M-health review: Joining up healthcare in a wireless world

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1 Introduction

In recent years, there has been a huge increase in the use of information and communication technologies (ICT) to deliver health and social care. This trend is bound to continue as providers (whether public or private) strive to deliver better care to more people under conditions of severe budgetary constraint.

One of the areas which is expanding is *m-health*. We define m-health as being the intersection between the health sector and mobile technologies, such as (but by no means limited to) mobile phones. The term was coined by Professor Robert Istepanian as use of "emerging mobile communications and network technologies for healthcare."(Robert S. H. Istepanian, Laxminarayan, & Pattichis, 2006)

M-health could be said to be a subset of *e-health*, the use of electronic (typically ICT) technologies for health services. The specific characteristics of m-health systems are that the ICT equipment typically:

1. is small and therefore portable
2. uses wireless rather than wired communication
3. has an integral power supply

More subtly, m-health as a concept tends to emphasise interactions between individuals rather than organisations, often between devices even more so than between people, and that there is a consequential decentralisation of effort.

An important concept when discussing mobile technologies is *ubiquity*. The Oxford English Dictionary defines this as "the capacity of being everywhere or in all places at the same time". Wikipedia states: "Ubiquitous computing (ubicomp) is a post-desktop model of human-computer interaction in which information processing has been thoroughly integrated into everyday objects and activities. In the course of ordinary activities, someone "using" ubiquitous computing engages many computational devices and systems simultaneously, and may not necessarily even be aware that they are doing so. This model is usually considered an advancement from the desktop paradigm" (Wikipedia, 2012). Ubiquity represents a change from the model of information technology where the computer was (at one extreme) a large device locked away in an air-conditioned room and attended to by a large team of acolytes to (at the other extreme) where computers are totally indistinguishable as distinct entities and are simply part of some other object. In the following sections, we will first of all review the relevant technologies and provide some background to their development and use. We will then attempt to extrapolate from past trends to foresee what new developments will become available in the future. In addition to the hardware, we will also look at some of the issues concerned with development of the software interfaces that are so important in making the whole technology system usable. We will also look at how the technology affects social trends, particularly relating to how governments will provide services to their citizens.

In later sections, we will describe a number of scenarios depicting how people might use m-health in the future in a number of healthcare contexts. We will also look briefly at how m-health is becoming a global phenomenon and the relationship between what happens in the UK and elsewhere in the world. Finally, our conclusions will reflect on what needs to happen to facilitate an m-health-enabled future.

2 Technology overview

In this section, we will briefly review some of the fundamental technologies that are relevant to m-health.

The basic concept of any mobile device is that it can move freely without being tethered by power cables, communication links or other physical restraints. This means that we need to look at how the device will communicate with the rest of the world, how small it can be, what form it will take, how it will tell where it is and how it will be powered. among other things.

2.1 Wireless

The fundamental communication mechanism for mobile devices is *wireless* technology. Wireless communication has been around for over 100 years, but its popular uses (radio and television broadcasting) required large stationary transmitters and thus facilitated only one-way communication. Two-way communication became commonly portable first in military applications (the "walkie-talkie"), then for the emergency services, and only for the general public in the 1970s (through "Citizen's Band" (CB) radio), and then in the 1980s and 1990s through mobile telephony. The initial applications were for voice only, but the integration of computing and communication technologies now means that voice is just one of a number of data communication applications.

A significant problem with wireless communication is the interference from different users broadcasting on the same frequencies. This severely limited the number of users that could communicate at the same time. The big leap that broke this barrier was the development of the cellular system (in the 1980s). This was the start of bringing mobile phone technologies to the masses and is often called 1G or first generation mobile. The infrastructure evolved into 2G, which had increased bandwidth, and like 1G used a cellular structure of base stations where every non-adjacent cell could reuse the same set of frequencies. Increasing the number of base station cells resulted in a massive increase in the capacity of concurrent mobile users.

The later 2.5G and 3G technologies built on the existing structures but are based on digital code reuse (as opposed to frequency reuse) and offered a further increase in bandwidth and capacity. The forthcoming B3G (Beyond 3G) and 4G technologies offer further step increases in capability with bandwidths of between 70-100 Mb/sec for moving devices and up to 1Gb/sec for stationary devices – effectively super broadband speeds. When we achieve such capacities, it will open up a range of new functionality, applications and business models. Very data intensive applications to mobile devices start to become realistic. Applications such as 3D images, holograms and very rich multimedia may become standard.

