – if people can be prevented from getting ill. What is less easy to demonstrate is that such benefits can be realised by aggregating and analysing knowledge about their lifestyle, interactions and health, or that this can be done cost-effectively and in a way that is acceptable in terms of data confidentiality.

At a high level, the greatest potential benefits of mHealth would be realised if mHealth services and applications could contribute to public health. Such applications can be thought of as a public good in the same sense as sewerage systems or the provision of clean water, which deliver utility to individuals but from which the greatest benefit is derived from their being universal, thereby reducing the threat of disease in a population. However, the question then arises – who should pay the costs of deploying and providing such services and applications, if the individual consumer or the particular technology provider derives no immediate or specific benefit?

While consumers cannot be expected to pay individually for the investment needed to assess and implement public-health-focused mHealth applications, such applications may be only a short step away, and that step might be taken by governments or other agencies. In fact, they may be implemented by leveraging some of the applications and associated investments that consumers and health system providers *are* prepared to pay for. The epidemiology-focused contact mapping application described in Section 3.4 is a good example of this: the team developing this app at the University of Cambridge is currently examining ways in which it can be combined with other, intrinsically profitable applications (such as those using location-based advertising) to make the case for its deployment more compelling. These public good arguments are among the most challenging for any would-be developer of mHealth applications that must integrate tightly with the public health system.

Finally, it worth noting that the need to evaluate the effectiveness of treatments or other interventions is becoming more important across all healthcare systems as the proportion of GDP spent on healthcare rises.

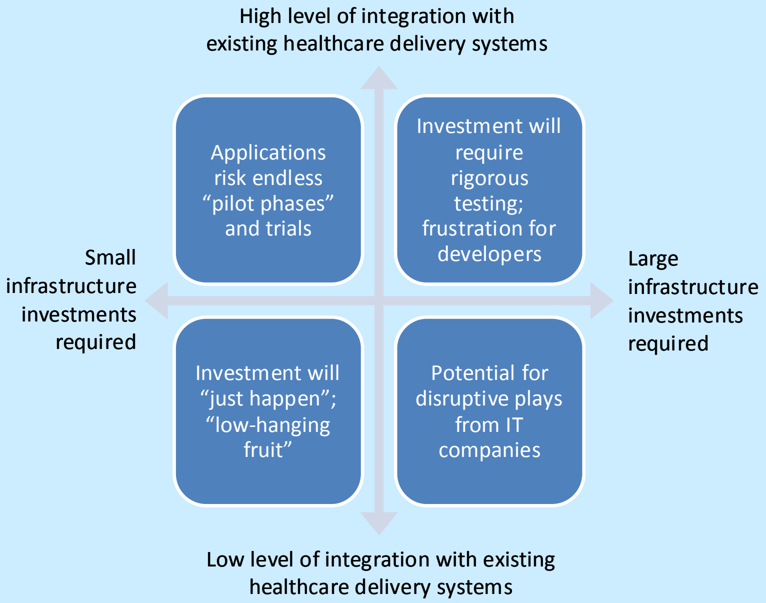
mHealth applications have an advantage here: they already use intelligent devices directly associated with the patient. As we have already seen at several points above, the mobile device can be used to provide reminders about treatment, but just as importantly it can be used to provide a channel for evaluating effectiveness of treatment, with or without the conscious active participation of the end user. While evaluation of the effectiveness of treatment might itself be seen as a distinct mHealth application, when integrated within a health delivery application, it becomes a critical part of the business modelling process for mHealth deployment and evolution.

Chapter 6

Deployment of mHealth Applications

The intersection of the largest economic sector (healthcare) with the largest information infrastructure transformations in history (the internet and public mobile networks) provides the foundations for a vibrant mHealth sector and an economically sustainable industry. Ingenious new applications are being announced every day, and the rate of innovation is increasing or even accelerating.

mHealth applications can be usefully segmented by the level of interaction required with existing health delivery systems, and the extent of additional infrastructure investment required to deliver the application:



In the next phase of development, generic service platforms will play a crucial role, providing processing power, storage, security, access control and other services to a wide range of mobile applications, including (but not limited to) mHealth.

The actors best placed to drive a move toward publicly available platforms include large network operators. Investments in generic services have the potential to contribute to multiple applications, and not all of those applications have to succeed for the investment to be justified. This consideration is particularly true for the operator, where scale and brand allow a very effective spreading of financial risk; reputational risk is also decreased, because the operator need not enter the health sector application business at all, merely enable it.

Realising all the potential benefits of mHealth, however, will require concerted action by many players – not only telecoms operators, but also policy-makers (governments, health NGOs, and regulators), system integrators, manufacturers and technology providers, and healthcare providers (including insurers).

6 Deployment of mHealth Applications

In previous chapters of this report we have reviewed evidence of the opportunities and needs that mHealth can address, and the great diversity of applications emerging in response to those opportunities and needs; we have also discussed the barriers to deployment, and touched upon the enablers:

- **Opportunity and Need** – expanding the reach of healthcare, and meeting development goals in unserved areas; globalisation and population mobility; an ageing and increasing population; rising income (leading to lifestyle changes), and increased expectations (partly due to rising income, but also the perception of medical advance); the threat of counterfeiting; the threat of pandemics; demands for the personalisation of medical care; and the slow but steady trend from a focus on treatment to a focus on behaviour change, disease prevention, "well-ness" and keeping people out of hospitals.

- **Diversity** – as Chapters 1 to 3 show, mHealth applications range across the administration of patient relationship with hospital, remote diagnostics and monitoring, self-diagnostics, management of long-term conditions, information systems for (para)medics, targeted public health messaging, data gathering for public health, supply chain management, and much else besides.

- **Enablers** – a near-ubiquitous, locatable, connected user interface device, often personalised, delivering computing power at an affordable cost, integrating a wide range of sensors and supporting mobility (which is essential in some applications but not all).

- **Barriers** – in developed economies, lack of integration (or conflict) with established health systems, and risk of unregulated treatment regimes; in low-income economies, lack of infrastructure and clear value-for-money propositions (to the health system or patient); and in all situations, the challenge of funding developments for the public good.

In this final chapter we review some of the implications for those whose decisions will determine how mHealth is deployed in the coming years – not only the mobile network operators, service providers and vendors whose investments will be essential, but also the governments, NGOs and other policy-makers whose interventions or regulatory actions will play a major role in shaping development.

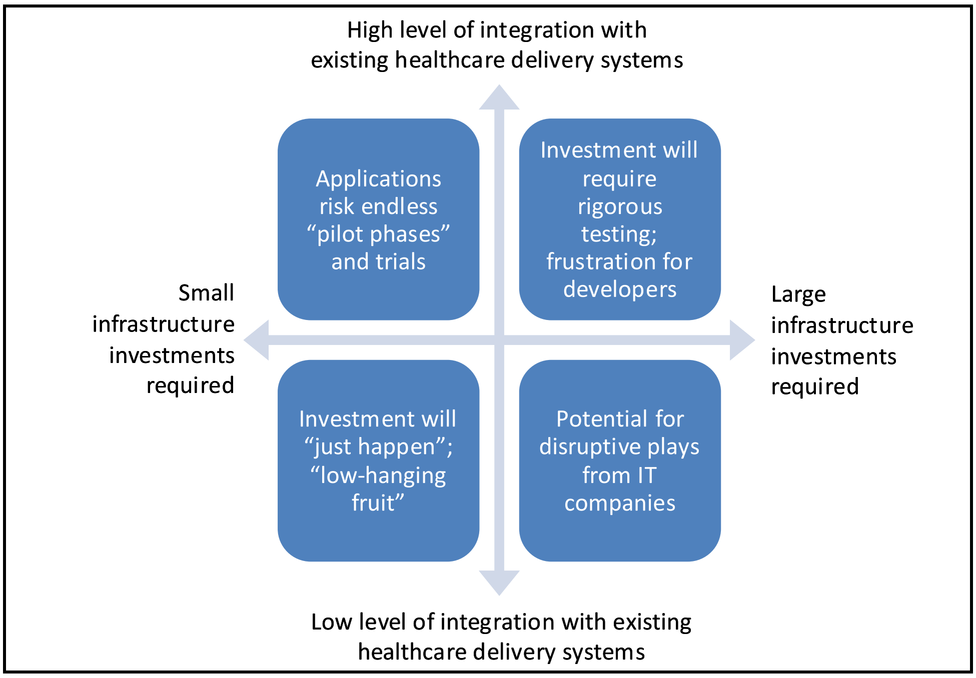
6.1 Segmenting mHealth Applications: Diversity and Circumstance

The intersection of the largest economic sector (healthcare) with the largest information infrastructure transformations in history (the Internet and public mobile networks) provides the foundations for a vibrant mHealth sector and an economically sustainable industry. In compiling this report, we constantly came across new applications of surprising ingenuity and diversity, and the continuous flow of announcements in the media suggests that the rate of innovation is continuing or even accelerating. There is no reason to suppose that the diversity of characteristics in mHealth applications is any less than of mobile applications in general. Any consideration of mHealth applications must take this diversity into account.

Those hoping to exploit mHealth for societal benefit and commercial gain must identify where the best opportunities are, and this means segmenting mHealth applications. As shown in Figure 19, there are two main dimensions in such a segmentation:

- the level of interaction required with existing health delivery systems
- the extent of additional infrastructure (and investment) required to deliver the application.

Figure 19: Segmentation of mHealth opportunities



These dimensions will interact with the circumstances of a particular market (i.e. the nature of the health-care infrastructure, the nature of network infrastructure and the penetration of handsets), which will vary between economies (developed, developing and low-income) and regions (urban and rural). Applications that are compelling in the USA will be different from those in sub-Saharan Africa, and likewise between urban and rural environments.

For many mHealth applications, deployment requires no intervention by policy-makers, and (where mHealth applications do not interact directly with medical practitioners) no intervention by the medical establishment. This is the lower left-hand quadrant of Figure 19. Where investments required are modest, application development and normal innovation processes will drive deployment; the enabler is simply the mobile infrastructure.

The enabling power of the mobile network and handset is perhaps most powerfully seen in the case of novel sensors. Consider an entrepreneur developing a novel sensor and corresponding software which together provide a diagnostic tool. If the sensor can be attached to the mobile handset through a standard interface, there are no further substantial infrastructure issues, even if processing cannot be performed directly on the handset. The global market is not partitioned by physical requirements – after all, the interfaces on mobile phones are more standard than the power sockets on the wall. These are very positive factors in engendering innovation.

But not all mHealth applications have this property of “plug-in” innovation. Many will need to interact with established healthcare systems, and therefore be subject to the testing and regulation of those systems. While the distinction between administrative systems and established healthcare practice (or medical culture) is important in understanding how such mHealth applications can be introduced, at a macro level they provide the same type of barrier to new technology. This will play out very differently in environments with different maturity of healthcare systems. Where the systems supporting healthcare are rudimentary or only cover a small part of the population, emerging mHealth applications will effectively sweep these aside to become the health system’s information system. Where there are highly developed information systems, integration is likely to be slow, driven by improvements in particular areas that do not disrupt the integrity of the overall system: that is, evolution rather than revolution.

More interesting are those systems that lie in the middle ground, for example with strong urban/rural divides and/or where economies are in transformative growth. The established information systems may be substantial, but there will be a clear perception that the system that will exist in the near future will be substantially larger. Here it is likely that replacement (and indeed competition) will occur, with mHealth applications being a driver for the new systems. Therefore, in considering the segmentation described in Figure 19 above, it is important to note that some applications may appear in both the upper and lower halves depending on the maturity of the healthcare system into which they are launched.

Applications that require relatively little infrastructure investment yet must be integrated with a country's healthcare systems in order to be most effective – the top left quadrant in Figure 19 – run the risk of being deployed on a small scale only, in pilot schemes and trials, but then failing to achieve their full potential. This applies just as much in countries with highly developed healthcare systems (where the complexity of integration is highest) as in those where the healthcare system is less well developed and therefore integration may not be possible on a wide scale. The challenge for mHealth developers and enablers in such situations is to ensure that trials are designed to prove the right things, and that issues of integration and scale are considered at the earliest opportunity.

6.2 Enabling Complex mHealth Applications: the Role of Platforms

Mobile network deployment has provided a connected computer with a powerful user interface to a very substantial proportion of the world's population. It is estimated that 70% of people now have mobile phones (of which 85% can access the Web), and that the number of 3G mobile Internet subscriptions will shortly pass 1 billion.[104] This is in itself enabling a range of mHealth applications, and allowing new incremental developments, particularly in sensors, to be rapidly deployed. The "low hanging fruit" is being harvested. But what can be done to engender innovation in complex mHealth applications? Can an environment be created for them that looks like the "plug-in" innovation mentioned above?

In the next phase of development and deployment, generic service platforms will play a crucial role. These will provide processing power, storage, security, access control and other services that are of use to a wide range of mobile applications, including but not limited to mHealth. Applications which reside completely on the mobile phone, or which simply access public information over the mobile network, have no need for such services; but more complex services, including those that back-haul sensor information for computationally intense processing, do require them.

Until recently, the deployment of an application that required "off-phone" services, such as storage or more powerful computation, required dedicated servers that had to be dimensioned for the application – and paid for by the application provider. The emergence of cloud computing is obviating this need. Cloud computing provides on-demand, pay-as-you-go computation platforms; providers include Amazon Web Services (its EC2 service portfolio), Google (Cloud Storage, AppEngine), Dell (Cloud Computing), traditional hosting companies like RackSpace and new entrant specialists such as GoGrid. Software companies such as Microsoft are also shifting their focus to the cloud delivery model, and network operators are well placed to play an important role, as they have the capability to guarantee the quality of service of cloud-hosted applications. Partnerships between software vendors and providers in the mobile ICT supply chain are emerging (e.g. Microsoft is partnering with HP, Fujitsu, Nokia, Verizon and China Mobile for the development and deployment of cloud-based services; Cisco has formed cloud delivery partnerships with large operators such as Orange; and EMC has partnered with AT&T). The use of these platforms allows the back-office servers of an application to grow and shrink with demand, and requires no upfront investment from application service providers.

Few current mHealth applications, however, use cloud-computing facilities; the generic services mentioned above are usually integrated with the application. While it would be incorrect to say that they are developed independently for each application, they are provided with it, and must be provided for in any business case. If these generic services were provided as publicly available platforms – much as the mobile network and Internet themselves are – there would be two important results:

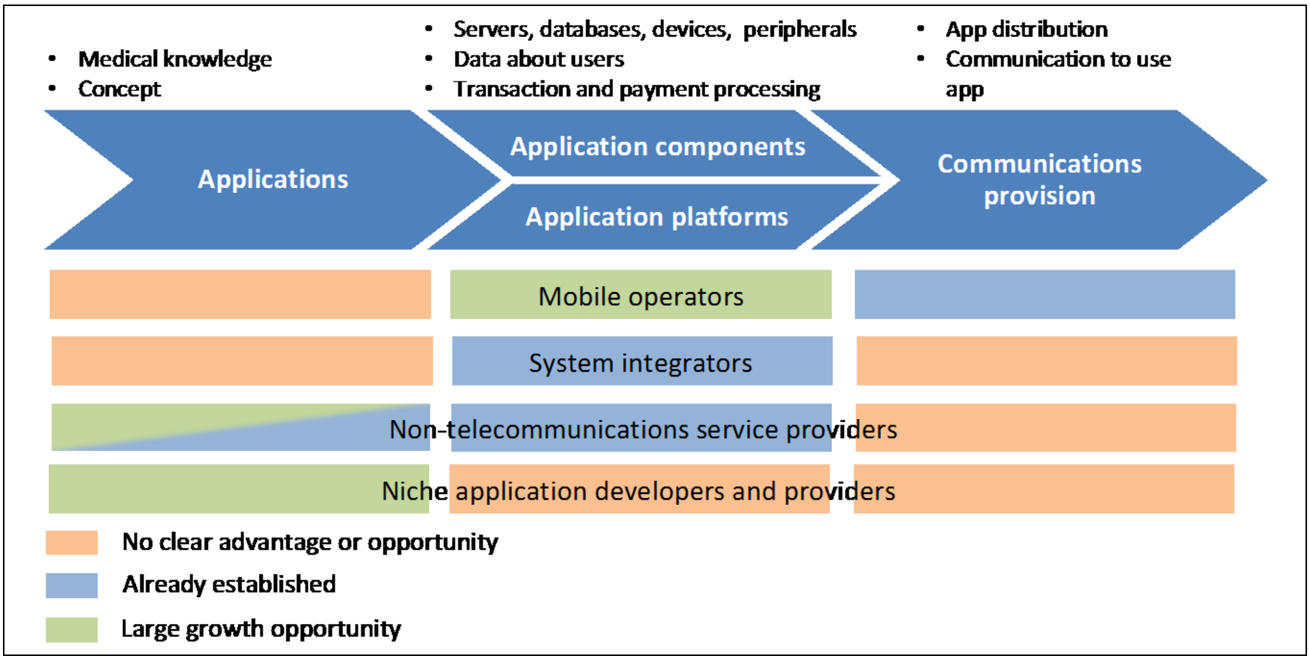
- the upfront investment required to deploy new applications would be decreased
- generic services would tend to be standardised.

The end result would be that opportunities falling in the right-hand quadrants of Figure 19 would become easier and potentially more attractive to deploy.

The actors best placed to drive a move toward publicly available platforms are also those that are best placed to provide public cloud facilities, including large network operators. Moreover, providing these platforms is one way for operators to manage the risk to which they expose themselves by entering the healthcare environment.

This approach requires another kind of segmentation, not of the set of mHealth applications, but of their separate components: rather than deciding *which* applications to provide, this is a matter of deciding *how much* of the application to provide, and how much to enable others to provide. Figure 20 depicts part of the value chain to illustrate this point.

Figure 20: Potential for value capture by main actors in mHealth



What we think of as the application actually relies on other services, either to run (platforms or components) or to be created (tools). Just as for communication systems, standardised platforms – either *de facto* or *de jure* – aid the process of value co-creation by different actors, and allow each actor to structure their particular competencies and capacities as services to the others.[105] Investments in generic services have the potential to contribute to multiple applications, and not all of those applications have to succeed for the investment to be justified. This consideration is particularly true for the operator, where scale and brand allow a very effective spreading of financial risk.

Reputational risk is also decreased by this approach. The operator need not enter the health sector application business at all, merely enable it. This both encourages sector-driven innovation, and allows applications to be developed which have too small a user base to be of interest to a large operator. It also separates any trust issues related to information privacy from the operator-provided infrastructure; trust becomes an issue between users and application service providers, which means that trust can be given (and withdrawn) much more easily.

The arguments against this approach mainly relate to revenue loss. Applications that provide high value, it is argued, tend to generate greater revenues than the generic services supporting them; some of these generic services are commoditised now, and in some respects the whole rationale for producing generic services is that they can be commoditised. For operators this debate is hardly new. History suggests that operators always have ambitions to provide, and to capture value from, so-called “value-added services” (which equate to “applications” in the terminology of the mHealth sector). History also suggests that they are not always successful in realising these ambitions – indeed some would say they are rarely successful.

Will operators see the opportunity to provide new generic services, and to realise the revenue that they will create – balanced with avoiding the risk of application deployment – as a sound business strategy? This may be the single most critical factor in the deployment of complex mHealth applications. It may not be the case that all operators make the same choice. There is also an interesting question as to what generic services should be provided. The user interface, device and connectivity are already present. Computation through cloud computing is being rolled out. Cloud-storage is under development, and is driven by cloud-computing needs. There is some work on management of personal information in the cloud, but very little on trust management in the cloud.

Development of these services may also provide an opportunity to harmonise data and meta-data standards. Application independence may actually be an advantage here, ensuring consistency not only across healthcare applications but across all applications, in healthcare and outside it. This would aid the process of correlating information from a wide range of application sectors. For infrastructure providers, participation in the development of generic cloud-based services may in fact be the only way of contributing to this harmonisation process.

There is also a role for telecoms regulators, who can support the use of communications networks for the benefit of the health of populations if they encourage operators to move up to generic services but not beyond. For example, they might allow operators to charge for generic services (and a few more) on the mobile phone bill. However, regulators should be mindful that the mHealth innovation ecosystem could go one of two ways: towards a system of big players competing hard with complex mHealth applications with limited success (or successfully, but with major issues of trust), or towards a commodity infrastructure with a small number of big infrastructure players and sector-generated innovation within a much more competitive environment. Without an appropriate regulatory environment, there is a risk that there will be market failures that may have health consequences.

6.3 Information Gathering for Public Health

Our investigations suggest that, to date, mHealth applications have not been used significantly in gathering data to inform public health. As we have seen, trials have been conducted and the benefits demonstrated, but no wide-scale deployments have taken place. One reason for this may be that, in comparison to individuals making decisions about paying for private benefit, cost-benefit trade-offs for public benefits are harder to define, and require acceptance by those running entire health systems.

Nevertheless, it is clear that mHealth applications already generate information that is potentially useful for public health – for example, time and place for reported symptoms, or demographics and location of those making hospital bookings of different types. This information is often a by-product of the application, and does not yet appear in volumes that will give rise to statistically significant results. As mHealth applications grow, the potential for more “by-product” information, both in volume and type, will also grow, and can be augmented by integrating more deliberate information gathering into applications. Aggregating such information could provide benefits such as early warnings of epidemics, allowing the earlier identification of infectious strains. At the same time, however, one must guard against drawing too many general conclusions from by-product data, which may only indicate the state of health of those who use mHealth applications. There is also a place for applications whose sole purpose is to gather information to inform public health decisions (as described, for instance, in Chapter 3).

Non-medical mobile applications may also produce information of use to public health authorities. If the storage and access control described above is applied to personal information in general, one could imagine the data mining of purchasing and lifestyle patterns in correlation with health outcomes. The use of mobile systems for environmental monitoring is another example of a non-medical application that can contribute to public health.

The transformation of private information into public good faces a number of impediments: incompatible data formats; privacy concerns, both real and perceived; locating the information; and the need to demonstrate efficacy to justify investment. The generic services discussed in Section 6.2 above would address some of these issues: data formats, access control, and perhaps even generic aggregation support. It is likely, however, that without significant intervention, public health applications will lag behind those applications that benefit individuals directly. Nevertheless, with suitable standardisation, “personal” mHealth applications can prepare the ground, both in terms of infrastructure and information, for public health applications, reducing the scale of intervention or investment required for their deployment.

6.4 Conclusions and Recommendations for Players

The sheer diversity of mHealth applications – and their global applicability – represent enormous opportunities for financial gain and healthcare benefit. However, this diversity and global scale also make for a very complex dynamic of innovation, development, and deployment. Crucially, this dynamic is driven (or impeded) by the degree of interaction with established healthcare systems. The great diversity in the maturity and coverage of healthcare systems around the world means that the opportunities for any given player will be similarly diverse. One implication is that global players in the telecoms industry have a strategic decision to make about where in the world they should make their investments, as well as what parts of the value chain they should target.

In this environment, many applications will be deployed independently of any strategic action by operators or policy-makers. Indeed we anticipate an explosion of applications based on “plug-in” innovation and rapid commoditisation of new sensors that can attach to or communicate with mobile handsets. A key strategic issue for operators and policy-makers is enabling the complex applications that will interact with healthcare systems, or become integral components of healthcare systems. Our research leads us to conclude that an innovation ecosystem can be created which will deliver major benefits: allowing infrastructure providers (including operators) to develop and generate revenue from generic platforms, reducing barriers for sector innovators who are then best placed to manage the healthcare risks associated with applications.

Other potential developments, however, will require concerted action – by policy-makers and other players – if their benefits are to be realised. This applies particularly to the gathering of information for public health from mobile applications (as opposed to targeted dissemination of public health information, which may well emerge from the innovation ecosystem we describe above). While we see the case for pilots and trials of innovative applications in this area, we also see enormous benefit accruing in the future if:

- data representations become standardised for mHealth and other applications; and
- trust, access, and aggregation models for personal information become promulgated and accepted.

As mHealth and other mobile applications concerned with personal information grow in use, an information base of unprecedented breadth and utility will emerge, from which correlations and inferences can be made and profound social benefits derived. However, in many regions it will only be accessible if individuals have some control over their personal information, and if a substantial number of them give informed consent to its use for well-defined purposes in research and public health.

Below we set out our recommendations for the major potential mHealth players (policy-makers; telecoms operators; systems integrators, manufacturers and technology providers; and healthcare providers, including insurers). Finally, we indicate the main areas that we believe are worthy of further investigation.

Policy-makers (including governments, health NGOs, and regulators)

Innovation in mHealth applications is being driven by commercial opportunity, social policy, altruism and intellectual curiosity. Deployment, however, will be driven by investments made within incentive structures that provide some confidence that such investments will pay back. In many parts of the world, these incentive structures are influenced by government. This might be as simple as the balance of public budgets for disease treatment versus disease prevention, but it is certainly related to how a government expresses its policies and priorities for healthcare. Hence our first recommendation for policy-makers:

Recommendation P1. Policy-makers should ensure that their policies and priorities for healthcare are complemented by financial incentives that reward those who deliver outcomes, particularly in disease prevention.

While this might appear a statement of the obvious, our investigations suggest that, in respect of mHealth, very little thought has been given to this – possibly stemming from a traditional top-down regime for the provision of healthcare, as opposed to the creation of incentives to support innovation familiar in other sectors. In the developed world, the absence of suitable incentive structures may mean that mHealth remains confined to those applications where the consumer derives and pays for created value.

Beyond narrow financial assessment of consumers’ willingness to pay, we encountered little evidence of systematic assessment of overall financial and health impacts from mHealth applications. Our second recommendation is based on the assumption that this was due to a lack of guidance (though in this early stage of application deployment it is also possible that ideas are being tried, tuned, and made robust prior to being assessed):

Recommendation P2. Policy-makers, healthcare agencies and professional healthcare bodies should provide guidance for assessing the healthcare and public financial benefits from emerging applications in a manner that can be understood by application providers, and create an expectation that such assessment should be an integral part of provision.

However, some of the greatest benefits of mHealth are unlikely to be delivered by the market, even if the above recommendations are followed. In particular, individual consumers are unlikely to pay for applications designed primarily to produce information from which public goods (such as better advance warning of the spread of epidemics) are derived. Some of the information required is currently collected as a by-product of existing applications, and as further applications are deployed, more types of potentially useful information will be collected; but it is likely that applications specifically targeted at acquiring public health information (though not necessarily marketed as such) may be required. Hence our third recommendation:

Recommendation P3. Public health authorities and agencies should engage in assessing the benefits and costs of acquiring information – whether as "by-products" or directly – from mobile applications, either to replace existing data gathering or to gain new knowledge. This requires clarity of ownership of, and access to, personal information.

While we found few examples of existing applications addressing the acquisition of public health information, it was one of the areas that the expert workshop felt had the greatest potential for health benefit in the future.

Our fourth recommendation is aimed largely at developed nations where existing systems and regulations may put a brake on innovation, and which may therefore miss out on the benefits of mHealth applications seen in emerging and developing economies:

Recommendation P4. Regulatory regimes and the medical establishment's guidance setting need to strike an appropriate balance between the risks and benefits of specific mHealth applications, distinguishing between those apps for which a light touch or a market-based approach is appropriate (i.e. those that pose no risk to health and may be effective, and which typically have little or no interaction with the established health delivery system) and those which have the potential to bypass or substitute other healthcare systems (i.e. those that might pose a risk to health unless properly regulated, or which might need to be robustly evaluated if health system money is to be put into them).

Finally, many mHealth applications are used only occasionally by a given individual, and are based on small value transactions, but nonetheless need to be paid for. Allowing these transactions to be part of the consumer's phone bill would enormously simplify service provision.

Recommendation P5. Telecommunications regulators should review any constraints that existing regulations may place on the deployment of mHealth applications. In particular they should consider allowing mobile operators to operate as micropayment banks, i.e. directly handling small financial transactions.

Policy-makers will also wish to consider how mHealth applications might contribute to policy goals other than those directly related to healthcare. For example, the deployment of mHealth applications might support policies to discourage migration from rural to urban areas, some of which is driven by the healthcare needs of an ageing population. Such broader considerations, however, are outside the scope of this study.

Telecommunications Operators

Telecommunications operators can benefit from mHealth by both revenue and brand enhancement. There are, however, risks related to how much of the value chain the operator wishes to capture.

On the one hand, operators will derive revenue simply from operating basic network services for mHealth applications. As healthcare grows as a proportion of the global economy, so the amount of network traffic related to healthcare will grow. Moreover, for remote areas in low-income economies, mHealth will be an additional driver for network deployment and enhancement. Many mHealth applications will simply run (or indeed are already running) over an SMS service, producing revenue without the mobile operator being aware of the application type.

Beyond this, operators will also have an opportunity to use their networks as platforms for delivering value-adding services that generate revenue. These could be mHealth applications themselves, or the generic platform services discussed in Section 6.2, such as payment processing, application distribution, advertising, and cloud infrastructure for databases and application servers – or even the management of trust and personal information.

Recommendation T1. Operators should have clear strategies – which might be different in different markets – for how much of the value chain (basic services, generic platforms, application provision) they wish to operate, balancing investment, financial return, reputational risk and the presence/absence of other players operating parts of the value chain.

Operators must recognise that if they do not provide open generic platforms, others will. Success in application provision will not be a result of being tied to the network. However, in some markets, and particularly when interacting with well-established healthcare systems, the brand name of the operator may be a competitive advantage. There is a distinction to be drawn between fixed-line operators in developed countries with established relationships to healthcare systems, and mobile operators in emerging economies with rapid innovation. The former are more likely to enter the application provision business than the latter, but even here it is likely to be confined to those applications that need to interact with established healthcare systems.

Recommendation T2. Mobile operators should promote their networks as platforms for innovation and small-scale application deployments, and should invest in the provision of generic service platforms for this purpose. They should facilitate the use of the platform for domain specific innovation (here healthcare, though the recommendation is more generally applicable) by third parties, recognising that, even if they choose to operate some applications directly, some applications will be too small (or present excessive risk) for the operator to provide.

As well as supporting innovation through such platforms, mobile operators will be able to offer the emerging community of mHealth start-ups a "partnership channel" to sell services both to subscribers and to large health organisations. If our Recommendation P5 is adopted, these services could involve micropayment collection.

System Integrators, Manufacturers and Technology Providers

Manufacturers may be tempted to lock devices to applications, rather than making the devices required by a particular application readily usable by others. In a business environment where co-created value will be the norm rather than the exception, this will not be a sound long-term strategy. Sensors with open interfaces will contribute to the value of the mobile handset platform. Our recommendations for system integrators, manufacturers and other technology providers are therefore:

Recommendation M1. Medical device manufacturers should exploit the power of the mobile handset as a computing and communications platform, even when the computation required to deliver a particular application cannot reside completely on the handset. The swiftest take-up will be of applications that rely only on voice, SMS and WAP.

Recommendation M2. There is an opportunity for technology providers to provide the tools for creating or running managed services related to mHealth, which will in turn enable operators to provide generic service platforms. Technology providers need to decide whether their strategy is (a) to build and sell or (b) to build, sell and operate, perhaps in direct competition with operators.

Manufacturers may also consider trying to drive sales of devices through sponsorship, or by preloading apps and delivering services from their managed platforms that are also sponsored. The health-related consumer goods market (particularly baby care) spends heavily on advertising.

Healthcare Providers (including Insurers)

This research has uncovered a number of pilot activities, but we found no evidence of pilots involving different types of actor with the aim of assessing complex service relationships – and the value created by and received by the different actors – on a holistic basis. What is needed is not so much a number of small-scale technology pilots, but rather large-scale demonstrators with effective evaluation. Such pilots would, we believe, demonstrate two kinds of immediate opportunity for healthcare providers and insurers:

Recommendation H1. Healthcare providers should examine mHealth applications as a means of managing exposure to costs – e.g. through the use of in-home monitoring to avoid hospital or residential stays. This might allow reduced charges or premiums, or increased profits.

Recommendation H2. Healthcare providers should consider how they might use data generated by mHealth applications to monitor and optimise the healthcare delivery chain itself, e.g. by improving the management and efficiency of expensive assets, or by better understanding the patterns of use.

Further Investigation

Finally, during the research for this report we have come across many interesting threads that we did not have the time to follow. Some areas will be followed through by operators, policy-makers or other players as they develop their strategies as described above; others require further investigation "at a distance" by a disinterested party. Three in particular have come up repeatedly in discussion:

- assessment of the efficacy of mHealth applications, and in particular the integration of assessment into the applications themselves
- the ways in which the wealth of data being generated might be used for public benefit
- the related issues of the management of personal information and trust.

In our view, these will not be progressed by natural market forces, but are nonetheless worthy of attention.

Special Feature: Summary of Case Studies of mHealth Deployments in China

S1 Introduction and Background

The sponsor of this report, China Mobile, has been involved in a variety of projects to test and deploy mHealth services within China. Because much of its work is little known (but of significant potential interest to actors within the broad mHealth community), we include below a series of short case studies illustrating some examples from the regions of Guangdong, Guizhou, and Tianjin.

These case studies cover a range of services and applications, some of which are being deployed commercially, while others are still at the pilot stage. The instances selected are not intended to be representative of all mHealth investment in China, nor to highlight any particular category of service; however, they do serve to illustrate the range of ways in which mHealth can assist with broadening access to healthcare, and help healthcare institutions to improve both the services they provide and their operational efficiency.

China's healthcare system is already vast. By the end of 2009 there were nearly one million healthcare institutions in the country, including over 20 000 hospitals and over 600 000 village clinics, and more than 7.8 million healthcare professionals (including doctors, nurses, pharmacists, assistants, managers and support service workers).[106] However, the penetration of healthcare professionals per head of population remains relatively low, and many people in non-urban areas (where over 43% of the population lives) do not have easy access to healthcare facilities; healthcare expenditure per head in 2008 was four times larger in urban areas than in rural areas, at CNY1862 per head vs CNY455.

Whilst total healthcare investment has been rising dramatically – from CNY866 billion in 2005 to CNY1454 billion in 2008 – to reach 4.83% of GDP, China has plans for major reform and development of the sector. The government announced its strategy in 2009, with a ten-year plan to deliver by 2020 a healthcare system that is effective and affordable for all citizens in both urban and rural areas. To this end it has initiated a major programme of investment, which over the three years to the end of 2011 will see extra expenditure of CNY850 billion in China's healthcare sector. The reforms being put in place are intended to:

- expand the use of medical insurance, through the basic medical insurance and new rural cooperative medical systems, to at least 90% of the population by the end of 2011 (thus improving general affordability of healthcare)
- improve nationwide access to basic medicine, eliminate the inequality of supply between urban and rural regions, and promote more equal access to healthcare
- improve primary-level medical care (particularly at county, township and village levels)
- improve administration, operation and supervision of public hospitals.

One of the strategies being employed for improving the efficiency of the system is to build a networked IT platform to support healthcare administration, to assist with monitoring and with information standardisation and sharing, and to provide the tools to support effective innovation in the healthcare sector.

In this context, one issue that planners have to address is the relative autonomy of healthcare institutions. These are typically run as independent businesses; although they are regulated by the government (and can receive subsidies from the state), they make their own decisions about IT and telecoms investments. Furthermore, because most hospitals, doctors' surgeries and clinics charge for services, and gain significant funding from those charges, they are largely in competition with one another. Top-tier medical institutions have access to much more finance and funding than smaller local counterparts; as a result, small local healthcare institutions often do not have the money or the skills needed to deploy the state-of-the-art IT infrastructures that are required to support service and operational improvements.

Investment from companies in other sectors, such as telecommunications and IT, is therefore important for driving appropriate strategy, ensuring a coordinated approach, and providing investment capital. Such external investors can provide the infrastructure for effective information-sharing, share the risks of new service development, bring new business models and ideas into the sector, and aid coordination between healthcare institutions. Their participation is being encouraged at national and provincial government levels, and it is against this background that China Mobile has been investing in services and infrastructure to support the country's healthcare system. Its mobile network plays an important role, providing networked IT access in rural areas, and enabling mobility of access to healthcare services (within hospitals, between healthcare providers, in rural areas, and even in patients' homes).

S2 CASE STUDY A: mHealth in Guangdong Province

There are about 96.4 million permanent residents in Guangdong Province, served by 16 238 healthcare institutions (including hospitals, community healthcare centres, maternity and child care centres, other specialised institutions, and 138 health inspection agencies, but excluding village clinics). 80% of medical resources are concentrated in the cities, with two-thirds of these further concentrated in well-equipped large hospitals. Resources in rural areas are inadequate, and hard to access.

Guangdong has about 548 000 health workers (plus 413 000 health technicians), of which 156 000 are medical practitioners and assistants, and 151 000 are registered nurses. This means the region offers slightly fewer health workers per head of population than the national average. Only 34 000 doctors and health workers are located in rural areas.

Many medical institutions at all levels in the Province have undertaken IT development projects of various kinds, with some hospitals trying to implement electronic case histories and remote diagnosis, and starting to construct Global Health Information Systems (GHIS). However data and information is not typically shared between hospitals, due partly to lack of standardisation, and partly to lack of wide-area inter-networking capabilities. This creates isolated pockets of knowledge – for instance the examination result from one hospital is unlikely to be recognised in another hospital, and community health service and maternity and child-care data are hard to share.

Against this background, China Mobile has been working with value-added service partners to develop a range of mHealth services and applications that are designed to assist hospitals to reach more patients more cost-effectively, to raise the general health of the population, to improve access to treatment, to enhance hospital management systems and to improve the patient experience. Key projects – each of which is described briefly below – include Medical Link, Medicine Link, Vaccine Link, 12580 Mobile Medical Service (as already described in Section 2.1 above), hospital CRM, mobile video visitation, and RFID based drug tracking and regulation.

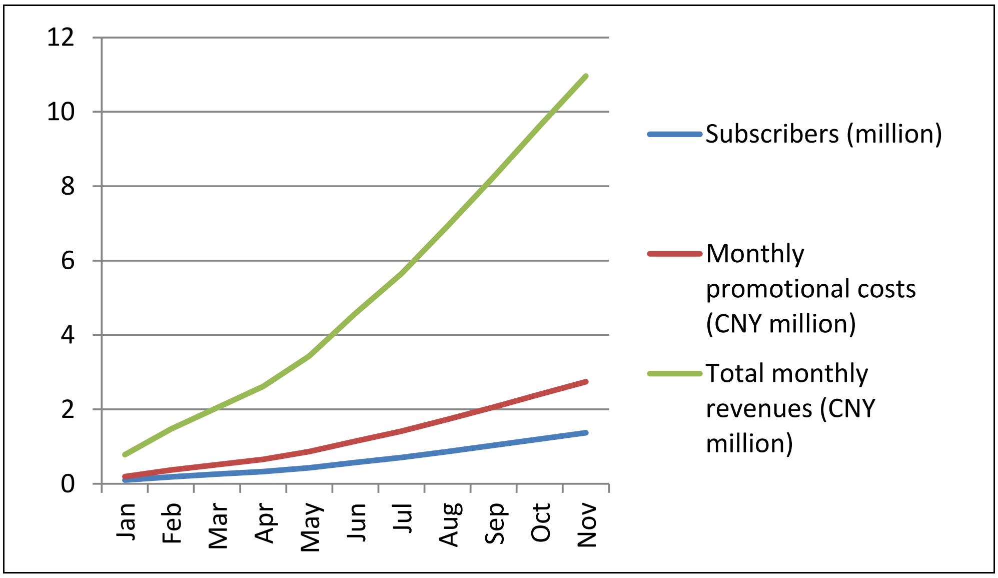
Medical Link

A service developed by Guangdong Company of China Mobile to deliver medical information and popular scientific health information to support the medical care process, and to promote healthcare service efficiency. For a flat rate of CNY8 per month, the subscriber can access four sub-services, as shown below. There is also a lower-rate service at CNY3 per month, which offers access to the Health Home sub-service.