Cellular data service offers coverage within a range of 10-15 miles from the nearest cell site. Speeds have increased as technologies have evolved, from earlier technologies such as GSM, CDMA and GPRS, to 3G networks such as W-CDMA, EDGE or CDMA2000.

Any mention of mobile phones should also include mention of the Short Message Service (SMS), or "texting". This was developed as part of the GSM standards as a means of sending short textual messages using the spare capacity of the telephone signalling paths, i.e. whenever a phone call is not being made. Although limited to 140 characters in length, text messaging has become probably the most widely used data application in the world. In addition to its well-known uses, it also provides a means of mobile communication for those who are hard of hearing or have other disabilities that prevent them making a voice call.

Of course, the cellular networks used by mobile phones are only one form of wireless data communication used commonly today.

The longest range is offered by mobile satellite communications. This is used where other wireless connections are unavailable, such as in largely rural areas or remote locations. It can also be used where the reliability of cellular networks is of doubt. Satellite communications are especially important for transportation, aviation, maritime and military use. Current technology provides limited bandwidth (9600 bit/sec on low Earth orbit systems rising to 512 Kbit/sec for geostationary systems), lack of inter-operability of devices, relatively bulky devices (though some with a form similar to that of a conventional mobile phone are becoming available), limited connectivity when not outdoors, and expensive call charges.

Wi-Fi is a wireless local area network that enables portable computing devices to connect easily to the Internet. Standardized as various sub-specifications of IEEE 802.11, Wi-Fi has a typical range measured in the 10s or 100s of metres (the latter when outdoors with suitable antennae).Wi-Fi approaches speeds of some types of wired Ethernet. Wi-Fi has become the de facto standard for access in private homes, within offices, and at public hotspots. Some operators are now rolling out Wi-Fi as a metropolitan area network, in other words providing enough hotspots to provide almost complete coverage within a city area.

Bluetooth and ZigBee are examples of an increasingly diverse set of short-range wireless technologies used for connecting small devices within a small area (e.g. a room). Bluetooth is frequently used to connect such devices as fax machines, mobile phones, telephone receivers and handsets, laptops, personal computers, printers, GPS receivers, digital cameras and video game consoles. ZigBee tends to be used for applications such as home entertainment, home/building automation, smart lighting, advanced temperature control, safety and security, movies and music, wireless sensor networks, industrial control, embedded sensing, medical data collection, and smoke and intruder warning. Both exhibit features that keep power consumption low, and permit the easy connection of devices to each other.

The most common problem with any form of wireless communication is lack of network coverage. Being "out of range" of a network node is something that only be addressed by adding additional transceivers in areas where there is not currently coverage, or by "moving up" to a wider-range technology such as satellite networks. However, even within the range of a transceiver, there are often "blackspots" where the wireless signal does not reach, perhaps because of geographic or environmental conditions, or caused by the insulating properties of the materials that a building or vehicle is made of. The solution to this sort of problem is either to turn up the strength of the signal to make it easier to penetrate to the blackspot, or to install additional "repeater" nodes in the affected area.

2.2 Miniaturisation

The key technological development of the past 50-60 years in our view is that the development of transistor and integrated circuit technologies has led to devices becoming smaller and smaller. Smaller devices are inherently more portable.

In electronics, miniaturization was witnessed by an empirical observation called Moore's Law that predicted that the number of transistors on an integrated circuit for minimum component cost doubles every 18 months. Equivalently, the same circuit becomes half the size or half the cost in the same timeframe.

The size of storage devices has reduced even faster than Moore's Law would predict, meaning that storage technology has become very cheap. Developments are also taking place in reducing the size and weight of power supply components such as batteries and mains adapters.