Health Life	Information services based on sinology (Chinese culture and academy), covering public health, health promotion and preservation, male health-care, female healthcare, child healthcare, and healthcare for the elderly.
Recovery Instruction	Edited by medical experts and professionals, this service provides self-service information on diagnosis and self-treatment for 42 kinds of common disease, covering the whole cycle from the cause, symptoms and development of diseases to cure, care and rehabilitation. It is designed so that users can treat minor illnesses without seeing a doctor and protect themselves against serious illnesses.
Industry Health Collection	Occupational health guidance for civil servants, police, and those in industries such as education, electronics, clothing, manufacturing, petrochemicals, logistics, etc.
Health Home	Targeted at family members, this service provides information for eight groups: the general public; females; males; children, young people; middle-aged and old people; pregnant woman; puerpera and infants. The services are designed to raise awareness of healthcare, and promote family health.

Medical Link is accessible via a mobile phone and is available throughout the whole of Guangdong Province. It has proved popular with Chinese consumers, with subscriber numbers rising from under 100 000 in January 2010 to nearly 1.37 million by the end of November 2010, and generating traffic of around 1.1 million SMS messages per day. Revenues from the service have grown rapidly, reaching a monthly total of nearly CNY11 million in November 2010, with monthly promotional costs of CNY2.75 million. At the same point, service penetration was only around 1% of the population, suggesting substantial room for growth.

Figure 21: Medical Link subscribers, revenues and marketing costs



Medicine Link

A mobile information service encouraging safe and rational drug use, set up by Guangdong Company of China Mobile, Guangdong Food and Drug Administration, and Guangdong Shanhe Science and Technology Company. Subscribers to the service receive three to five messages per week on subjects such as sensible drug use, food and drug safety, and healthy eating, as well as information on policy changes and important notices from the food and drug authorities on potential adverse reactions to medicines. An example message might be:

"State Food and Drug Administration reminder: Vitamin C Yinqqiao Tablets are compound preparations of traditional Chinese and western medicine, containing chlorphenamine maleate, paracetamol and vitamin C. The product is prohibited for those who are allergic to the ingredients, and should be used cautiously by those with allergic constitutions. Overdose and prolonged treatment should be avoided. After using this product, if you have itchy skin, a rash, difficulty in breathing, loss of appetite, dark urine, or yellowish discoloration of skin, stop using this product immediately and go to see a doctor. Medicine Link."

The service is provided via SMS messaging to mobile phones and is available throughout the whole of Guangdong Province, generating around 160 000 messages per day. It had 300 000 subscribers as of October 2010 (a penetration of 0.3% of the population).

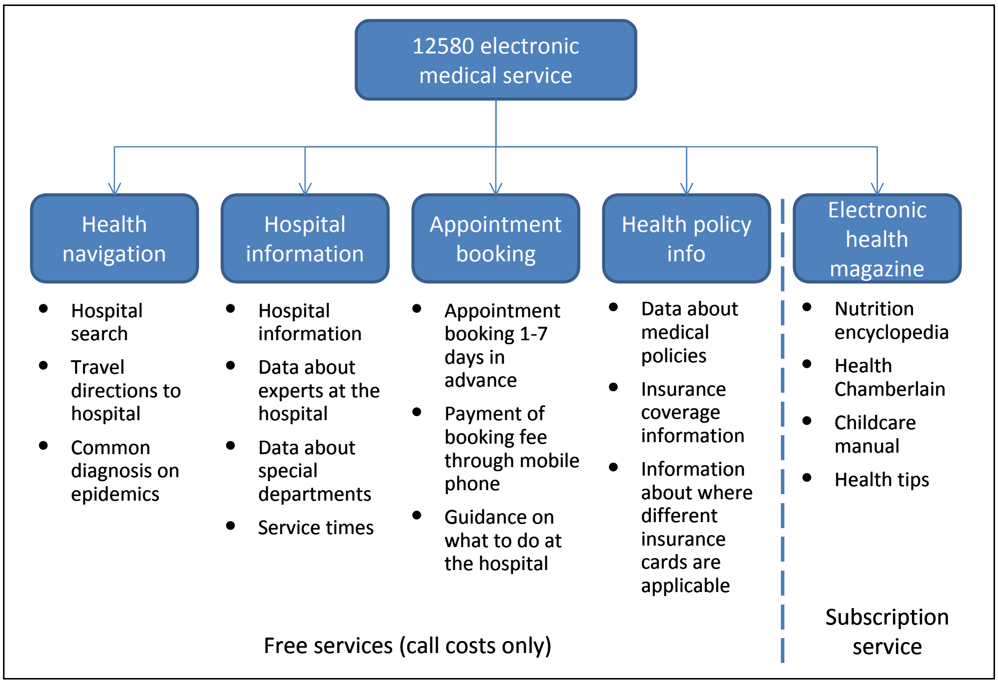
Vaccine Link

Vaccine Link is a vaccine information system for parents and children, targeted particularly at parents of children up to the age of seven already registered with vaccine inoculation stations. This service sends vaccine inoculation notices to parents, and can also send child-health-related information on infant feeding, early education, maternal and child healthcare, child and parenting classes, etc. Provided via mobile phones, Vaccine Link is available in three cities: Shenzhen, Foshan, and Qingyuan. It had 100 000 subscribers as of October 2010 (a penetration of 0.2% of the population), generating around 50 000 messages per day.

12580 Mobile Medical Service

The 12580 Mobile Medical Service is designed to make it more convenient for patients to book hospital appointments; to help them find their way to hospitals; to reduce waiting times at hospitals; and make the general hospital inpatient service more efficient.

Figure 22: Elements in the 12580 Electronic Medical Service



The core of the service is the booking system, which can be accessed via a number of means including a downloadable mobile app, from a WAP site, via an IVR system, via China Mobile's 12580 call centre, and via a normal website. A variety of associated value-added services are also provided, including general hospital information services, travel guidance, and advice on the applicability of insurance cards in different healthcare establishments. SMS messages are the main means of confirming bookings, and sending information to users.

Figure 23: Agent responding to hospital booking requests in the 12580 call centre in Guangzhou

The service is available throughout Guangdong Province. The appointment booking system provides access to 89 hospitals in the Province, and as of October 2010 had handled over 300 000 bookings, generating approximately 1100 SMS registration messages per day. Across the full range of features, the 12580 Mobile Medical Service has been used by more than 4.5 million customers, and generated an income of CNY89 million.

Subscribers calling 12580 pay only basic-rate call charges; China Mobile does not charge a value-added service information fee for facilitating bookings (although users can pay their appointment fees via their mobile phones). Most of the revenue is generated from hospitals paying to have the appointment reservation system installed. Additional fees are generated through advertising placed on appointment confirmation messages, and through branding of the voice hotlines. Eventually the service is intended to generate more revenue by charging a registration fee and a consultation fee through the mobile payment service, and by printing registration receipts using wireless POS end devices.

Hospital CRM

China Mobile and its partners have developed a hospital CRM system which manages information about patients before, during and after hospitalisation. Before hospitalisation it assists with appointment registrations; during hospitalisation it provides health tips and important information related to the patient’s stay (such as examination results notified by message); and after hospitalisation it supports follow-up care for discharged hospital patients (such as guidance on trauma, food, medicine doses, follow-up consultations, etc).

The service is provided via mobile phones in Guangzhou City, and is designed for use by medical institutions, predominantly hospitals, which issue their staff with MAS information devices customised by China Mobile. The service had 20 hospital clients as of October 2010, of which 12 were actively using the service, generating an average of 8000 messages per day.

Mobile video visitation

The mobile video visitation project is currently being trialled in Dongguan Tungwah Hospital in Guangdong Province. This service uses video cameras to monitor patients in intensive care and infants in incubators. As well as enabling real-time monitoring by hospital administrators, family members can see patients, and talk to them, via Internet connections or smartphones.

RFID-based drug tracking and regulation

China Mobile's RFID-based Drug Tracking and Regulation service is under development in a joint R&D project with Guangdong Food and Drug Administration. The goal is to establish a medicine information service platform using RFID and bar-code technology to assist the government in tracking, supervising and monitoring medicine supply and distribution; monitoring for adverse reactions to drugs; improving information systems related to the supply of basic medicines; and standardising drug procurement and distribution.

China Mobile has invested around CNY10 million in capital expenditure on the various projects, mainly for hardware and software development. Other investment costs have been borne by partners, including development costs for Medicine Link, Medical Link and Hospital CRM.

There are also significant operating costs. As of October 2010, the running costs for the 12580 Service had reached around CNY4 million (mainly for the cost of the call centre); at the same point in time, the running costs for Medicine Link totalled CNY3 million, Medical Link CNY10 million, and Vaccine Link CNY800 000. The running costs of Hospital CRM (mainly promotional costs) were around CNY80 000 at that point.

However, China Mobile sees clears returns on investment for itself and medical institutions. For instance it estimates that the 12580 booking system had saved hospitals around CNY4.35 million as of October 2010, and the total saving (compared to what it would have cost for all the relevant hospitals in Guangdong to build their own systems) could be as much as CNY20 million.

S3 CASE STUDY B: mHealth in Guizhou Province

Guizhou Province in central southern China is home to nearly 40 million people, 80% of whom live in agricultural areas. It has a diverse geography, including mountainous regions, hills and relatively flat areas to the south and east of the Province. There are 23 000 medical care institutions spread across over 19 500 cities, towns and villages, including village clinics, outpatient clinics and over 2000 hospitals. Medical care expenditure in the region in 2009 was almost CNY10 billion (USD1.5 billion), which represented USD37.5 per person, or just over 2.5% of regional GDP (significantly lower than the national average).

Given Guizhou Province's strong agricultural base, great importance is attached to the **New Rural Cooperative** system. This is a medical care mutual aid system designed to help farmers access expensive medical treatment, and to assist in alleviating poverty caused by disease. It is funded by voluntary private contributions from farmers and collectives, and by government subsidy.

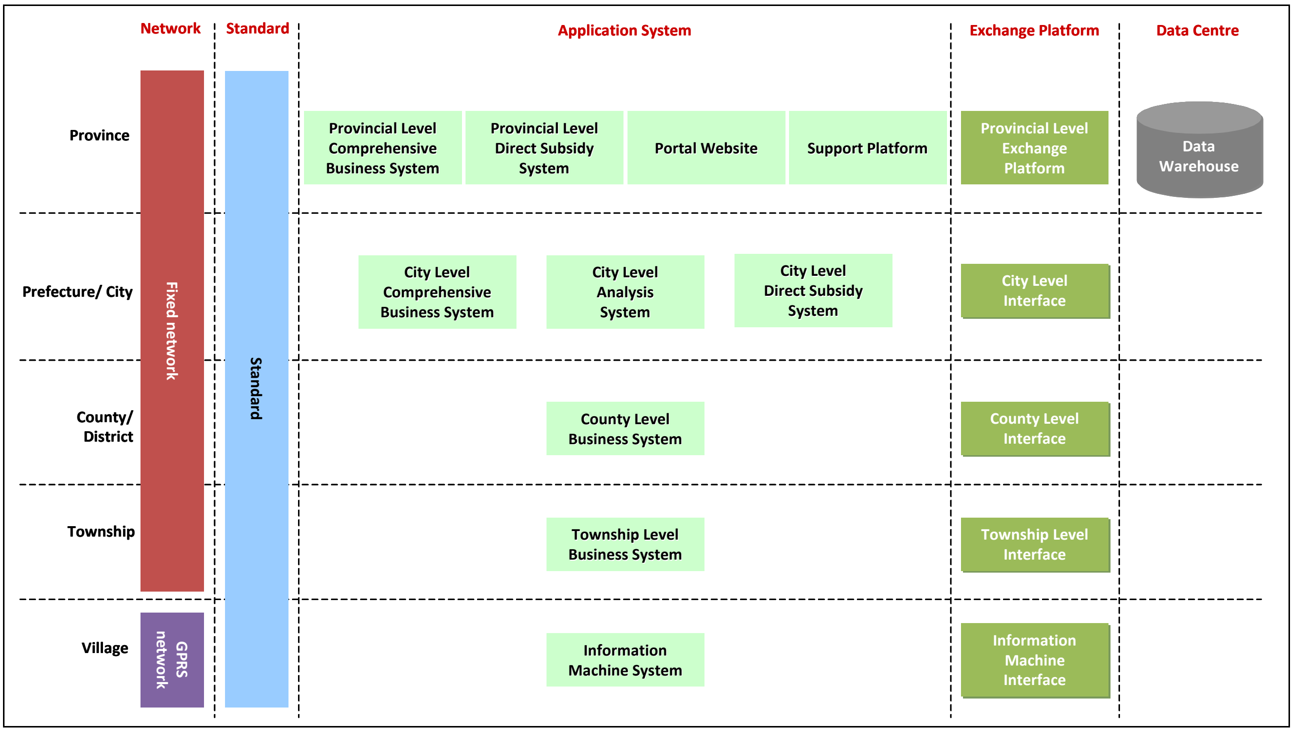
A project to implement a modern IT system to support The New Rural Cooperative was launched in 2003. Whilst progress was made, the project left a lot to do. Development was uneven across the different counties within Guizhou; data was not shared between counties (due to lack of infrastructure to enable sharing); lack of funds meant systems could not be adequately maintained (with some counties reverting to paper based systems after installation); and the county-level systems did not extend to cover small towns and villages, meaning work was still done manually in those areas.

In May 2009 the Guizhou Branch of China Mobile signed a strategic cooperation agreement with the Health Department of Guizhou Province. The objective of the agreement is to provide a platform for modernising Guizhou's health system, including a comprehensive package of services and support (which may include communications services, IT services and healthcare information services). To begin with, the new partners are deploying a Province-wide communications and IT platform for the New Rural Cooperative; this will subsequently serve as the basis for other Province-wide networked eHealth information services.

Specifically for the New Rural Cooperative project, China Mobile is deploying a fixed and mobile network linking administrative and health offices at Province, prefecture, county, township and village levels. A fixed network will link sites all the way out to townships, with a GPRS network being used to provide connectivity for village clinics. China Mobile is also providing technicians to promote the system in rural areas, delivering training for administrators and users, and helping to solve any problems faced locally. A single data centre in the provincial capital will be used to consolidate data for the whole Province, and initially to enable centralised management functions.

Alongside the network, appropriate platforms are being implemented at each administrative level, as shown in Figure 24.

Figure 24: System specification for new rural cooperative IT and communications support system



- A **provincial level system**: web portal and tools for direct subsidy management, enquiry services, decision analysis, data collection, funds analysis, and reporting. The direct subsidy platform enables instant subsidisation of payments for outpatient services, hospitalisations and referrals, trans-regional subsidisation, and subsidisation for non-local patients. It is designed to shorten timescales and reduce complexity for subsidy authorisation, and enables real-time monitoring.

- A **county and village level platform:** to enable local management of the New Rural Cooperative system, including systems for data capture and authorisation, and certificate/card management. (An “all-purpose card” enables farmers to receive subsidised treatment when not in their local areas.)

- **Terminals for village clinics**. Connected to the rest of the system via GPRS, these terminals enable enquiries about treatment, family accounts, and medicine price lists; allow the printing of documents; and provide access to outpatient statistics.

The project began in May 2009 with specification work and the selection of systems integrators, followed by the launch of four pilot programmes. It is due to run till June 2011, concluding with roll-out to all 88 counties in the Province.

The new system is designed to deliver a range of benefits. Previously it was not possible to apply for reimbursement at village clinics; this meant people either did not see doctors when they needed to, or had to travel into townships to clinics where they could apply for reimbursement. The new IT architecture means they can receive funded treatment in their own villages. Meanwhile hospitals, staff and the government benefit from supervision and cost-management capabilities, as well as efficiencies in processes to do with verification and payment.

A sum of CNY107 million (USD16 million) is being invested upfront in the system, including network construction. On-going third-party system support fees will also be payable (around USD333 000 per year), as well China Mobile’s own operating costs. This is funded by payments from the government, with fees ranging from CNY360 (USD55) per year for a clinic terminal, up to USD544 per year per site for county-level health institutions, with a Province-wide management fee. The technology platform is expected to generate revenues of around CNY20 million per year (USD3 million).

Once the network is in place the incremental cost of adding new applications will be much lower. There are, therefore, plans for further expansion, and projects are underway to deliver a range of extra applications, as the table below shows:

Application name	Target users	Main functions
Hospital business management system	Small-scale township-level hospitals	Hospital fees management, pharmacy management, registration management
Hospital case management system	County-level (or above) hospitals; provincial administrative departments	Hospital management, data reporting, statistical analysis of disease trends
Resident health records	Healthcare administrative department, medical institutions, general population	Collection and maintenance of individuals’ health records, and enquiry service for legitimate third-party users
Health resource database	Healthcare administrative departments at all levels	Collecting, recording and analysing health statistics in the region, for government use
Electronic government affairs for health	Healthcare administrative departments at all levels	Emergency guidance, information about health supervision and law enforcement
Reproductive life knowledge	Pregnant women, puerpera and their families	Provision of healthcare information and related knowledge

Not all of these require mobile networks, but many are accessible from mobile terminals. Without the investment in the rural mobile network and terminal system, the efficacy and usefulness of the platforms would be substantially diminished.

S4 CASE STUDY C: mHealth in Tianjin

The population of Tianjin Municipality reached 12.3 million in 2009, a figure which includes one of the highest proportions of elderly people anywhere in China. According to the Tianjin Aged Commission, 1.7 million people in Tianjin are 60 years old or more, accounting for almost 14% of the region's total population. Local surveys suggest that more than 30% of these older people suffer from cardiovascular disease and have an urgent need to access health services. Moreover, older members of the population usually have low levels of income (most are dependent on social insurance, and have monthly income levels below CNY800), and find it difficult to pay for hospital consultation and treatment.

As in other regions of China, medical care resources in Tianjin are concentrated in developed areas and large cities. In fact Tianjin has a relatively high level of urbanisation, with urban residents accounting for more than 70% of the total population. The region has well-developed infrastructure and a good road network, but the level of private car ownership is low. Most people use public buses for long-distance transport (and hence to access medical care).

Power supply and telephone services are provided to all villages, and mobile services are widely available throughout the region. Mobile coverage in Tianjin is 100%. The education levels of the local population, however, are comparatively low, with most people being below middle secondary education level; as a result, they have relatively weak IT skills, and require simple and easy-to-use equipment. These characteristics of the region make the mobile network an attractive platform to use for service delivery.

China Mobile signed a strategic cooperation agreement with the provincial government in 2009, agreeing to develop telehealth and mHealth infrastructure in Tianjin. The partners identified an urgent need for a comprehensive healthcare information platform for hospitals and the general public, capable of supporting disease prevention, improving patient service, enabling remote diagnosis and facilitating the supply of health education and information. In particular the partners pinpointed a particular requirement to deliver support to older people who find it difficult to travel, or for whom travel might be risky because of illness or infirmity.

The **Patient Link** project was conceived to meet these needs. It is designed for use by patients who want to see doctors, as well as those receiving treatment in hospitals; all medical staff in hospitals (including doctors and nurses); patients' relatives; and hospital managers and administrators. It provides:

- a platform giving patients access to timely healthcare information, and enabling them to communicate remotely with doctors (including video consultation)
- a mobile office platform for doctors (with facilities from a special landing page on the mobile phone, e.g. to send and receive messages, provide digital signatures, manage approvals, etc.)
- remote access for doctors to information about patients' conditions
- a platform allowing doctors to arrange times for consultations
- remote "visiting" of sick patients.

At the system management level, the objective is improve access to and use of cardiovascular healthcare resources, reduce waiting times (and diagnosis times) for patients, improve utilisation rates for hospital healthcare resources, and raise hospitals' income.