Miniaturisation brings the following advantages:

- smaller devices tend to weigh less, also contributing to their portability
- smaller devices tend to require less power (through there is a caveat to this in that if the surface area of the device becomes too small, there can be difficulties in dissipating heat) – reduced power consumption can also mean that a smaller power supply can be included, so furthering portability

2.3 The diversity of mobile devices

There are currently many different types of mobile devices, all of which could be said to be ubiquitous, including the following:

- Laptop computers – These are portable computers that embody much of the technology of desktop computers, but with a smaller form factor. They include a keyboard and screens of up to 19-inches in size, and can include large amounts of both random-access memory and hard-disk storage. They typically provide ports for a wide variety of connections (e.g. USB, VGA, HDMI, serial, parallel, speakers and microphone).
- Netbooks and Notebooks – These are small laptops that are designed to connect to the Internet and be very portable. They are characterised by having fewer features than a conventional laptop.
- MP3, MP4 players (in particular the Apple iPod) and other music devices – These small music and multimedia devices build on existing electronic, computing and storage technologies to provide personalised storage of music files. They are characterised by a minimalist user interface, with the main output device being a pair of headphones that has to be plugged in.
- Tablets (in particular the Apple iPad) – Similar to Netbooks and Notebooks, these provide very personalised computing power and access to the Internet. The key differentiator for these is that they replace the separate keyboard by using the touch-sensitive screen as an input device.
- Personal Digital Assistants (PDAs) – These have mostly disappeared or evolved into smart phones. They effectively were small computers providing personal assistance or ICT support. Again, their characteristic was a touch-sensitive screen that could be operated by finger or stylus.

- Mobile phones – These can be classed in two main groups: basic and smart. The 'basic' models provide functionality to receive or send voice calls and text messages, and many incorporate limited additional functions such as clocks, calculators and the ability to play games or music. Smart models have greatly more sophisticated features including access to the Internet. They effectively have all the capabilities of small computers (in terms of CPUs, storage, etc.) plus common PC functionality (calendar, address book and email applications; web browsing, etc.).

Many devices (especially smart phones) now incorporate additional technology, either embedded within the device itself or attachable through standard plugs and sockets or wirelessly. These include:

Generic	Health and fitness specific
• camera (capable of taking photographs or videos) • GPS receivers (see below) • accelerometers • gyros • light sensors	• weighing scales • heart rate monitor • blood pressure monitor • glucometer (blood glucose monitor)

There is a rapidly expanding market in mobile "apps" – small software applications that run on a mobile device and offer a specific service. At the moment, the app market is constrained by the inability of an app developed for one type of phone or tablet to run on any other. The common types are those based on the following operating systems: Apple's iOS, Google's Android, Microsoft's Windows Mobile, Nokia's Symbian and RIM's Blackberry OS. It is anticipated that these will tend to converge in the future towards a single common standard, which we anticipate will employ web technologies, such as the recently released version 5 of HTML.

2.4 Wireless tags

Wireless tags can be worn by people, and/or attached to equipment or assets, enabling them to be identified and located. Some tags include motion and light sensors, which will trigger an alert if they are moved (Ju, Kim, Yoon, & Lim, 2007). They can create a bridge between the real world and the digital virtual world by eliminating the need for human intervention in the form of data entry. While the ubiquity of the tags provides a wide variety of opportunities for their use, durability (the capability to withstand wear and tear and to continue operating) has been recognized as the main limitation.

There are two main types of tag: Radio-frequency identification (RFID, for which there are a variety of domain-specific standards) and RuBee (IEEE 1902.1).

RFID tags are small wireless devices that can emit and compute information using radio-frequency electromagnetic fields. In general they can be categorised as active, passive or battery-assisted passive. An active tag has an on-board battery, whereas a passive tag gets its energy through the reader. An RFID system has mainly three subsystems:

1. a wireless tag that can be embedded and/or attached to the asset being tracked

2. a tag reader capable of querying any tags within range of it
3. middleware that handles management of data collected from the tags

RFID tags have been used in many industries, including transportation and logistics, healthcare, libraries and museums, sport and more.

Despite the potential of RFID technology, its adaptation in the healthcare domain is still limited. Fosso Wamba (Fosso Wamba, 2012) reviewed papers published on the development and use of RFID technology in healthcare within the Journal of Medical Systems, using a classification framework developed from that of Van Oranje et al. (Van Oranje et al., 2009)[1]. Whilst most articles highlight the "efficiency and quality gain" of RFID adoption (Fosso Wamba, 2012), more research is required on the impact of RFID technology in healthcare sector, in particular to investigate how it could be developed to enhance patient-centred services.

The mass roll out of RFID tags has also raised a number of issues related to the interaction model (i.e. how tags should interact with real world objects or to be interfaced with different mobile handsets), security (i.e. access control, tracking tags) safety (i.e. how safe is to use RFID in management of patient's medication) and privacy (i.e. how to prevent disclosure of personal data to unauthorised users (Sun, Wang, & Wu, 2008; Thuemmler, Buchanan, & Kumar, 2007; Wu, Lichtenstein, Hogeboom, & Thielst, 2011)),that should be further researched to identify and determine the balances and best practice in the context of m-health applications.

In contrast with RFID, RuBee tags use low frequency, Long Wave (LW) magnetic signals to send and receive short data packets in a local regional network based on a two way active wireless protocol (IEEE standard 1902.1). The long wavelengths and ultra low power consumption mean that it will operate normally even near steel and/or water, so making it robust for use in harsh environments and able to be detected even when the tag is contained within a steel object (e.g. a car). RuBee tags may have a full 4-bit microprocessor with static memory. They can have optional displays, and sensors for such things as temperature, humidity or motion. The RuBee protocol uses internet (IP) addressing, meaning that it facilitates the "Internet of things" concept (see section 2.9 below).

Although RuBee has been around for about six years (and was standardised in 2009), its use in a variety of different domains (including healthcare) has not yet been extensively trialled.

2.5 Wearable technology

Advances in miniaturisation have meant that more and more technology can now be carried by people, attached either to their body or their clothing. Development of small physiological, bio-kinetic, and ambient sensors is fuelling advances. Wireless

[1] The research highlighted 22 articles focusing on applications including, asset management (Bendavid, Boeck, & Philippe, 2011; Catarinucci, Colella, Esposito, Tarricone, & Zappatore, 2011), patient management (Chen-Yang & Jyh-Wen, 2011; Jesun, Jar-Yung, & Chih-Cheng, 2011), and staff management (Wen, Chao-Hsien, & Zang, 2011). Other recent research includes studies on patient identification and tracking (Fisher & Monahan, 2008), and management of medication in terms of dosage (Fosso Wamba & Ngai, 2011). Huber (Huber, 2011) presents a scenario of RFID embedded in human tissue to give physicians information about the condition of orthopaedic implants.

connectivity that allows the subject to move about while being monitored (Bonato, 2005) has also contributed.

The health uses for wearable technology can be divided into three main areas:

- monitoring of activities and/or vital signs – this is currently the primary function (and also is a prerequisite for the other two areas);
- medication adjustment and dispensing;
- physical compensation or rehabilitation.

Monitoring, and data recording, can take place at different frequencies, from intermittent (say daily) to effectively continuous, depending on the purpose. The results of monitoring can be collected, aggregated and investigated as part of a diagnostic process (for example, investigating a subject's heart arrhythmia over a period (Murray, 2011)). Alternatively, alerts can be issued in real time should thresholds be breached (blood pressure is too high, or activity suggests onset of depression (HEALTH.infoNIAC.com, 2012)), or advice can be given, in an effort to prevent an unwanted effect (a fall, a stroke).

Different sensors (worn or embedded) can be combined into a Wireless Body Area Network or WBAN (Edwards, 2011; Hanson et al., 2009; Latre, Braem, Moerman, Blondia, & Demeester, 2010), passing raw data to a hub (for example, a smart phone). The data can then be sorted and evaluated, and further actions taken (information passed to a medical practitioner, an alert raised, a text prompt sent to the subject to take medication, for example).

Medication requirements can be monitored, and the dosage adjusted and dispensed by a worn or implanted device, potentially reducing the problem where people forget to take their medication, or where the incorrect dose is administered (Doughty, 2011b; Latre et al., 2010). An increasingly common example of this type of device is the insulin pump that continually monitors a Type 1 diabetic's blood sugar and adjusts their infusion of insulin, though practical difficulties remain (AmyT, 2011; Finkle, 2011; Medeiros, 2011).

Wearable technology may be able to compensate for disability, increase ability, or aid rehabilitation. Examples exist already – spectacles, crutches, a back brace, an artificial hip joint. The classic example of electronic wearable technology is the hearing aid, which has been available for over 50 years. Sophisticated exoskeletal devices are being developed, in the first place to aid the military, which in future might be able to support paraplegic patients and allow movement again (Chen, 2010; Mitchell-Magaldi & Weires, 2011). In this area should also be included those technically sophisticated fabrics that now aid sport and military performance and could also play a part in health (Barrie, 2012; Coyle & Diamond, 2010).