Services supported by the Patient Link platform – including public disease prevention, chronic disease management and community health – are initially being provided in and around Tianjin. After the completion of deployment in Tianjin, services will be extended to hospitals in Inner Mongolia and Gansu

Provinces, reaching nearly 50 million additional people. Both Mongolia and Gansu Provinces have low population densities, so Patient Link will provide important remote healthcare facilities.

From a technical point of view, Patient Link encompasses six key elements:

1. **General Service Platform** –providing online appointment registration, facilitating the provision of online consultation and guidance regarding medicines and medical treatment, and supporting the delivery of other information services
2. **Video Visitation System** – enabling teleconferencing for situations where physical patient visits are not possible, economic or desirable
3. **SMS Broadcasting Platform** – supporting the delivery of health guidance, and the results of consultations, to users or service subscribers
4. **Video Ward** – enabling visual monitoring of patients by doctors and nurses using mobile phones
5. **Mobile V Network** – local mobile services supported by local macro base stations, with calls only going through those base stations to keep traffic off the tandem exchange and reduce pressure on the wide-area mobile network; they are typically provided to a group of China Mobile subscribers who live and work within the same area, and who enjoy lower rates for using the services
6. **Mobile Office Automation** (MOA) facilities – based on an adapted mobile phone with OA page.

These technical elements make use of both fixed and mobile technologies, and various different devices. For example, the General Service Platform can be accessed via the Internet over a mobile phone, or from a PC. The V Network and SMS Broadcast systems are specifically mobile. Meanwhile the Video Visitation and Video Ward systems use remotely controlled wireless video cameras. Remote users need 3G phones with video capability running the Patient Link end-user software. The healthcare expert and virtual doctor services will typically be delivered over fixed broadband network access by the professional, but accessed over mobile phones by the patient.

Special portable medical terminals are required to measure heart rates, blood pressure, and so forth. These terminals automatically send data to the medical service platform via China Mobile's mobile broadband. A medical expert then analyses and interprets the data for users, and sends advice via SMS or MMS messages. Some of the medical terminals can send messages to default mobile phone numbers.

In addition, Pingantong terminals (special mobile phones released by China Mobile) can provide integrated positioning and remote control services for children, the elderly, disabled people, and patients. The devices enable parents or guardians to track and monitor the person carrying the terminal, and control its usage remotely through SMS or the Web.

These technical elements of the Patient Link platform have been brought together to deliver a number of services as shown in the table on the following page.

Patient Link currently serves 45 hospitals, including Taida Cardiovascular Hospital, Peking University Third Hospital, Tianjin First Center Hospital, and Tianjin Children's Hospital. As of October 2010 the service had over 28 500 website members and was supported by 135 contract doctors; the first-stage deployment can support up to 500 000 website subscribers. Around 10 000 WAP page hits were being recorded per day (over 100 hours of WAP and WEP usage per day).

Service	Details
Mobile Clinic	A virtual doctor service, which in its first incarnation takes the form of The Cardiovascular Disease Prevention and Health Education service, providing healthcare for people with cardiovascular problems. It offers support throughout the lifecycle, from diagnosis and test results, through capturing patient data to build a case history, to providing treatment advice to the patient and their family members, and advice to aid recovery following treatment. It may also encompass the use of the video visitation cart while the patient is in hospital to enable family members to keep in touch (either because they cannot travel to the hospital, or because there is a need to secure the treatment environment).
Heart Link	Provides a real-time monitor for heart surgery patients, video visitation services for relatives, and remote monitoring for doctors. Special mobile Internet devices are used to dynamically collect, process, and display certain physiological indicators, and to provide treatment advice.
Remote Diagnosis (DICOM)	Combines the TD-SCDMA mobile broadband network with DICOM digital image processing technology to provide video applications for real-time remote diagnosis, and health analysis. It is designed to prevent the need to travel to hospital, and also offers online appointment booking.
Influenza A Epidemic Prevention System	A system linking the general public, hospitals, the health bureau and other government departments to enable real-time supervision of infectious diseases and major epidemics, and to provide online expert consultation for real-time diagnosis and treatment. This system takes advantage of China Mobile's wireless broadband access to collect epidemic and infectious disease information that can be analysed by hospital experts. If an epidemic is suspected it is reported to the local department in charge of healthcare, and if confirmed, in turn to the relevant local government department. The system can then be used to help coordinate hospitals and communities, and to encourage residents to take measures to control the spread of the disease.

At the same point in time, Video Visitation was being used for around 1500 sessions per month, generating 50 hours of video calls (including video visitation) per day. The Mobile Clinic service was being used by more than 300 doctors to deliver cardiovascular disease prevention and health education to 30 000 elderly people; it was also being used in cooperation with Tianjin Health Bureau to provide child disease prevention and congenital heart disease screening for 50 000 children in Tianjin. The Mobile Clinic system has the capability to support 300 users online at the same time.

Patient Link's SMS notification services can support eight million mobile subscribers. As many as 10 000 SMS messages and 300 MMS messages are now sent daily, plus hundreds of emails and dozens of file transfers. Overall, peak network traffic for the Patient Link services reaches more than 30 Mbps.

Although it is still in its pilot phase, the project has clearly generated a high level of traffic and usage, which is only expected to grow with the participation of more hospitals, doctors and patients. Furthermore the service (which has grown largely by patient registration on the website) is now being promoted by sales channel partners of China Mobile, through SMS marketing and advertising. As of October 2010, the Mobile Clinic service covered only 1.75% of local aged people, so has tremendous room for development.

The start-up capital invested in Patient Link was CNY3 million, with total early-stage investments (excluding running costs) of CNY6 million, covering the costs of the Patient Link service platform, the video service system, extra mobile base stations and indoor mobile distribution equipment, terminals, and WLAN infrastructure.

The costs will ultimately be recovered from fees for using the services. Website access is provided for free (over and above basic mobile data costs). Voice consultation services are provided at standard phone rates.

The video visitation services are temporarily free, but will eventually be charged according to length of time used. The mobile office services are also temporarily free, but will ultimately incur a monthly flat-rate charge. The Patient Link service is expected to break even within five years from 2010.

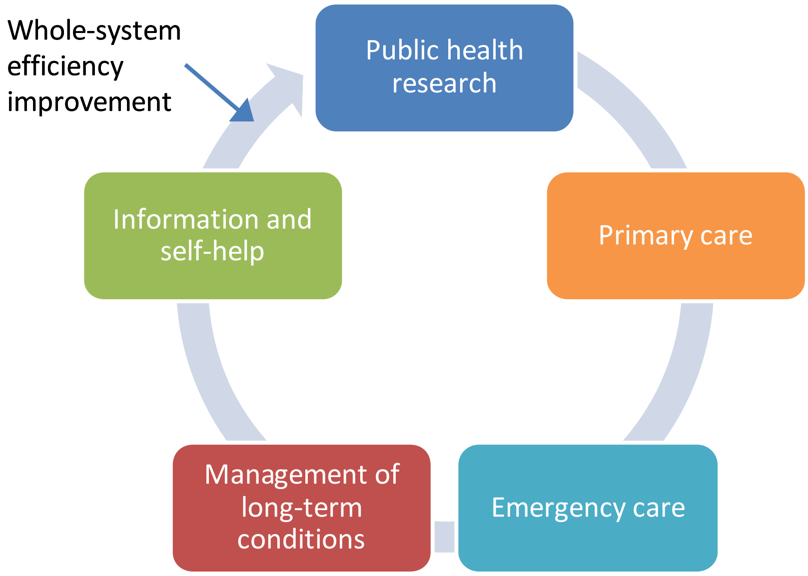
Annex A: mHealth Applications Identified in the Course of the Project

This annex lists over one hundred and twenty-five mHealth applications – whether available now, currently being trialled or concepts in development – which were identified in the course of research for this report. We give a brief description of each, indicate where in the world it is being trialled or deployed, and where possible we include a URL indicating where further information can be found. The data is largely based on websites accessed at the end of 2010. Our definition of mHealth is:

An mHealth service or application involves voice or data communication for health purposes between a central point and remote locations. It includes telehealth (or eHealth) applications if delivery over a mobile network adds utility to the application. It also includes the use of mobile phones and other devices as platforms for local health-related purposes as long as there is some use of a network.

The applications are grouped according to the six themes set out in Chapter 1. The six themes are:

Six “themes” into which mHealth applications can be grouped



Some applications do not fall neatly into a single theme: where this is the case we have listed them under the primary category, and noted their relevance to other themes. For example, “emergency care” and “management of long-term conditions” overlap in the case of the remote monitoring of elderly people so that help can be summoned if they fall. A similar issue arises with maternity apps – they might be considered as “information and self-help” or “primary care” (for pregnancy advice and health-system-delivered services) or “emergency care” (for apps which are designed to ensure that expectant mothers with problems are treated quickly). Applications designed for babies at risk of sudden infant death syndrome are likewise difficult to categorise.

The list is not exhaustive. Indeed it could have been very much longer; in particular, there are many thousand iPhone and Android apps that have a health or fitness aspect, from which we have included only a few for the purposes of illustration. Similarly there are many services providing primary health advice by phone, such as Telemedic in Mexico, Healthline in New Zealand, Fonemed in the USA and elsewhere, and NHS Direct in the UK. We have included a small number of these in the list in order to indicate how widespread these are. Finally, new announcements are being made almost every day, with the result that any list is outdated as soon as it is published. Nevertheless it is informative to include such a list, to illustrate both the diversity of applications, and the ingenuity and innovativeness of the concepts that they so often embody.

Public health research		
Mobile access to AIDS/HIV information portal: use of mobile phones to inform digitally excluded communities http://research.microsoft.com/en-us/events/mhealth2009/mpoeleng-poster.pdf	Integrated Healthcare Information Service through Mobile telephony (IHISM) project, conducted by researchers at the Department of Computer Science, University of Botswana, with the support of Microsoft Research. Explores the use of mobile phones by the general public in Botswana to access HIV/AIDS information from healthcare portal. At the heart of the system are intelligent personal information centres designed to derive and present appropriate information for individual users. The project aims to demonstrate how under-served communities can benefit from opportunities afforded by the power of ICT to achieve development goals; expected benefits include enabling digitally excluded communities to improve understanding, prevention and control of their medical conditions, and minimise visits to hospitals.	Botswana (trial)
Nokia Data Gathering Project: disease surveillance (monitoring of dengue fever through mapping of reports of outbreaks via mobile) http://www.nokia.com/corporate-responsibility/society/nokia-data-gathering/english/health	Project designed to help contain the spread of the dengue virus, using customised questionnaires distributed to field health agents' mobile phones. Health data and GPS location information are integrated to enable immediate analysis and identification of areas with high infection levels. Feeds into larger monitoring of dengue fever outbreaks (www.denguewatch.org).	Brazil (active)
Influenza A Epidemic Prevention (China Mobile): real-time information and coordination system	A system linking the general public, hospitals, the health bureau and other government departments to enable real-time supervision of infectious diseases and major epidemics, and to provide online expert consultation for real-time diagnosis and treatment. The system can also be used to help coordinate hospitals and communities, and to encourage people to take measures to control the spread of the disease.	China (active)
AESSIMS: reporting of disease incidence and allocating resources accordingly www.voxiva.com/aessims.asp	AESSIMS is designed to build health capacity at the field level by enabling front-line health workers to report disease incidence through an innovative combination of phone and web-based technology that leverages available infrastructure. AESSIMS enables health officials to better understand the scope of disease impact and to allocate resources to areas with the highest prevalence and need.	India (active)
EpiSurveyor.org: data collection tool for disease surveillance, drug stock tracking, surveys, etc. http://www.episurveyor.org/user/index	An online system developed by DataDyne.org that allows rapid development of forms which can be downloaded to mobile phones for data collection: user can go from concept to fully functional mobile data collection system in hours. Used in over 120 countries for outbreak investigation, disease surveillance, and drug stock tracking, as well as health and economic surveys and veterinary studies.	Kenya & worldwide (active)
Maternity/childbirth problem detection: community health worker app for diagnosis http://www.grandchallenges.org/Explorations/Pages/GrantsAwarded.aspx	App developed by World Vision for community health workers to support diagnosis of problems during pregnancy and childbirth, and to gather data for research; trialled in central Mozambique. Prompts community health workers caring for pregnant women and newborns to assess, take action, and refer care in cases of complications and emergencies. Data gathered from this study will help refine the app and inform plans to scale up the program.	Mozambique (trial)
Cell-Preven: data collection relating to STD transmission http://www.prevenperu.org/preven/	Healthworkers use mobile phones to send SMS messages with real-time data on symptoms experienced by clinical trial participants. This enables immediate response to adverse symptoms. Disease surveillance is based on monitoring of prescriptions of certain drugs.	Peru (trial)

EmotionSense: mobile-phone-based platform for experimental social psychology research http://www.cl.cam.ac.uk/~cm542/papers/ubicomp10.pdf	Developed at the University of Cambridge's Computer Lab, EmotionSense is a way of assessing individuals' emotional state by analysing data from the handset's microphone using a speech/tone analysis algorithm running on a smartphone. Data can be combined with information from location and movement sensors also on-board the phone. Trials show that the system is effective at detecting individuals' emotions, holding out the prospect of designing effective social psychology experiments without requiring obtrusive cameras or voice recording devices.	United Kingdom (trial)
Fluphone: trial of contact mapping for influenza epidemiological research https://www.fluphone.org/	A study recording how often different people (who may not know each other) come close to one another in their everyday lives, and mapping this against 'flu symptoms. Volunteers install a small piece of software on their mobile phones and carry their phones with them during their normal day-to-day activities. The software looks for nearby phones periodically using Bluetooth, records this information and sends it back to the research team via the cellular phone data service. This information provides a better understanding of how often people congregate into small groups or crowds (e.g. when commuting or through work or leisure activities); also, by knowing which phones come close to one another, it is possible to work out how far apart people actually are, and how fast diseases could spread within communities. Participants also report any influenza-like symptoms they may experience during the study period, so that the spread of 'flu can be matched to the underlying social network of encounters made.	United Kingdom (pilot)
mHealth Initiative Inc. Demonstration Project: proposed communication and participatory health project to improve service delivery http://www.mobih.org/project/	mHealth Initiative Inc. is seeking support to demonstrate how changing the behaviour of patients and the general public can improve health and reduce costs. The demonstration project is designed to reduce healthcare costs through better communication and reduction of visits, improve quality of care and reduce disparities, as well as to make the healthcare system more convenient and address shortages of staff.	USA (proposal)
Voxiva Health Watch: an integrated surveillance platform to support integrated disease surveillance http://www.voxiva.com/solutions/public_health/diseaseSurveillance.html	Integrated surveillance platform to support disease surveillance and the coordination of responses. Users can use the web or mobile phone to submit real-time reports that can be configured on-line and added to records Data can be filtered and displayed as epi graphs and maps of outbreaks.	Worldwide (active)

Primary care		
BreastScreen Rural Broadband Digital Mammography Project: breast cancer screening and control in the Tasmanian outback http://www.ericsson.com/thecompany/stories/100624_breast_scan_20100624135445	Women in rural Tasmania have previously had to travel great distances to receive screening and then wait for more than two weeks for a response. Telstra is supporting the project with integrated mobile broadband based on Ericsson's end-to-end HSPA/WCDMA solution. The fixed and wireless broadband networks installed in the screening service vans enable large image files of breast screens (30-50Mb) to be sent digitally from screening points to assessment centres, reducing the risk of damaged or lost images when compared with physical x-rays, and improving productivity. Wireless broadband overcomes the logistical problems of installing temporary fixed-broadband services. Using the mobile broadband network, the breast screen images can be captured digitally, integrated with an electronic patient record, sent to a BreastScreen assessment centre and stored electronically in a picture archiving communication system.	Australia (pilot)

National Health Call Centre Network or "HealthDirect": primary health advice by phone http://www.health.gov.au/internet/main/publishing.nsf/Content/national-health-call-centre-network-team-overview	Helps patients (particularly in remote areas) to make informed decisions about their healthcare and improve confidence in health system. Open 24/7 and staffed by registered nurses supported by electronic decision support software and algorithms to provide effective health triage, information and advice to callers. Has the capacity to support add on services and to assist in health threats and emergency situations.	Australia (active)
Smartphone-based foetal monitors: pregnancy tracking system to monitor foetal growth http://research.microsoft.com/en-us/collaboration/focus/health/smartphone_fetal_monitor.aspx	With financial, software, and hardware support from Microsoft External Research, Tan and Masek are developing software that can be downloaded at no cost to any Windows Mobile phone. When connected to a low-cost foetal monitor, the phone will enable expectant mothers to track and keep a record of the foetal heart rate and activity in the womb and transmit that data to obstetricians or midwives at urban or regional health centres. The system can also be used to track and relay critical information during premature births.	Australia (trial)
Healthline: primary health advice by phone http://www.telenor.com/en/corporate-responsibility/initiatives-worldwide/healthline-mobile-access-to-medical-services	24/7 medical call centre staffed by physicians, aimed at people in remote areas in Bangladesh. Can provide information on access to doctors and medical facilities, drugs and pharmacies, and to laboratory results, medical advice and emergency advice.	Bangladesh (active)
Diagnostic tools connected to mobile devices: connection of ECG and blood pressure tools via mobile http://research.microsoft.com/en-us/news/features/digital_inclusion_final.aspx	Microsoft Digital Inclusion Project on connecting tools for monitoring of long-term disease, including design of a kit that connects tools to perform electrocardiograms or to measure blood pressure to a mobile device. An optional global-positioning system could identify geographical information such as risk zones or particular-case regions.	Botswana (trial)
Telehealth (Ontario): primary health advice by phone http://www.health.gov.on.ca/en/public/programs/telehealth/	Free, confidential 24/7 telephone service to get health advice or general health information from a registered nurse. Helps a patient to decide wither they need to visit a doctor, contact a community service or go to A&E.	Canada (active)
Hospital CRM (China Mobile): information management system for patients before, during and after hospitalisation	A hospital CRM system managing information about patients before, during and after hospitalisation. Before hospitalisation it assists with appointment registrations; during hospitalisation it provides health tips and important information related to the patient's stay (such as examination results notified by message); and after hospitalisation it supports follow-up care for discharged hospital patients (such as guidance on trauma, food, medicine doses, follow-up consultations, etc).	China (active)
12580 appointment registration (China Mobile): SMS/MMS-based system for hospital appointments and provision of transport information	In China's Guangdong Province, the "12580" service provides multiple patient contact services, which have been developed over time. These include navigation tools (location of and directions to hospitals); information (on hospitals, doctors, departments, opening times, policy-related information); and a hospital appointment reservation service. A health-related e-magazine is also provided for an additional charge. The hospital appointment reservation system is provided as a managed service to hospitals; 93 hospitals in nine cities in Guangdong use the service.	China (active)
New Rural Co-operative Project (China Mobile): networked IT support for rural healthcare	Project to deploy a networked IT infrastructure which supports the delivery of healthcare services in rural areas, and which provides a platform to enable more efficient local health system operation and management.	China (active)
Mobile Video Visitation (China Mobile): video feeds of patients in hospital	Service enabling relatives to monitor patients in intensive care or in baby incubator units using mobile or PC-based video calls to mobile cameras in the medical units.	China (pilot)

Mobile phone accessory for telemedicine microscopy: microscope for blood/fluid samples for immediate analysis in the field http://www.plosone.org/article/info:doi/10.1371/journal.pone.0006320	The prototype microscope has the approximate diameter of a US Quarter or UK 2p piece, weighs just 46g and builds on an imaging technology known as LUCAS (Lensless Ultra-wide-field Cell Array platform based on Shadow imaging). Instead of using a lens to magnify objects, LUCAS generates holographic images of microparticles by using an LED to illuminate objects and a digital sensor array to capture their images. The technology can be used to image blood samples and other fluids in the field. Not only is the lensless device much lighter than a traditional microscope, it also eliminates the need for a trained technician as images are analysed by a computer, making results available immediately.	Concept (in develop-ment)
Smartphone-based ultrasound probes: http://research.microsoft.com/en-us/collaboration/focus/health/msr_ultrasound.pdf	Development by Microsoft Research of very small ultrasound probes, costing less than USD1k, that can be used with smartphone platforms, based on devices initially developed for laptops.	Concept (in develop-ment)
Disposable Malaria Biosensor: SIM malaria biosensor http://www.engineer.ucla.edu/newsroom/more-news/archive/2010/ucla-engineering-awarded-grant-from-the-bill-melinda-gates-foundation	A disposable biosensor to enable malaria detection to be performed using a mobile phone, making diagnostic testing more widely available in rural areas. It also allows for automated transmission of the results to centralised healthcare facilities for diagnostics and follow up patient management.	Concept (in develop-ment)
Telemed: primary health advice by phone http://www.thefreelibrary.com/New+Telemedicine+Services+Link+Caribbean+Islands+With+Mass+General...-a018686003	Telemedicine installation linking Caribbean hospitals to medical facilities in USA aimed at reducing costs and providing better healthcare. Reduces patient travel costs and allows hospitals to extend their services and provide patients in the Caribbean with access to specialists.	Dominican Republic (active)
HMRI: Phone consultation and counselling, information on facilities, drugs, mobile health clinics (vans) http://www.hmri.in/	The ambition of HMRI is to create the world's largest integrated digital health network. Includes a health helpline, provides medical information, advice, counselling and 24/7 support in several languages. Also has a mobile-technology-enabled once-a-month travelling health service for the rural poor who do not live near a healthcare provider.	India (active)
TeleDoc: remote diagnosis of rural patients http://www.comminit.com/en/node/116145/307	TeleDoc has provided handheld mobile phone devices to village health workers in India, permitting them to communicate with doctors who use a web application to help diagnose and prescribe for patients.	India (pilot)
Sana Mobile: data collection tool for patient data http://www.sanamobile.org/	Open-source software system relying on smartphones running Google's Android operating system to connect healthcare workers in rural regions with physicians in urban areas. Using the Sana application on their phones, the workers collect patient data, including pictures and video, and send them in a text message to an electronic -record database. A doctor then reviews the data and sends a preliminary diagnosis to the healthcare worker by text.	Many countries (active)
HealthFrontier ecgAnywhere device: remote ECG testing, data storing and effective readings http://www.healthfrontier.com/	The ecgAnywhere unit fits in the palm of the hand and is capable of holding up to forty readings. Data can be transmitted via an analogue telephone line or digitally through a USB port or bluetooth to the HealthFrontier Remote Health Monitoring System (RHMS), or display results on the device in real time, particularly useful for situations where immediate analysis is required. The combination of the ecgAnywhere and RHMS allows physicians to perform a 12-lead ECG remotely and evaluate readings centrally. The system is designed for use in the management of Congestive Heart Failure and similar afflictions.	Many countries (active)

Telemedic: primary health advice by phone http://fonemed.com/telemedicine/hispanic-health-card	Hispanic Healthcard, available in USA or Mexico, allows cardholders to receive toll-free telephone access to a registered nurse 24/7. Advice is given relating to self-treatment at home, immediate or scheduled visit to doctor and emergency treatment. Families are also entitled to two house-calls and two ambulance dispatches a year, and discounts on nationwide network of health services.	Mexico (active)
MedicallHome: Phone consultations, information on facilities, drugs, discounts at clinics, pharmacies http://www.medicallhome.com/	Access to a doctor's advice by telephone 24/7. Free, confid-ential service. Also provides home call outs (at a cost), and ambulance service if necessary. Furthermore allows access to a network of specialists across Mexico at discounted rates.	Mexico (active)
Smartphone oximeter: remote non-invasive testing for pneumonia for immediate diagnosis http://research.microsoft.com/en-us/collaboration/focus/health/smartphone_clinical_diagnosis.aspx	With financial, software and hardware support from Microsoft External Research, the University of Melbourne has developed an inexpensive (USD10) smartphone-powered oximeter that can give health workers a front-line tool in the battle against pneumonia. An oximeter measures the oxygen content in red blood cells by measuring the absorption of red and infrared light waves as they pass through a patient's fingertip or ear lobe. Haemoglobin, the oxygen-carrying component of blood, is often in a depleted state in people with severe pneumonia. Because the light wavelengths used in oximeters are the same as those in an optical mouse or a TV remote control, the LEDs needed for an oximeter sensor are widely available and inexpensive.	Mozambique (trial)
Healthline: primary health advice by phone http://www.moh.govt.nz/healthline	Free telephone health information service staffed by registered nurses offering information and advice to decide on the appropriate level of care required.	New Zealand (active)
Teledoctor: primary health advice by phone http://www.telenor.com.pk/pressCenter/pressrelease.php?release=158&lang=en	24/7 access to qualified GPs, able to provide basic health information, medical advice and laboratory report information in local languages. Female callers can also talk to female doctors. Designed to provide an assessment of symptoms and answers to medical health related questions based on internationally recognised decision making protocols. Also provides online access to medical records of previous callers to facilitate better follow up	Pakistan (active)
Nacer: maternal and child health data management system for individual and public health decision making http://tghin.org/node/151	Nacer is a phone- and web-based information and communic-ation system for maternal and child health that allows health professionals in remote locations to communicate and exchange critical health information between themselves, medical experts, and regional hospitals. All reported data is recorded in a central database, and is available to health officials in real-time for analysis and decision-making. Health workers in locations without Internet connectivity can access the system using any phone (satellite, fixed-line, mobile, or community pay phone). As well as supporting the delivery of primary care the application is also beneficial for public health research.	Peru (active)
Fonemed Asia-Pacific: primary health advice by phone http://www.philstar.com/article.aspx?articleid=453552	24/7 medical advice to callers on health concerns, staffed by registered nurses and physicians to assess severity of situation and recommend right course of action. Uses a database of 700 000 medical protocols to accurately assess callers' symptoms or health concerns.	Philippines (active)
Telemed (Puerto Rico): primary health advice by phone http://www.fortherecordmag.com/archives/052410p20.shtml	Video and telephone conferencing from hospitals in Puerto Rico to Boston's MassGen hospital. Allows consultants to assess patients visually and interact with other medical staff. Used for remote monitoring of ICU patients at present; to be expanded into other areas of healthcare.	Puerto Rico (pilot)

Eastern Cape Health Call Centre: primary health advice by phone http://www.ecdoh.gov.za/	24/7 call centre and online information portal connecting registered nurses with the general public to answer questions or offer medical advice. Primarily centres around sexual health, but nurses are trained in all aspects of teleadvisory.	South Africa (active)
MedStar Health Information: primary health advice by phone http://www.medstarhealth.org/body.cfm?id=14	Provides health information to current patients of one of the MedStar hospitals. This includes the giving of medical results, advice about care, symptom checkers and a phone line to the office of your physician to call for support.	Trinidad and Tobago (active)
eSTI^2: STI diagnosis by mobile phones http://www.sgul.ac.uk/media/latest-news/mobile-phones-could-be-the-key-to-better-sti-diagnosis	A team led by St George's Hospital at the University of London, UK, is developing low-cost, self-test devices for sexually transmitted infections (STIs). The devices will be plugged into a mobile phone for immediate analysis of the outputs and provision of diagnosis and recommended treatments (without the need to make appointments at clinics or interact with a clinician). The consortium will use nanotechnology to create devices for testing multiple STIs, such as chlamydia and gonorrhea, similar to pregnancy test kits, which would be available in different settings (pharmacies and even vending machines). Software on the phone will analyse the sample, make a diagnosis and recommend action.	United Kingdom (in development)
NHS Direct: primary health advice by phone www.nhsdirect.nhs.uk	Provides advice, information, and reassurance through a telephone and website service. Also offers commissioned services to other parts of the National Health Service to meet patients' needs: out-of-hours support, telephone support for those with long-term conditions, pre- and post-operative support for patients, 24 hour response to health scares, and remote clinics via telephone. It is to be replaced by a new "111" service offering health advice and information about out-of-hours GPs, walk-in centres, emergency dentists and 24-hour pharmacies, staffed by mostly non-specialist "call advisers" rather than nurses.	United Kingdom (active)
3G Doctor iPhone FaceTime consultation: video conferencing with doctors as primary diagnosis http://www.3gdoctor.com/index.php?faq=1	The 3G Doctor service, available on iPhone 4,allows patients in UK and Ireland to consult with a registered doctor via a 3G video call. Patients log in to the secure mobile website where they can top up their account (each consultation costs GBP35), enter their problem and fill out a medical questionnaire. They then wait for a doctor to video call them and conduct the consultation.	United Kingdom (active)
Fonemed: primary health advice by phone http://fonemed.com/	Round-the-clock telephone or web-based access to medical advice, information, products, and services, using outsourced nurse triage services from a North American call centre; the company also supplies qualified partners with the tools, technology, protocols and know-how to operate proprietary Medical Call Centres as either installed systems (for internal use only) or with concession agreements.	USA (active)
Informed Health Line (Aetna): primary health advice by phone http://www.aetna.com/docfind/cms/assets/pdf/columbia/IHL.pdf	Unlimited freephone access to registered nurses to learn more about medical conditions and possible options for treatment. It is aimed not only at offering advice on the condition, but also to teach how to explain symptoms and ask the right questions during consultations with doctors.	USA (active)
Mobile phone eye testing accessory (aberrometer): eye testing though device attached to mobile phone screen http://www.mobiletor.com/2010/06/25/mits-media-lab-team-devises-netra-eyesight-testing-with-phones/	A small plastic device is attached to a mobile phone's screen with the patient looking into a small lens, pressing the handset's arrow keys so that parallel sets of red and green lines overlap. This process is repeated eight times at different angles for each eye, taking less than two minutes before software loaded on the phone provides prescription data. The cost of the device is between USD1-2.	USA (active)

Alere/Monica AN24 wireless foetal-maternal monitor: pregnancy monitoring service and risk identification for high risk conditions http://www.alere.com/docs/Monica_Alererelease_final_to_PR_Newswire.pdf	Configurable monitor for high-risk pregnancy management, with continuous monitoring of uterine activity, maternal and foetal heart rates, and maternal movement for bed-rest compliance; data can be easily serviced and retrieved from the home, and alerts sent to medical staff if readings fall outside pre-set safe levels. The device's connectivity makes risk assessment, risk identification and triage for patients with high-risk pregnancy conditions possible in a wireless real-time environment.	USA (active)
ThinkLabs heart/lungs visualiser for digital stethoscope: digital stethoscope which records data inputs for analysis over time period http://reactual.com/headphones/digital-stethoscope-connect-to-pc.html	As well as recording and displaying waveforms and spectograms in real time, the app offers a number of other functions designed to augment the usefulness of the ds32a digital stethoscope. Sounds can be translated into a visual format and can also be edited on screen. A doctor can also save and email recordings they take. Within the app, priced at USD70, is a library of pre-recorded sounds which can be used as a training aid or as a reference for when listening to a patient.	Worldwide (active)
WebMD Mobile: self diagnosis tool for smartphones http://www.webmd.com/mobile	The symptom checker function monitors the symptoms entered into the program to provide an immediate diagnosis. Very easy and quick to use, but reliability of results not guaranteed. Information is also available about medications and treatments, and there is a virtual First Aid Kit.	Worldwide (active)
Symptom MD: self diagnosis tool for smartphones http://www.symptommd.com/	Symptom checker for immediate response to concerns; also available in paediatric version for diagnosis of baby's symptoms.	Worldwide (active)

Emergency care		
LifeComm PERS: emergency call button for assistance for senior citizens, with embedded GPS http://mobihealthnews.com/7635/qualcomms-lifecomm-reborn-as-mobile-pers-service/	The mobile Personal Emergency Response System (PERS) is aimed at seniors and their carers, and is designed to provide affordable emergency assistance. It takes the form of a lightweight wearable device with one-touch access to an emergency assistance call centre. The PERS includes a mobile modem enabling voice and data communications, and an embedded GPS, which (combined with other sensors) enables location-based tracking and monitoring of the wearer.	Concept (in development)
Sikker Baby Monitor: baby health monitor http://medgadget.com/archives/2010/03/sikker_concept_baby_monitor_connects_parent_and_child_via_bracelet_1.html	Monitor designed for applications with babies at risk of sudden infant death syndrome. Both parent and baby wear a chargeable bracelet, supporting two-way communication as well as allowing the parent to monitor the baby's temperature and heart rate.	Concept (in development)
AT&T Fall-Prevention wireless slippers: emergency alerts for elderly patients who fall http://mobihealthnews.com/5675/att-develops-smart-slippers-for-fall-prevention/	The slippers are being developed with Texas Tech University, and use an accelerometer, pressure sensors and ZigBee technology to monitor a person's gait. The slippers use AT&T's network to transfer foot movement data; should anything be amiss an SMS or e-mail is sent to alert a doctor, potentially preventing a fall or alerting them if the wearer has already fallen.	Concept (in development)
Maternity/childbirth problem detection: D-Tree International diagnosis tool (decision support) http://www.grandchallenges.org/Explorations/Pages/GrantsAwarded.aspx	Development and testing of a mobile-phone-based tool using clinical algorithms that rapidly identify women at risk during labour and delivery, and facilitate emergency transfer to a hospital. The tool is a combination of phone decision support, data storage, on-line banking and communications on a single device at the point of care to improve maternal health outcomes. If successful, this tool could significantly reduce maternal mortality in low-income countries.	Concept (in development)

Coordinated mHealth action in disasters: telehealth system for international disasters http://mobileactive.org/issue-categories/emergency-response	As a response to the 2010 earthquake in Haiti, a group of health innovators are collaborating on a telehealth ecosystem to provide remote health monitoring equipment and infrastructure solutions: A&D Engineering by donating scales, blood pressure monitors and stethoscopes; Nonin by providing portable pulse oximeters; and Digicel (the largest mobile operator in the Caribbean) by providing connectivity for these devices. The partnership is looking to use mHealth and remote monitoring solutions to fill the void that has been created through the redirection of health services to the worst hit areas.	Haiti (in develop-ment)
iMonSys Verity: mobile phone and monitor for fall prevention http://www.imonsys.com/	Device designed for personal monitoring of elderly patients, taking readings from a range of sensors embedded in the strap of a wristwatch. Readings are transmitted to a mobile phone that responds by talking to the wearer should any of the readings be outside the norm. The wearer then confirms he or she is OK, or if there is no response, the mobile phone will call one or more nominated contacts or the emergency services.	United Kingdom (pilot)
Wellcore Personal Emergency Response Medical Alert System: emergency alerts and monitoring for those at risk of falls www.wellcore.com	Wireless device aimed at the elderly or those suffering from conditions such as Alzheimer's, providing autoalert automatic fall detection. The person monitored wears a small personal activity monitor, which detects a fall and immediately alerts an emergency call centre. Activity and rest patterns are monitored, tracked and relayed to a private password-protected website where carers can view data and receive alerts and reminders.	USA (active)
Exmobaby Wireless Pyjamas: wireless-enabled baby clothes for monitoring for SIDS http://www.gizmag.com/exmobaby-pajamas-real-time-baby-monitoring-cell-phone/16183/	Baby garment designed to monitor a baby's heart rate, emotional state and activity level, which relays the information wirelessly to a cell phone or computer of the parent who can monitor it; designed to help detect indicators of risk of sudden infant death syndrome.	Worldwide (pilot)

Management of long-term conditions		
Tracking mental health of teenagers: mobile electronic diary for mental health tracking http://www.mcri.edu.au/pages/research/news/2010/8/mobile-phones-track-teens-mental-health-in-Albury-Wodonga.asp	At the Murdoch Children's Research Institute in Australia, mobile phones have been used to track the mood of children and young people aged 14-24 with mental health problems. The program uses an electronic diary that allows youths to report a board range of daily experiences including mood, stress levels, coping strategies, alcohol and cannabis use, exercise, eating patterns and general lifestyle factors. Responses are sent to a website interface which evaluates and assesses each patient's mental well-being and produces an individual report for the doctor to help them determine what treatment is required.	Australia (trial)
SIMsystem smart incontinence detection pants: monitoring and alert for incontinence in elderly patients http://www.mhealthupdate.com/?p=889	It is estimated that 80% of Australian Aged Care facility residents are incontinent and that the government spends AUD1.5bn on managing this each year. Trials suggest that SIMsystem can save up to AUD2k in the labour costs associated with incontinence management per bed, per annum. The manufacturers also say that more accurate assessment of continence events leads to improved management of incontinence sufferers and therefore improved quality of life for residents of Aged Care facilities.	Australia (active)

SubQore implantable radio: low-power radio for monitoring of medical equipment/implants http://www.cambridgeconsultants.com/cs_subqore_wiremed.html	SubQore is suitable for devices using the Medical Implant Communications Service (MICS) frequency band in the USA, and the Ultra-Low-Power Active Medical Implants band (ULP_AMI) in Europe. This 402-405MHz band is rapidly becoming adopted in other countries around the world. Among the applications for which SubQore is appropriate are implantable pacemakers, defibrillators, orthopaedic devices, pain management, neurostimulation, and swallowable imaging and diagnostic systems.	Concept (in develop-ment)
SmartTrack Drugs Tracking for HIV/AIDS & other drugs: drug tracking to monitor supply and prevent stock outs http://research.microsoft.com/en-us/collaboration/focus/health/smarttrack.pdf	Developed from similar programme for cancer drug tracking in the USA called eMedOnline, this is a system that could be deployed in other parts of the world for HIV and other treatable diseases such as malaria and tuberculosis. It is being developed to work with basic cell phones and a text-free interface, with RFID tags on drugs to track their movement through the supply chain.	Ghana (trial)
Mobile Direct Observation Treatment (MDOT): using video-enabled mobile phones to monitor medication adherence http://www.prohealthservicezone.com/Customisation/News/IT_and_Communications_in_Healthcare/Communications_equipment/Mobile_video-enabled_phones_help_to_monitor_medication_adherence_of_TB_patients.asp	Pilot study on the effectiveness of mobile video-enabled phones in meeting the requirements for monitoring medication adherence by tuberculosis patients. (The World Health Organization recommends directly observed treatment of tuberculosis patients to monitor medication adherence, as non-compliance with the medication protocol can lead to the more dangerous Multidrug Resistant TB). The study also examined the reactions of participants to text and video health messages sent via the mobile phone.	Kenya (pilot)
Weltel: patient-centred text messaging supporting antiretroviral medication adherence http://www.weltel.org/	HIV-positive patients are sent weekly text messages inquiring about their well-being; where patients respond that they have a problem, a healthworker calls back to assist them. Weltel also provides health-related information to the public, designed to facilitate behaviour change; is able to track diseases in an area or population; supports remote data collection; gives long-distance support to health workers; and facilitate logistics of moving health related products.	Kenya (trial)
Cardiocom pulse oximeter for home teleheath: pulse oximeter for remote testing, integrated with telehealth communication platform www.mhealthafrica.com/?p=29	Minneapolis based Cardiocom, a designer and manufacturer of telehealth communication devices and vital sign peripherals including blood pressure systems and weight scales, has added a pulse oximeter offering to its telehealth platform, designed for use in the home telehealth environment.	Many countries (active)
Medtronic M-Link cellular accessory for implanted cardiac devices: monitoring of cardiac devices remotely, and alert when problems are encountered http://www.medtronic.com/carelink/	The M-Link cellular accessory simplifies the connection to the CareLink Network, securely connecting any CareLink patient monitor, allowing patients to transmit data from their implanted device to the clinic through the secure network, and providing a simple and convenient means of staying connected whether at home, work or travelling globally. The device also transmits notifications when any programmable alert conditions are met. The M-Link accessory allows clinicians to remotely monitor more patients implanted with devices, and to view transmitted data through a secure website, meaning they can review the functionality of a patient's device in real-time.	Many countries (active)
Vidanet: education strategies and advice for people living with HIV/AIDS http://www.voxiva.com/content/case_studies/VidaNET.pdf	Vidanet gives people living with HIV the ability to register to receive messages to help improve their adherence to their specific treatment, with the aim of generating changes in attitude towards self-healthcare, health risk prevention, and adherence to specific prescribed treatments.	Mexico (active)

Diabediario: diabetes self management tool for treatment advice and medication adherence http://www.voxiva.com/content/case_studies/Diabetes.pdf	Any diabetic person with a TelCel mobile phone can participate in the programme, which uses telecoms to generate changes in attitude towards risk prevention and adherence to prescribed treatments. Diabediario supplements rather than replaces doctor's visits or medicines. This system empowers the patient to take control of their health by taking steps to control their diabetes.	Mexico (active)
TRACnet: collects and disseminates drug and patient information relating to HIV/AIDS care and treatment http://www.un.org/esa/sustdev/publications/africa_casestudies/tracnet.pdf	TRACnet is designed to collect, store, retrieve, and disseminate critical program, drug, and patient information related to HIV/AIDS care and treatment. Under the leadership of the Rwandan Ministry of Health and the Treatment Research and AIDS Centre (TRAC), the system was implemented to support the government's vision of scaling up HIV/AIDS clinical services in a variety of healthcare settings. As well as supporting the management of these LTCs the application is also beneficial for public health research.	Rwanda (active)
AED Satellite: support systems and information for those with long term conditions http://www.healthnet.org/uhin	ICT initiatives through the US-based not-for-profit Academy for Educational Development providing support for HIV/AIDS, malaria, child and maternal health, and health systems management programs.	Uganda, Mozambique (active)
Bayer Didget: blood glucose monitoring system for children, linked to computer games http://www.bayerdidget.co.uk/	Blood glucose monitoring system which rewards children for consistent testing with fun games they can play online or through Nintendo DS. The CONTOUR blood glucose meter plugs into the Nintendo DS which motivates children to test. Nurses are also available on phones to help with testing and monitoring.	United Kingdom and Europe (active)
Diabetes self-management trial: diabetes self management through telehealth http://www.primarycare.ox.ac.uk/research/vascular/Research/Telehealth and mHealth application reference material\Oxford mobile phone diabetes.pdf	GPRS-based system developed to assist in the self management of patients with Type 1 diabetes. Uses direct data download from blood glucose machine, with immediate wireless transmission of the readings to a central server. Clinical staff can then contact the patient by SMS or by telephone if there is cause for concern.	United Kingdom (active)
Proteus Smart Pills UK trial: reminders for patients who might otherwise forget to take medication http://www.mhealthupdate.com/?p=1322	The Royal Berkshire and Imperial College healthcare trusts will be conducting a clinical trial using "smart pills" developed by US company Proteus Biomedical. The system was originally tested in the USA. Subjects are given versions of their regular beta blockers and diuretic pills that include a small microchip. The pill sends signals to a patch worn by the patients, which then sends them a text message if they forget to take their prescription. It is hoped that it will lead to increased efficiency and better patient care by improving patient compliance (which is typically poor) and reducing hospital readmissions.	United Kingdom (trial)
Phone-based platform for monitoring drug compliance: combining diagnostic test with economic rewards for submission of test results http://www.grandchallenges.org/Explorations/Pages/GrantsAwarded.aspx	A novel drug-compliance platform combining the use of mobile phones for a simple diagnostic test with economic incentives. The device will include a platform that measures drug metabolites in bodily fluids to generate a readout. Test results submitted on time will result in immediate economic rewards, such as additional cell phone minutes.	USA (in develop-ment)
mCare: case management of reintegrated soldiers http://www.usamraa.army.mil/pages/announce/W81XWH-10-R-0141/Amendment_0001.pdf	US Army Medical Department mobile phone messaging application for the case management of reintegrated wounded soldiers. Includes SMS-based wellness tips, and appointment reminders for US service members returning from duty. Ported content from afterdeployment.org to a cell phone. HIPAA compliant.	USA (active)

DIMA Dietary Intake Monitoring Application: mobile health application for dietary insight for a chronically Ill, low-literacy diabetic population http://www.cs.indiana.edu/surg/Projects/DIMA_SURG_Page/DIMA.html	Personal digital assistant to assist dialysis patients to accurately monitor their fluid and sodium intake. Leads to more accurate results as patients are not reliant on their memory to record levels. Patients are given immediate feedback on their fluid and sodium intake and researchers gain information about compliance.	USA (active)
WellDoc Chronic Illness Management/Patient Coach: disease management tool for chronic illness to increase medication adherence http://www.welldocinc.com/	WellDoc provides a modular platform for the management of chronic illnesses, capable of being configured to support a number of applications including medication adherence and multi-disease management. Their Patient Coach system conveys educational and contextualised data as a means of encouraging patients into better self-management and healthier lifestyles. The solution can be applied to diabetes, cardiovascular illnesses, mental health and general wellness. Outcomes from clinical trials of diabetes suggest that the platform could unlock savings of up to USD50bn for the US healthcare system.	USA (active)
MedApps HealthPAL: chronic disease monitor for the home http://www.medapps.net/	Telehealth app to deliver connectivity to electronic health records, promote patient wellness and reduce healthcare costs by improving patient compliance. Collects, stores and reports health information. Can connect to pulse oximeters, glucose meters, blood pressure monitors or scales to report back to healthcare professionals. Health Pal mobile phone collects and transmits readings from off the shelf medical devices.	USA (active)
Cinterion/Philips Respironics System One Sleep Therapy Device: sleep apnoea solution to aid sleep therapy http://www.cinterion.com/news-detail/items/cinterion-healthimo-and-philips-respironics-selected-as-mobile-health-expo-2010-award-winners-for-best-mobile-healthcare-device.html	Machine-to-machine sleep apnoea solution combining mobility and reliable two-way wireless communications with significant advances in sleep apnoea therapy to help millions of patients and their healthcare providers who must meet rigorous new reporting standards. The device currently operates on the nPhase AT&T network in the USA and is scheduled to be rolled out in markets around the world.	USA (active)
Congestive heart failure disease management trial: management tool for CHF sufferers http://www.telecareaware.com/index.php/meridian-healthmedapps-telehealth.html	Collaboration between New Jersey based healthcare provider Meridian Health and developer of remote health monitoring technology MedApps, to initiate a chronic disease management pilot targeted at sufferers of Congestive Heart Failure (CHF). The aim of the programme is to monitor participants on a near real-time basis with a view to improving patient outcomes and decreasing readmissions to hospital within 30 days.	USA (active)
MAHI Mobile Access to Health Information: management tool for glucose for diabetic sufferers http://www.texting4health.org/slides/sabadosh%20cdc%20T4H%2002%2029%2008.pdf	Each time a diabetic patient uses a glucose meter, he or she receives a phone call to gather data on why they are using it, using a java-enabled cell phone connected to the glucose meter via Bluetooth. Individuals record several messages per day. Data typically collected include pictures of food, pictures of confusing food labels, voice notes with specific problems.	USA (in develop-ment)
HealthPartners/Diversinet MobiSecure platform: monitoring and communication tool for high-risk patients http://healthcare.tmcnet.com/topics/healthcare/articles/92634-healthpartners-leverages-diversinets-mobisecure-platform-improve-quality-care.htm	HealthPartners, the largest consumer-governed, non-profit healthcare organisation in the USA, has licensed Diversinet's MobiSecure platform in an effort to enhance mobile communications with its 1.3 m subscribers. The first applications will be for the use of women with high-risk pregnancies and sufferers of chronic illnesses recently discharged from hospital, aimed at reducing premature births and hospital readmissions. The platform enables HealthPartners to communicate with and increasingly monitor patients in a more personalised, more detailed and continuous manner.	USA (in develop-ment)

Autism interaction via mobile devices: images on mobiles to help autistic children learn http://research.microsoft.com/en-us/collaboration/focus/health/smartphone_autism_comm.aspx	Device designed for children with autism, using PECS (Picture Exchange Communication System) style communication methods on a smartphone. Software also tracks which pictures are being used and how often, in order to help teachers assess learning progress.	USA (trial)
iMPak Health Journal for Pain: wireless diary to record pain levels during the course of medical treatment http://www.homecareagencynews.com/home-care/health-journal-for-pain-to-be-first-offering-from-impak-health/#	A portable, lightweight, wireless-enabled diary that allows users to record pain levels before and after their medication. Doctors are then provided with detailed, readily available patient information pertaining to the success of pain-killing prescriptions. The Health Journal for Pain has been developed around Cypak's Touch and Post technology and Near Field Communication technology.	Worldwide (active)
iPro2 glucose monitor: monitoring of glucose levels to transmit to healthcare professionals http://wwwp.medtronic.com/Newsroom/NewsReleaseDetails.do?itemId=1275922276198&lang=en_US	iPro2 Professional CGM uses a tiny glucose sensor to record as many as 288 glucose readings over a 24-hour period. Glucose data captured in the system is uploaded to CareLink iPro Software and viewed retrospectively by healthcare providers.	Worldwide (active)
Entra MyGlucoHealth: wireless upload of blood test for diabetes patients on Nokia and other smartphones http://www.entrahealthsystems.com/news/MyGlucoHealth_Diabetes_App_Available.html	App making it possible for users to wirelessly upload blood test results to the MyGlucoHealth portal, so that results can be reviewed and evaluated using the handset, data can be charted, and weight, exercise and nutritional information can be entered. The app also makes it possible to notify family, physicians and carers via automated SMS and to set reminders for when readings exceed previously defined thresholds. Users can use the app for two-way communications with their doctor and to order replacement test strips for their glucose meter.	Worldwide (active)

Information and self-help		
Medicine Link (China Mobile): mobile information service on health issues	A mobile information service encouraging safe and rational drug use. Subscribers to the service receive three to five messages per week on subjects such as sensible drug use, food and drug safety, and healthy eating, as well as information on policy changes and important notices from the food and drug authorities on potential adverse reactions to medicines.	China (active)
Medical Link (China Mobile): mobile information service on health issues	China Mobile offers a variety of information services as part of its Medical Link offer in Guangdong. It charges a fee for regular access to information about healthy lifestyles, and on specialist topics of interest to different groups of subscribers. It is also a platform to disseminate public health information.	China (active)
Vaccine Link (China Mobile): vaccination information system for parents and children	A vaccine information system for parents and children, targeted particularly at parents of children up to the age of seven already registered with vaccine inoculation stations. This service sends vaccine inoculation notices to parents, and can also send child-health-related information on infant feeding, early education, maternal and child healthcare, child and parenting classes, etc.	China (active)
UNICEF/Georgia: HIV/AIDS video distribution by mobile http://www.ehealtheurope.net/img/document_library0282/mHealth_for_Development_full.pdf	20 minute film on HIV/AIDS aimed at young people in Georgia, with well known young actors portraying the health risks of everyday decisions and behaviours. Has been converted into a format that is viewable on mobile phones, and disseminated to young people who were encouraged to pass it on to their friends.	Georgia (active)

Freedom HIV/AIDS: mobile-based games targeting different mindsets and psychology of mobile users http://www.freedomhivaids.in/	HIV/AIDS awareness initiative using mobile phone games aimed at children and young people in remote regions without access to other information. Play-and-learn method is used to help engage young people with information relating to prevention of HIV/AIDS. Four different games to appeal to different mindsets; safety cricket, ribbon chase, the messenger and quiz with Babu. The games are deployed on low-end monochrome to sophisticated high-end devices.	India and various African countries (active)
mDhil: SMS- and mobile web-based healthcare information http://www.mdhil.com/	mDhil provides SMS-based and mobile web-based access to healthcare information; its SMS health text alert services cost Rs1 per day (minimum 10 day subscription), and provide information about health issues such as weight, diet, stress, skin and beauty, plus specific information geared to diabetes and tuberculosis patients. It has over 150 000 subscribing customers and is growing rapidly.	India (active)
Food and exercise motivational mobile phone app: app to monitor food intake, and exercise and deliver tailored, location-based motivational messages http://www.eu.ntt.com/en/about-us/newsroom/news/news/article/ntt-com-ntt-resonant-and-foolog-to-field-trial-worlds-first-cloud-based-mobile-service-for-heal.html	Monitors food intake and daily exercise activities, in order to be able to provide timely recommendations about how to lead a healthier lifestyle. The app works through taking photos of the food consumed to estimate calorie intake, and through motion sensors detecting exercise and daily walking; the system then compares these two data sets. Customised messages are sent to the person being monitored, as well as being shared with social networking sites to ensure take up.	Japan (active)
Mobile4Good: Information distribution by SMS for health promotion http://www.mobile4good.biz/	Includes mobile gaming for educating audiences about HIV/AIDS prevention and management, in a format they are comfortable with. There is also a MyQuestion service allowing people to anonymously ask HIV/AIDS related questions, and a health tips service to provide tips on pertinent health issues. Unusual in that those who receive such text messages have to pay for them.	Kenya (active)
CardioNet: healthy living advice and guidance based on personal information about lifestyle and habits http://www.comminit.com/en/node/310875/3076	CardioNet promotes self-healthcare, health risk prevention, and adherence to prescribed treatments. Individuals complete a questionnaire on sex, age, weight, height, known health problems (e.g. diabetes or smoking) as well as blood pressure and cholesterol if known. Based on these answers, the individual is evaluated according to WHO standards; from this assessment the individual begins receiving educational messages encouraging exercise and healthy eating.	Mexico (active)
Project Masiluleke: build awareness of HIV status, encourage HIV/AIDS testing and treatment http://www.poptech.org/project_m	Various support services for those with HIV/AIDS, including: • Please Call Me: information added to text messages commonly sent by pay-as-you-go subscribers requesting a call back, covering healthcare, counselling and referrals to local testing clinics. Since the initiative started there have been over 1.5 million calls to the National AIDS helpline. • TxtAlert: SMS to remind patients of scheduled clinic visits to ensure adherence to anti-retroviral drug programmes. • HIV Self Testing: Low-cost self testing with counselling support via mobile phone. Free, private way for people to establish their HIV status. Stigma has been identified as a major barrier to the control of HIV/AIDS, as people do not want to be known as HIV positive. Self-diagnosis may help halt spread as people are not afraid to test themselves without the stigma associated with going to a clinic.	South Africa (active)

Text to Change: HIV/AIDS awareness quiz and information and monitoring http://www.texttochange.com/AIC-TTC%20Arua.pdf	Uses mobile phones for HIV education and to motivate the public to go for HIV counselling and testing services in the north-west of Uganda. TTC (a Dutch non-profit organisation) is a complementary service provider using mobile telephony as a medium to communicate about health related issues to support (existing) health communication campaigns. Also captures information about behaviour patterns and knowledge levels of users which will be fed into the national health system database to help in programme planning and policy formation.	Uganda (active)
NHS Drinks Tracker iPhone app: alcohol unit calculator and advice on drinking habits (for smartphones) http://www.nhs.uk/Tools/Pages/iphonedrinks.aspx	The NHS Drinks Tracker – available through iTunes – allows users to figure out how many units a particular beverage contains as well as to log and review how much they have consumed over a given period. The NHS Drinks Tracker also provides personalised feedback on drinking habits and provides the locations of nearby NHS clinics and advice centres.	United Kingdom (active)
MiQuit: feasibility trial of smoking cessation intervention for pregnant smokers http://www.medschl.cam.ac.uk/gppcru/index.php?option=com_content&view=article&id=312:miquit&catid=12:project-profiles&Itemid=59; http://www.researchkm.nihr.ac.uk/2010Event/Posters/MiQuit%20summary.pdf	Trial of an SMS-based system for delivering personalised encouragement and support to pregnant smokers who want to stop smoking. The trial provided individualised written and text-message support to pregnant smokers, with the primary aim of assessing the feasibility and acceptability of a computer-tailored smoking cessation intervention for this group. The study showed the system was capable of delivering valuable messages to individuals, and practical to implement.	United Kingdom (trial)
iPLATO patient messaging: smoking cessation text messages and campaigning http://www.iplato.net/uncategorized/greenwich-patients-benefit-from-text-messages-from-their-gps.html	The iPLATO Patient Care Messaging system is credited with reducing missed appointments in several London boroughs by 26%-40%. In terms of health promotion, the service is to be used as part of the NHS's Smoke Free campaign, communicating more directly than TV advertisements and posters by targeting a patient's mobile phone, which is by and large a personal device. Using searches on the GP system a text message is sent out asking whether a patient smokes; replies are simply 'yes' or 'no', and follow up messages are sent to all those who replied 'yes'. From here, advice and information is much more focussed and therefore cost efficient as it is directed solely at those to whom it is of value. As well as providing support to those wishing to improve their health, the application also has benefits for whole system efficiency.	United Kingdom (pilot)
Text4Baby: free SMS information service for pregnant mothers http://www.text4baby.org/	Text messages provide reminders and information about immunisations, nutrition, oral health and child development, as well as toll-free numbers for health services. Text4Baby was formed as a public-private partnership, including government, corporations, academic institutions, professional associations, tribal agencies and non-profit organisations. Targeted at low-income communities and launched in February 2010, it already has over 100 000 users.	USA (active)
MedicareBlue PPO: hospital/physician locator http://www.yourmedicaresolutions.com/plan_options/medicareblue_ppo/2011/index.html	Helps callers to find a doctor, clinic or hospital within network coverage, or online. It offers a comparison between the options to find the most suitable location.	USA (active)
Mobile MedlinePlus: Information service on health topics, news, diseases and medications http://m.medlineplus.gov/	An extension of The US National Library of Medicine's web-based health information system MedlinePlus, designed to "meet the health information needs of an on-the-go public". MedlinePlus provides consumer health information to over 10 million visitors each month, and includes summaries for over 800 diseases, wellness topics, latest health news, an illustrated medical encyclopaedia and information on prescriptions and over-the-counter medicines.	USA (active)

Web-based mobile support for Tobacco Quitline http://smoking-quit.info/local-partners-study-mobile-support-for-dc-tobacco-quitline	The Washington DC Tobacco Quitline is currently updating its system to take real time smoking cessation data and close the loop using feedback to improve adherence; also adding web interface to integrate with telephone quitline.	USA (pilot)
Tap and Track, Calorie, Weight and Exercise Tracker: healthy eating tracking and advice app http://nanobitsoftware.com/	A weight loss tool for use on smartphones, similar to CalorieCounter, but this app also measures the breakdown of food consumed into fat, protein, carbohydrates, fibre, sugar, and sodium, and calculates a GI Index of all food consumed.	Worldwide (active)
iQuit: iPhone smoking cessation app http://itunes.apple.com/us/app/iquit/id294206243?mt=8	Free iPhone app providing smoking cessation routines from which users can choose. Integrates with Facebook so that friends can encourage the user to stop smoking.	Worldwide (active)
iFitness: iPhone app providing tailored fitness programmes http://gigaom.com/apple/ifitness-workout-smarter-with-your-iphone/	An app for iPhone and iPod Touch, priced at USD 2, which provides training programmes to suit different fitness regimes working different muscle groups. Programmes can be customised, and the app allows goals to be set and progress to be monitored.	Worldwide (active)
RunKeeper: free iPhone app measuring speed and distance of runs http://runkeeper.com/	iPhone app that uses the GPS capabilities of the device to measure speed and distance of runs (and also calculates calories burned). Data can be uploaded to a website so that the exercise history can be stored.	Worldwide (active)
CardioTrainer: mobile fitness app for Android phones http://www.androidfreeware.net/download-cardiotrainer.html	Mobile fitness app for Android phones, using GPS to show the user's real-time position on a map, and allowing the route to be saved on the phone or server for later review, or shared with Facebook friends in order to harness their encouragement for achieving fitness goals. Available as free download; users are then offered several paid-for apps.	Worldwide (active)
Pregnancy Tracker: tracking throughout pregnancy, providing information for the different stages http://www.whattoexpect.com/mobile.aspx	Informative foetal monitoring system to monitor a pregnancy week by week, using a smartphone. It provides information and advice for each stage for both mother and child health. Is used as an advertising tool for baby products.	Worldwide (active)
CalorieCounter & Diet Tracker: healthy eating tracking and advice app http://www.myfitnesspal.com/	A weight loss tool for use on smartphones. Monitors calorie intake by the user entering (or photographing) food intake. The user also inputs personal details and exercise regime. The app then provides relevant advice as required.	Worldwide (active)

Whole system efficiency improvement		
Appointment reminders by SMS: improving patient attendance by mobile phone reminders http://www.ncbi.nlm.nih.gov/pubmed/16879098	In Melbourne, Australia, an assessment of the effectiveness of SMS reminders for over 20 000 patients at the Royal Children's Hospital found that "Did Not Attend" rates were significantly reduced when a SMS reminder was sent. The study concluded that the cost of sending the SMS messages was outweighed by the increase in revenues and other benefits, and that SMS is a very cost effective approach for improving patient attendance.	Australia (active)
Response to disease outbreaks: using mobile phones to direct rapid response http://instedd.org/map/cambodiaoutbreakrrtcoordination/	In Cambodia, Rapid Response Teams (RRTs) under the control of the country's Communicable Disease Control (CDC) Deputy Director receive information from central HQ about disease outbreaks very rapidly via mobile phones. RTTs can engage in chats with each other about the outbreaks using InSTEDD's open source GeoChat collaboration platform. The system has been used since May 2009 to send updates and information to the RRTs, starting with H1N1 and more recently for a severe diarrhoea outbreak. The ability of headquarters to keep field staff informed prepares them to be 'on the watch' for certain diseases much earlier than before.	Cambodia (active)

Appointment reminders by mobile phone or SMS: improving patient attendance by mobile phone reminders http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2170466/	A randomised controlled trial of SMS text messaging and mobile phone reminders at a health promotion centre, conducted at Zhejiang University, China, showed that both methods of reminding patients were effective; the attendance rates were significantly higher in SMS and telephone groups than that in the control group. No difference was found between the two methods in terms of effectiveness (though the cost of the SMS reminder was lower than the cost of telephone call reminders).	China (active)
PatientLink (China Mobile): integrated IT platform for hospitals, patients and public - multiple applications built on converged fixed/mobile platform	A platform giving patients access to healthcare information, enabling them to communicate remotely with doctors (including video consultation). Also a mobile office platform for doctors, giving remote access for doctors to information about patients' conditions. Includes facilities to arrange times for consultations and remote "visiting" of sick patients.	China (active)
Drug RFID smart regulation (China Mobile): drug tracking through supply chain using RFID-tagged drugs	In China's Guangdong Province, a "smart drug regulation" system is being established for piracy prevention. A single central database holds information on the provenance of medicines. Each package is coded with both an RFID tag and a 2D barcode. Fixed or mobile networks can be used to access the central database and authenticate a package. The aim of the system is to establish a regulated standard that the central government agencies and manufacturers can adopt.	China (active)
SMS-based information system for low-end phones: prototype content authoring platform http://www.grandchallenges.org/Explorations/Pages/GrantsAwarded.aspx	A prototype (developed for the Grameen Foundation USA) of content authoring and management software for delivering health information and tools to low-end mobile phones able to display only 160-character SMS messages on small screens. Creating a platform for the dissemination of new and already existing information through mobile phones can provide much-needed access to critical health resources.	Concept (in development)
Phone-based biometric vaccination registry: field registry based on fingerprint scanning http://www.grandchallenges.org/Explorations/Pages/GrantsAwarded.aspx	VaxTrak is a mobile phone-based vaccination registry that uses fingerprint scans to track those who have received immunisations. The aim of the development is to reduce redundant doses and boost coverage levels in developing countries, particularly in Africa.	Concept (in development)
ChildCount+: mHealth platform to empower communities and improve child survival and maternal health http://www.childcount.org/support/	Uses SMS messages to facilitate and coordinate the activities of community-based healthcare providers, and to register patients and their health status on a central web dashboard that provides a real-time view of the health of a community. Automated alerts help reduce gaps in treatment.	Kenya (active)
Nigerian drug authentication trial: SMS-based authentication service to address challenges of drug counterfeiting http://www.sproxil.com/blog/?p=297	The Nigerian National Agency for Food and Drug Administration and Control trialled a Mobile Authentication Service for a drug used in diabetes treatment. Consumers confirm the authenticity of the drug by scratching a label on the packaging to reveal a code number, and sending this number by SMS to a database server. An immediate text reply confirms whether the drug is genuine or a fake (or if the secure PIN has already been used or is not recognised), and also contains a helpline number. The study concluded that the costs of the trial were less than the benefits to the pharmaceutical company through sales recovery and brand retention.	Nigeria (trial)
ResultsSMS: open-source platform to disseminate test results, patient education, appointments and adherence reminders to patients via SMS http://resultssms.org/	SMS based results delivery system that builds on existing electronic medical record systems to automatically send test results to patients as well as healthcare providers and researchers as they become available. Also allows for the delivery of targeted public health messages based on test results to assist patients with follow up.	Rwanda/ Uganda (active)

Orange Smartnumbers: phone transfer service to other doctors if one is unavailable http://business.orange.co.uk/home/public/products-and-services/applications-and-solutions/orange-smartnumbers	Enables organisations to handle calls made to mobile numbers in accordance with specific service needs. For example, if a doctor is on duty and unavailable to take a call, it is diverted to the appropriate colleague. This creates a more flexible and efficient healthcare service. Smartnumbers will be particularly useful for health workers in the field such as midwives, nurses and carers for whom 60% of ordinary call attempts to colleagues fail to reach the right person first time.	United Kingdom (active)
Digital pen and paper: midwives using smartphones and "electronic pen and paper" for note taking http://www.bjhcim.co.uk/news/2010/n1003015.htm	Midwives working with Portsmouth Hospital in the UK use BlackBerry smartphones and electronic pen and paper technology to take notes during consultations in the community; the system allows the notes to be automatically sent back to the hospital's clinical system, without hindering the patient consultation. When a nurse fills out the form, the pen captures what is written and then automatically encrypts and sends the data via Bluetooth to the phone, which in turn sends the data to the maternity unit's patient records system. It is claimed that the system has generated time savings equivalent to five full-time midwives, and paid for itself in the first year.	United Kingdom (active)
PatientKeeper: multi-device patient information platform http://www.patientkeeper.com/	Connects patient information from hospitals, GP practices, healthcare community systems, etc., to create a single actionable view for ease of access and treatment when needed.	USA (active)
eHealth record access validation platform: credentials platform for access to health records http://www.verizonbusiness.com/about/news/pr-25645-en-Verizon+To+Issue+Identity+Credentials+to+Nearly+All+U.S.+Health+Care+Professionals.xml	Telehealth portal allowing any medical professional to be able to access and share patient information (such as medical notes, laboratory test results, x-rays, images, and other important information) to enable accurate diagnosis and to record information about patients regardless of which physician is in charge of their care.	USA (active)
Epothecary: drug pedigree tracking and authentication using mobile phones http://cs.nyu.edu/~mpaik/pubs/epothecary.pdf	The Epothecary system, developed at New York University, uses 2D matrix barcodes on drug cartons and mid-level phones with cameras (and GPS modules if available), together with SMS-based or GPRS mobile-data-based communication, for authentication and track/trace applications. The system enables the location of consignments to be known whenever the 2D code is scanned or photographed; this information can be compared with database records of buyers and sellers within the supply chain.	USA (in development)
FrontlineSMS: SMS service to send and receive SMS with large groups of people for information dissemination http://www.frontlinesms.com/, http://medic.frontlinesms.com/	Frontline SMS is a free, open-source software platform that enables large-scale, two-way text messaging using only a laptop, a GSM modem, and inexpensive cell phones. Used for monitoring of disease outbreaks, disaster relief coordination, natural resource management, field data collection, co-ordination of rural clinics, conducting public surveys, mobile education projects, etc. in over 40 countries worldwide. FrontlineSMS: Medic is an extension of the platform for patient management, electronic medical records via the cell phone, low-cost mobile diagnostics, and mapping of health services.	Worldwide (active)
Epocrates iPhone app: enabling healthcare professionals to request information from Pfizer and report adverse effects of medication http://media.pfizer.com/files/news/press_releases/2010/pfizer_epocrates_access_060210.pdf	Using Pfizer's app for the iPhone (and other smartphone platforms), clinicians are able to make direct contact through the drug reference app to the manufacturer, and apply the information they download to patient care. The aim is to enhance the safe and effective use of medicines and improve the quality of patient care. Any adverse reactions can be reported, and doctors can expect rapid and tailored scientific responses to their questions about the drugs.	Worldwide (active)

Elpas Enhanced RTLS Nurse Call System: real-time location system integrated into nurse call system http://www.medicexchange.com/Visonic-Technologies/rauland-borg-a-visonic-brings-rtls-to-responder-5.html	A real-time patient location system integrated into the nurse call system for quicker response to wandering patients in hospitals. Functions at high levels of accuracy throughout the hospital, and includes automatic visual indication that a patient's needs are being responded to as well as automatic nurse call cancellation.	Worldwide (active)

Annex B: Participants in the Workshop and the Interview Programme

Professor James Barlow holds a Chair in Technology and Innovation Management at the Imperial College Business School. He is the Principal Investigator of the EPSRC Health and Care Infrastructure Research and Innovation Centre (www.haciric.org) and an executive member of the NIHR Northwest London CLAHRC. His research focuses on innovation in complex sectors of the economy, with a particular emphasis on healthcare. He is currently working for the Department of Health on the evaluation of its Whole System Demonstrators programme. He recently led an inquiry into the uptake and spread of innovation in the NHS for the Policy Exchange. In 2006 he led a foresight project on telehealth futures for the Department of Trade and Industry, which shaped the current Assisted Living Innovation Platform programme. He has been a member of expert panels on healthcare innovation issues for the Department of Trade and Industry, Department of Health, Ofcom, the Welsh Assembly Government, the European Commission, the Royal Society and the King's Fund. Before joining Imperial he held positions at SPRU (University of Sussex), the University of Westminster and the Policy Studies Institute. He has a PhD from LSE and a background in geography and economics. http://www3.imperial.ac.uk/people/j.barlow

Dr Michael Barrett, Reader in Information Technology and Innovation, Judge Business School, University of Cambridge. Michael's research interests include service innovation and knowledge exchange in health care, and the use of mobile infrastructures to enable social innovation in emerging economies. He has worked extensively with WHO in the development of their knowledge management strategy, and conducted research on implementation of a regional health information infrastructure and service innovation for emergency response and telemedicine in Crete. In the NHS, he researched the implementation of electronic patient records and decision support systems for multidisciplinary health care teams for cancer care in the UK. He holds an MSc from the University of Ottawa, an MBA from McMaster University and a PhD from Cambridge. http://www.jbs.cam.ac.uk/research/faculty/barrettm.html, http://www.health.jbs.cam.ac.uk/people/faculty.html

Dr Alan Blackwell, Senior Lecturer, Computer Laboratory, University of Cambridge. Alan's research focuses on constructing and applying models of human behaviour when interacting with technology. These models take a variety of forms, with a particular interest in neuroeconomic models of abstraction formation and use - a theoretical base which is broadly applicable to the design of new technologies, including software that is programmable and customisable by end-users, and the use of domestic technologies. Alan is co-director of Crucible, the Cambridge University network for research in interdisciplinary design (http://www.crucible.cl.cam.ac.uk), whose purpose is to encourage interdisciplinary collaboration of technologists with researchers in the arts, humanities and social sciences. http://www.neuroscience.cam.ac.uk/directory/profile.php?afb21

Ms Tao-Tao Chang (Project Adviser) works in the field of International education and cultural relations, with particular focus on China. Her current role is as Consultant to the Fitzwilliam Museum in Cambridge, developing the Museum's international strategy with a view to expanding its presence and engagement with cultural institutions in East Asia; previously she was responsible for developing the University of Cambridge's institutional partnerships and alliances overseas (as Head of the International Office). Earlier in her career she worked at Queen Mary College in London as International Officer for East Asia. Tao holds an MA in Modern Chinese History and Politics from SOAS and a BA in Classics from Cambridge. http://uk.linkedin.com/in/ttchang9jl

Professor Jo Chataway, Professor in Biotechnology and Development, Open University, and Director, Innovation and Technology Policy, RAND Europe. Jo's research interests focus on translating innovation into processes, practices and policies that have the potential to make a practical difference to societies, particularly those in developing countries. At RAND Europe her team has four broad research areas: research evaluation; understanding the issues around information and communication technologies in society; regulatory policy; and finally, looking at health-related research and innovation systems in a diverse range of countries. She retains her Chair at the Open University, and also her involvement as co-director of the ESRC INNOGEN centre for research on social and economic aspects of life sciences innovation. She has a BA in Sociology from Colorado College, an MPhil in Development Studies from the University of Sussex, and a PhD in Technology Policy from the Open University. http://dpp.open.ac.uk/people/chataway.htm, http://www.rand.org/randeurope/about/news/02_February_2010.html

Dr David Cleevely FREng, Founding Director, Centre for Science and Policy, University of Cambridge. David has over thirty years experience in the telecoms industry as a director, business consultant and government adviser. After completing his PhD at Cambridge he joined the Economist Intelligence Unit in London before founding telecoms strategy consultancy Analysys in 1985. He later co-founded Abcam (1998), 3G pico base station company 3Way Networks (2004), and spectrum monitoring company CRFS (2007). He has been a prime mover behind Cambridge

Network, was co-founder of Cambridge Wireless and a member of the Ofcom Spectrum Advisory Board. In his latest role at the University, David is leading an initiative to improve evidence-based policy-making by developing better relationships between scientists and policy-makers in Whitehall. http://csap.org.uk/article/?objid=3253

Dr Gari Clifford, University Lecturer and Associate Director of the Centre for Doctoral Training in Healthcare Innovation, University of Oxford. Gari completed his PhD in Oxford in 2002. From 2003 to 2009, he worked at MIT as a Principal Research Scientist, during which time he developed expertise in open-source medical record systems and clinical decision support. In 2007 he co-founded Moca, now Sana, an open-source mHealth system which recently won the mHealth Alliance Award and the Vodafone Wireless Innovation Prize. His research interests lie in intelligent patient monitoring and signal processing/data fusion with application areas in health, including critical care, sleep and resource-constrained environments (particularly developing countries). http://www.robots.ox.ac.uk/~gari/

Dr David Coyle, Marie Curie post-doctoral Research Fellow, Rainbow Research Group, Computer Laboratory, University of Cambridge. The interests of the Rainbow Graphics and Interaction Group span computer graphics, image processing, interaction devices, and interdisciplinary design. David specialises in mental healthcare technologies, particularly the design of engaging technologies for mental healthcare interventions for adolescents experiencing difficulties such as anxiety and depression. His PhD research at Trinity College Dublin explored how psychological models can be integrated into compelling 3D computer games, which enable therapists to engage more easily with at-risk adolescents. www.cl.cam.ac.uk/~dc495

Professor Jon Crowcroft, Marconi Professor of Communications Systems, Computer Laboratory, University of Cambridge. Jon graduated in Physics from Trinity College, Cambridge in 1979 and gained an MSc in Computing in 1981 and PhD in 1993 from University College London. His research interests include personal data handling in the digital economy, and “constructing communications networks out of society, whereas previously, people have built communications networks (roads, canals telephone, Internet) and societies have emerged on them”. Recent projects have included FluPhone, which aims to understand how fast influenza and other infections can spread within a population by using mobile phones to record how often different people (who may not know each other) come close to one another, as part of their everyday lives. http://www.cl.cam.ac.uk/~jac22/

Dr Jenny Dean, Executive Director, Centre for Health Leadership and Enterprise, Judge Business School, University of Cambridge. Jenny was an NHS doctor between 1996 and 2005, specialising in anaesthesia. She then worked as a service improvement manager of an acute NHS foundation trust hospital and as a clinical design consultant on the National Programme for IT's electronic health records. She has also worked as a management consultant in the UK healthcare sector for Bupa Health Dialog and for Tribal. She has an MSc in Remote Healthcare which included 18 months' continuous service as the medical officer on a British Antarctic Research Station.
http://www.health.jbs.cam.ac.uk/people/deanj.html

Dr Kevin Doughty, Centre for Usable Home Technology, University of York. Kevin has been involved in assistive technologies, telecoms and medical electronics for over 25 years. Trained in physics and electrical engineering, Kevin developed his ideas within the BT Research Centre in Martlesham (where he was a Visiting Academic Research Fellow), and set up the UK’s first Telecare Research Unit at the University of Wales in Bangor in 1993. At the core of his research was the design of intelligent sensors to detect emergency situations within the home environment. In 2003, he became the part-time Deputy Director of the Joseph Rowntree Foundation Centre for Usable Home Technologies (CUHTec) at the University of York, where he continues to develop new ideas with a focus on ensuring that products are relevant to users who might have limited dexterity, cognitive, intellectual or sensory capabilities. Other interests include evolving technologies (such as robotic devices, personal electronic appliances, and virtual presence) and their role in managing long-term conditions, physical frailty, social isolation and depression. Kevin is the Telecare Editor of the Journal of Assistive Technologies, the patron of the Wales and South West England Telecare Alarm Group, and acts as an independent telecare and assisted living consultant throughout the UK.
http://telehealth.holyrood.com/index2.php?option=com_content&view=article&bw=500&bh=500&id=724

Ms Pam Garside, Fellow in Health Management, Judge Business School, University of Cambridge (Co-Director of the Cambridge International Health Leadership Programme). Pam has her own management consultancy, Newhealth, specialising in organisational strategy and development in healthcare; she works extensively with boards of a wide range of healthcare organisations on leadership, governance, strategy and organisational change issues. She began her professional life in management in the NHS and subsequently spent ten years studying and working internationally based in the USA. Since the mid-1980s she has worked as a management adviser and consultant concentrating on the reform of healthcare systems, and leadership and management development. She holds an BSc from the University of

Durham and an MSc in Hospital and Health Care Administration from the University of Minnesota. http://www.jbs.cam.ac.uk/research/associates/garsidep.html

Dr David Good, Lecturer, Department of Social and Developmental Psychology, University of Cambridge. David's research interests include the interpersonal and psychological processes underlying human communication, and the social consequences which follow. This involves studying phenomena ranging from interactional breakdown in certain psychopathologies to the use of new media in the creation of electronic town halls. Recently, his focus has been on the study of information and communication technologies, and the use of ideas from human communication in the design of novel ICT. In late 2000, he established a group called Crucible (http://www.crucible.cl.cam.ac.uk) with Dr Alan Blackwell dedicated to developing interdisciplinary work in technology design. David took his BA in Social Psychology and Cognitive Studies at the University of Sussex and his PhD at the University of Cambridge Department of Experimental Psychology. http://www.psychometrics.ppsis.cam.ac.uk/page/65/david-good.htm, http://www.sdp.cam.ac.uk/contacts/staff/profiles/dgood.html

Dr Mike Grant, CEO, Caru Ventures. Mike has over twenty years of experience as a consultant and business leader in mobile telecoms and media, and has advised clients on issues including connected TV, mobile media, and content monetisation online. Until recently he was the head of the global Media and Services practice at telecoms consultancy Analysys Mason, assisting organisations across the media value chain achieve their goals in a converging media and telecoms landscape, providing advice on corporate strategy, policy development, and M&A. Earlier in his career Mike was behind the introduction of 3D graphics into the mobile industry, establishing one of the world's leading mobile gaming companies, and was part of the team that secured the licence for what ultimately became Orange UK. Mike is a Cranfield MBA and has a PhD in coherent fibre optic communication systems from the University of Glasgow. http://uk.linkedin.com/in/drmikegrant, http://www.caruventures.com/

Mr Anthony I'Anson, Business Development Director, Strategic Industries, Alcatel-Lucent. Anthony is responsible for sales to Government, Health and Public Safety verticals within the Strategic Industries Division of Alcatel-Lucent covering North Europe. Anthony was formerly at Virgin Media Business where he held roles with the Wholesale Division covering Business Development, Channel Sales, Strategy and Product. Prior to that Anthony ran the IP Product Group for Telia Sonera in EMEA. Anthony holds a degree in Combined Arts from the University of Durham.

Dr Peter Jarritt is Head of the Department of Medical Physics and Clinical Engineering at Cambridge University Hospitals NHS Foundation Trust. The Department provides a comprehensive range of scientific and technical services to support the treatment of patients, both within Cambridge University Hospitals and through a range of specialist services provided to other Trusts in East Anglia. Physicists, engineers and technicians offer services ranging from managing over 12,400 items of highly specialised medical equipment, to providing specialist advice on the safe use of radiation, and providing essential physics support for radiotherapy treatments for patients with cancer. www.cuh.org.uk/addenbrookes/services/clinical/medical_physics/medical_physics/medical_physics_index.html

Dr Houyuan Jiang, Senior Lecturer in Management Science, Judge Business School, University of Cambridge. Houyuan's research interests lie in combinatorial optimisation, mathematical programming, applied operations research and management science. He is currently undertaking two projects relating to cost and service efficiency of healthcare operations: the first studies how service providers should release time slots to online outpatient appointment systems; the second investigates a performance-based contracting scheme and compares it with the existing payment-by-results contract framework in the NHS. Before coming to Cambridge he was a Senior Research Scientist at the Commonwealth Scientific & Industrial Research Organization (CSIRO) in Australia and a post-doctoral research fellow at the University of Melbourne; he also taught mathematics at both undergraduate and graduate levels at the Guizhou University of Technology in China. He holds an MSc from the Chinese Academy of Science and a PhD from the University of New South Wales. http://www.jbs.cam.ac.uk/research/faculty/jiangh.html, http://www.health.jbs.cam.ac.uk/people/faculty.html

Dr Matthew Jones, University Lecturer in Information Systems, Judge Business School, University of Cambridge. Matthew's research interests lie in the relationship between information systems and social and organisational change. In the healthcare area, his work focuses on organisational changes associated with the adoption of computer-based information systems in clinical settings. Studies that he has undertaken include: an evaluation of electronic record systems in several UK hospitals; a survey of electronic record system adoption in the Netherlands; an investigation of doctors' use of mobile computing devices; and an investigation of changes in work practices associated with the introduction of a clinical information system in critical care. Among his published papers is one entitled "*Computers can land people on Mars, why can't they get them to work in a hospital?*" He holds a BSc from

Newcastle University and a PhD from Reading University. http://www.jbs.cam.ac.uk/research/faculty/jonesm.html, http://www.health.jbs.cam.ac.uk/people/faculty.html

Dr Eiman Kanjo, Lecturer, Anglia Ruskin University, and owner of Cambridge Mobile Sensing Ltd. Eiman is a former Research Associate at the Mathematical Sciences Centre and Computer Laboratory at the University of Cambridge. Her research interests are in pervasive computing systems, including mobile computing applications, location based services, temporal and spatial sensor data visualisation on 3D GIS systems, wireless sensors for personal data collection and for scalable wireless sensor networks, communication between sensors and mobile phones, and pervasive health. She gained her PhD from the Computer Science department, University of Abertay Dundee, UK, in 2005, in the area of pervasive and tangible interfaces based on Computer Vision. http://uk.linkedin.com/in/eimankanjo

Dr Sonja Marjanovic, Senior Analyst in the Innovation and Technology team at RAND Europe. At RAND, Sonja has been working on and leading a number of projects in the fields of health research evaluation and innovation in health systems. Prior to joining, Sonja completed a PhD at Cambridge Judge Business School, where she was a Wellcome Trust scholar and worked in the areas of international collaboration strategy for health-sector innovation. Sonja has also worked for the Economic and Social Research Council's Centre for Business Research in the area of UK innovation competitiveness. She also has research and consulting experience in healthcare innovation policy and neglected disease R&D policy; intellectual property services; and commercial experience in business development, founding and managing a diagnostic start-up. Her interests include innovation strategy and policy, international development, and healthcare policy. http://www.rand.org/about/people/m/marjanovic_sonja.html

Dr Cecilia Mascolo, Reader in Mobile Systems, Networks and Operating Systems Group, Computer Laboratory, University of Cambridge. Cecilia's research interests are in protocols, and in systems and modelling for and of mobile systems. Her research projects include emotion and interaction sensing with mobile phones, social and mobile networks analysis and communication protocols for sensor systems. She received a Diploma di Laurea in Scienze dell'Informazione in 1995 and a PhD in Computer Science in 2001 from the University of Bologna, and spent eight years in the Department of Computer Science at University College London before coming to Cambridge in 2008. http://www.cl.cam.ac.uk/~cm542/

Dr Felix Naughton, Research Associate, General Practice and Primary Care Research Unit, University of Cambridge. Felix's research interests lie in understanding how to change health behaviours – particularly the use of tailoring in behaviour change interventions and the use of new technologies in healthcare and health promotion. He joined the General Practice and Primary Care Research Unit in 2005 to work on the development and evaluation of a computer tailored smoking cessation self-help programme for pregnant smokers. This automated programme (MiQuit) provides smokers with an individualised advice leaflet and text messages tailored to personal characteristics, smoking beliefs and behaviours. http://www.medschl.cam.ac.uk/gppcru/index.php?option=com_content&id=248&Itemid=77

Professor Martin Roland CBE, Professor of Health Services Research, Department of Public Health and Primary Care, University of Cambridge. Martin's main areas of research interest are developing methods of measuring quality of care, and evaluating interventions to improve care in the NHS. He has been a practising GP for 30 years. He trained at the University of Oxford, where he obtained his doctorate; following vocational training in Cambridge, he worked in London and in Cambridge before moving to the Chair in General Practice in the University of Manchester in 1992. In 1994, he established and subsequently became Director of the National Primary Care Research and Development Centre. Between 2006 and 2009, he was also Director of the NIHR School for Primary Care Research, a collaboration between the five leading departments of primary care in England.
http://www.medschl.cam.ac.uk/gppcru/index.php?option=com_content&view=article&id=324&Itemid=46&catid=0

Professor Stefan Scholtes (Project Adviser), Professor of Health Management, Academic Director of the Centre for Health Leadership and Enterprise, Judge Business School, University of Cambridge. Stefan's research focuses on operations strategy for health service providers and firms in the pharmaceutical industry. His current research projects are concerned with the effect of staff workload on clinical quality, the effect of increased involvement of clinicians in the top management team of hospitals on cost-efficiency, and with R&D productivity and the economics of collaborative innovation in the pharmaceutical industry. Prior to his current position, Stefan was a Professor of Management Science at Judge Business School. He has also taught at the University of Karlsruhe in Germany, London Business School, and in Cambridge's Engineering Department. http://www.health.jbs.cam.ac.uk/people/faculty.html, http://www.jbs.cam.ac.uk/research/faculty/scholtess.html

Professor Derek Smith, Professor of Infectious Disease Informatics, Department of Zoology, University of Cambridge. Derek is also a member of the Department of Virology at Erasmus Medical Center in The Netherlands, and a Senior Research Fellow at the Fogarty International Center at the United States National Institutes of Health. He is a temporary advisor to the World Health Organization, a member of its influenza vaccine strain selection committee, and is also involved in vaccine strain selection for other human and non-human pathogens. His research is focused on how pathogens evolve, to what extent this evolution is predictable, and determining public and animal health measures against such ever-changing pathogens. He received a United States National Institutes of Health Director's Pioneer Award in 2005 for his work on Antigenic Cartography, a method that enables detailed study of pathogen evolution. http://www.antigenic-cartography.org/cam/, http://www.zoo.cam.ac.uk/zoostaff/smithd.html, http://www.infectiousdisease.cam.ac.uk/directory/profile.php?derekjsmith

Mr Tobias Söderlund, Research Engineer, Ericsson. Tobias works for Ericsson in Sweden as a Research engineer within the mobile health segment. http://tobiassoderlund.se/projects

Professor Stephen Sutton, Professor of Behavioural Science in the Institute of Public Health, and Director of Research and Head of the Behavioural Science Group in the General Practice & Primary Care Research Unit, University of Cambridge. Stephen studied social psychology at LSE and computer science at City University. He received his PhD from the University of London in 1981 for research on the effects of fear appeals. Before moving to Cambridge in 2001, he held posts at the Institute of Psychiatry and UCL. His research programme focuses on risk communication and behaviour change; he has a particular interest in the methodological issues surrounding the specification and testing of theories of health behaviour and the evaluation of theory-based behaviour change interventions. http://www.medschl.cam.ac.uk/gppcru/index.php?option=com_content&view=article&id=251%3Asutton-stephen&Itemid=82&catid=16

Professor Peter Williamson, Professor of International Management, Judge Business School, University of Cambridge. Peter's research interests lie in globalisation and its implications for corporate strategy; strategies for success in China and the internationalisation of Chinese companies and their global impact, merger and acquisition strategy and post-merger integration; and strategies for a carbon-constrained world. Before coming to Cambridge, he spent ten years with the Asian Business and International Management faculty at INSEAD (1997-2007); between 2003 and 2007 he was also Visiting Professor in Strategy at the Cheung Kong Business School in Beijing. He has experience in China since 1983, assisting numerous multinationals and joint ventures, and more recently, Chinese companies venturing abroad. He holds a PhD in business economics from Harvard. http://www.jbs.cam.ac.uk/research/faculty/williamsonp.html

Dr Eiko Yoneki is an EPSRC Research Fellow in the University of Cambridge Computer Laboratory, Systems Research Group. She works on the EPSRC project D*ata Driven Network Modelling for Epidemiology*, the EU FP7 RECOGNITION project *Cognition for Self-Awareness in Content-Centric Networks*, and the EU FP7 SOCIALNETS project *Harnessing Adaptive Human Social Structures*. She received her Ph.D. degree in 2006, and a Postgraduate Diploma in Computer Science in 2002, both from the University of Cambridge. She had been a Postdoctoral Research Associate at the University of Cambridge Computer Laboratory prior to being awarded an EPSRC Career Acceleration Fellowship in 2009. Previously, she spent several years with IBM (US, Japan, Italy and UK) working on various networking products. Her research interests span distributed systems, networking, and databases over mobile/wireless networks including complex, time-dependent networks and multi-point communication. Her recent work focuses on designing algorithms and modelling dynamic networks such as delay tolerant networks, inspired by social science and biology. http://www.cl.cam.ac.uk/~ey204/

References

1 http://www.unfoundation.org/global-issues/technology/mhealth-report.html
2 http://www.mhealthalliance.org/
3 http://www.chathamhouse.org.uk/about/chathamhouserule/
4 http://www.datadyne.org/episurveyor
5 http://www.childcount.org/reports/ChildCount_Kenya_InitialReport.pdf
6 http://www.nokia.com/corporate-responsibility/society/nokia-data-gathering/english/health
7 http://www.imshealth.com
8 http://info.cvscaremark.com/
9 http://www.ericsson.com/ericsson/corpinfo/publications/telecomreport/archive/2008/australia/australia1.shtml
10 www.3gdoctor.com
11 http://www.sanamobile.org/tech.html
12 www.wellcore.com
13 http://www.research.att.com/projects/Telehealth/index.html
14 http://newsroom.orange.co.uk/2010/07/16/orange-brings-e-health-expertise-to-uk-with-smartnumbers/
15 http://mobileactive.org/issue-categories/emergency-response
16 http://www.frontlinesms.com/
17 http://www.primarycare.ox.ac.uk/research/vascular/Research/Telehealth
18 http://www.prohealthservicezone.com/Customisation/News/IT_and_Communications_in_Healthcare/Communications_equipment/Mobile_video-enabled_phones_help_to_monitor_medication_adherence_of_TB_patients.asp
19 http://www.mcri.edu.au/pages/research/news/2010/8/mobile-phones-track-teens-mental-health-in-Albury-Wodonga.asp
20 http://www.medschl.cam.ac.uk/gppcru/index.php?option=com_content&view=article&id=312:miquit&catid=12:project-profiles&Itemid=59; http://www.researchkm.nihr.ac.uk/2010Event/Posters/MiQuit%20summary.pdf
21 http://www.freedomhivaids.in/FreedomHivAids.htm
22 http://www.nlm.nih.gov/pubs/techbull/jf10/jf10_mobile_mplus.html
23 http://www.epocrates.com/index.html
24 http://medic.frontlinesms.com/
25 http:///www.sanamobile.org
26 http://www.sproxil.com/blog/?p=297
27 www.emis-online.com
28 www.inps4.co.uk
29 http://www.ncbi.nlm.nih.gov/pubmed/16879098
30 http://www.iplato.net/clients
31 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2170466/
32 http://www.rfid.averydennison.com/pdf/WalgreensSuccess.pdf
33 http://www.odintechnologies.com/healthcare-rfid-drug-pedigrees
34 http://www.sproxil.com/blog/?p=297
35 http://cs.nyu.edu/~mpaik/pubs/epothecary.pdf
36 Photograph reproduced by kind permission of Sproxil Inc.
37 http://lib.bioinfo.pl/paper:12834165
38 http://www.sanamobile.org/
39 www.3gdoctor.com
40 http://www.pewinternet.org/Reports/2010/Mobile-Health-2010.aspx
41 http://runkeeper.com/
42 http://itunes.apple.com/app/ifitness/id290451423?mt=8
43 http://itunes.apple.com/us/app/iquit/id294206243?mt=8
44 http://www.symptommd.com/
45 http://www.nhs.uk/Tools/Pages/iphonedrinks.aspx
46 http://www.mhealthsummit.org
47 http://www.mhealthalliance.org
48 *mHealth for Development: The Opportunity of Mobile Technology for Healthcare in the Developing World,* 2009, UN Foundation & Vodafone Foundation Technology Partnership, http://www.unfoundation.org/global-issues/technology/mhealth-report.html
49 http://www.cl.cam.ac.uk/~cm542/papers/Ubicomp10.pdf
50 http://www.sgul.ac.uk/media/latest-news/mobile-phones-could-be-the-key-to-better-sti-diagnosis?searchterm=STI
51 http://web.media.mit.edu/~pamplona/NETRA/Pamplona_et_al_SIGRAPH1010_low_res.pdf. Photography by Andy Ryan, reproduced by kind permission of MIT Media Labs.
52 http://wwwp.medtronic.com/Newsroom/NewsReleaseDetails.do?itemId=1273496329472&format=print&lang=en_US
53 http://www.research.att.com/projects/Telehealth/index.html
54 http://www.imonsys.com/
55 http://www.weltel.org/

56 http://www.voxiva.com/content/case_studies/Diabetes.pdf
57 http://www.welldocinc.com/LinkClick.aspx?fileticket=88UTWs71_nE%3d&tabid=61
58 http://www.poptech.org/system/uploaded_files/27/original/Project_Masiluleke_Brief.pdf
59 http://instedd.org/map/cambodiaoutbreakrrtcoordination/
60 http://www.iplato.net/news-appointment-reminders-and-mobile-health-promotion/press-releases/2008-press-releases/text-messaging-boosts-obesity-battle.html
61 http://www.iplato.net/news-appointment-reminders-and-mobile-health-promotion/press-releases/gp-surgeries-use-sms-to-advise-patients-on-swine-flu.html
62 http://www.researchkm.nihr.ac.uk/2010Event/Posters/MiQuit%20summary.pdf
63 http://www.sljol.info/index.php/SLJBMI/article/view/1774
64 http://www.ncbi.nlm.nih.gov/pubmed/19135907
65 http://www.google.org/flutrends/
66 http://users.cis.fiu.edu/~lzhen001/KDD_USB_key_2010/docs/p65.pdf
67 http://www.utdallas.edu/~muratk/publications/healthsec_risk_management_framework.pdf; http://users.cis.fiu.edu/~lzhen001/KDD_USB_key_2010/docs/p493.pdf; and see also the work carried out by Microsoft Research in this area (http://www.cra.org/ccc/docs/init/Healthcare.pdf)
68 http://openmrs.org/about/
69 http://www.sanamobile.org/tech.html
70 http://www.cl.cam.ac.uk/research/srg/netos/fluphone/
71 http://www.alcatel-lucent.com/wps/portal/!ut/p/kcxml/04_Sj9SPykssy0xPLMnMz0vM0Y_QjzKLd4x3tXDUL8h2VAQAURh_Yw!!?LMSG_CABINET=Docs_and_Resource_Ctr&LMSG_CONTENT_FILE=News_Releases_2008/News_Article_001142.xml
72 http://enterprise.alcatel-lucent.com/?solution=Healthcare&page=TeleHealth
73 http://www.ehealtheurope.net/news/5815/nokia_supports_diabetes_app
74 http://mobihealthnews.com/7618/five-mhealth-patent-applications-from-apple/
75 http://www.mdhil.com/
76 http://www.text4baby.org/
77 http://mobihealthnews.com/6908/3-million-downloads-for-android-health-apps/
78 http://www.androidfreeware.net/download-cardiotrainer.html
79 http://www.who.int/mediacentre/factsheets/2003/fs275/en/
80 http://apps.who.int/medicinedocs/index/assoc/s14179e/s14179e.pdf
81 http://www.pfizer.co.uk/SITES/PFIZERCOUK/MEDIA/Pages/CrackingCounterfeitEurope.aspx
82 http://www.fides.org/aree/news/newsdet.php?idnews=27230&lan=eng
83 For references see http://en.wikipedia.org/wiki/Barefoot_doctor
84 www.3gdoctor.com
85 http://lib.bioinfo.pl/paper:12834165
86 http://www.mtbeurope.info/news/2010/1009015.htm
87 http://www.activecare.com/pal
88 http://www.ncbi.nlm.nih.gov/pubmed/19965264
89 Unit Costs of Health and Social Care 2007, Lesley Curtis, Personal Social Services Research Unit, University of Kent
90 http://www.pssru.ac.uk/pdf/dp1719.pdf
91 http://www.childcount.org/reports/ChildCount_Kenya_InitialReport.pdf
92 http://www.fastuk.org/research/projview.php?id=1436
93 http://portal.acm.org/citation.cfm?id=1753659; http://portal.acm.org/citation.cfm?id=1753718
94 http://www.researchkm.nihr.ac.uk/2010Event/Posters/MiQuit%20summary.pdf
95 http://www.scss.tcd.ie/David.Coyle/docs/PI-ITSE-Preprint.pdf
96 http://www.ncbi.nlm.nih.gov/pubmed/19135907, http://www.researchkm.nihr.ac.uk/2010Event/Posters/MiQuit%20summary.pdf
97 http://www.eng.ox.ac.uk/samp/diabetes.html
98 http://portal.acm.org/citation.cfm?id=1753610http://portal.acm.org/citation.cfm?id=1753610
99 http://www.bioportfolio.com/resources/pmarticle/36899/the-use-of-smartphones-for-clinical-communication-on-internal-medicine-wards.html
100 See Barry et al., *"Electronic feedback in a diet- and physical activity-based lifestyle intervention for weight loss: randomized control trial."* Abstract presented at the Convergence and Society: Science, Health, and New Dimensions of Communication Meeting. October 11-12, 2010. Columbia, South Carolina, USA. Also, on eHealth and mHealth design challenges see http://www.bledconference.org/proceedings.nsf/0/ae380e72bb55a11ac125775700388986/$FILE/08_Simons.pdf
101 http://www.grameenfoundation.applab.org/uploads/Grameen_Foundation_FinalReport_3_.pdf
102 http://www3.imperial.ac.uk/portal/pls/portallive/docs/1/5375912.PDF
103 http://www.biomedcentral.com/1756-0500/3/250
104 http://mobithinking.com/mobile-marketing-tools/latest-mobile-stats
105 For further discussion of these concepts, see Irene Ng, "The future of pricing and revenue models", *Journal of Revenue and Pricing Management* (2010) **9**, 276-281.
106 See http://www.moh.gov.cn/publicfiles//business/htmlfiles/zwgkzt/ptjty/digest2010/index.html for statistics cited.