The advantages of wearable technology are:

1. The subject can pursue their normal everyday activities, therefore affording a more realistic monitoring of the interesting feature (as opposed to the so-called 'white coat syndrome' where subjects' blood pressure readings are abnormally high because of the clinical context of the measurement) (Niiranen, Kantola, Vesalainen, Johansson, & Ruuska, 2006).
2. More people can be monitored more closely, more cheaply, and in real time.

3. The monitoring can be unobtrusive for the subject, and discreet. It can be much more convenient to the subject not to have to disrupt their lives to have an assessment performed. For example, see Healthrageous (http://www.healthrageous.com/Home.aspx). Dignity and comfort are not compromised.

Issues raised by wearable technology include:

- Not all application areas are the same – each requires a different solution, depending on the disease / condition being monitored. We can't just add the technology layer to solve the problem – the data collected needs to be understood in the disease context, and the resulting actions tailored to that understanding. There is a cost to establishing the "normal" range for each individual being monitored. This will be more cost-effective where monitoring will take place over an extended period, as is likely to be possible with chronic conditions.
- Acceptability will depend on the perceived value of the technology (Bowes, 2009) – inpatients in intensive care will accept a more intrusive monitoring regime than an elderly person trying to live her independent life with "just a little bit of help".
- Sensitivity and specificity (false positives, false negatives) are very important if the information is to be relied upon and where incorrect responses may cause actual harm (McNeil, Keller, & Adelstein, 1975).
- Security and privacy are large concerns with this very personal data (mHIMSS, 2012; Schultz, 2012) (and see section 2.7 below).
- There are issues to do with control of vulnerable people, and with consent, with some of the technology solutions, especially implantable devices (Rowlands, 2011).

2.6 Geo-location/satnav

One of the major innovations of mobile devices is their capability to determine their location. This has come about through the miniaturisation of GPS (Global Positioning System) devices and their subsequent incorporation into other devices.

The US government introduced GPS in the 1970s for purely military reasons, but since the 1990s it has also been available for civilian use, and since 2000 it has provided a resolution of about 20 metres. The system works by precisely timing the signals received from satellites deployed in medium Earth orbit. By combining the signals from four satellites using a technique known as trilateration, an accurate location in three dimensions can be calculated, and errors arising from clock inaccuracy corrected.

GPS devices used to be large bulky objects, but nowadays a GPS receiver can easily be fitted on a chip. Mobile phones (beginning with the Benefon Track in 2000) are perhaps the best known portable devices that contain one.

A device that knows its own location (and has network connectivity) can do various things. It can show the user their location on a map, and it can therefore provide input to a route planning application to help navigate the user to their destination. The user's location can also be sent to various systems that allow help to be sent in times of distress, used as input to a resource planning system (e.g. taxi or ambulance dispatching), or used to track the user's movements (e.g. for legal reasons).

GPS is not the only global navigation satellite system. Russia has one called GLONASS, and both the European Union (Galileo) and China (COMPASS/Beidou) have systems under development (launching 20-30 satellites being the major cost). France, India and Japan also have prototype systems. Having rival systems is considered inevitable, given that the US would potentially restrict the availability of GPS in times of military conflict.

At the moment, mobile devices tend to only use GPS, but the iPhone 4 can also use GLONASS to track its position and we believe that as the new satellite systems start to provide global coverage, devices will commonly operate to multiple systems. While it might be expected that manufacturers in Europe might choose Galileo as their second navigation network, it is more likely that the choice will be made on purely economic grounds.

2.7 Security and privacy

The security of mobile devices suffers from the same risks as non-mobile systems, plus some additional risks that derive from the characteristics of mobile devices and their communication mechanisms. These factors include:

- Wireless signals are inherently less secure than wired electronic connections since the signal is broadcast over the uncontrolled airwaves – anyone with a suitable set of electronic listening technologies can pick up those signals.
- Wi-Fi signals sent in the clear, or encrypted using Wired Equivalent Privacy (WEP), can be read with relatively cheap equipment. Wi-Fi Protected Access (WPA) and its successor WPA2 (which uses a more robust cipher) are the current state of the art, but flaws in them have been identified. Similarly, the A5/1 cipher protocol used to secure GSM mobile phone networks has had claims made of it that it contains flaws.
- To eavesdrop a wireless network does not typically require physical access to a building, so physical security barriers are not effective.
- The small form factor and limited power availability of a mobile device might cause its designers to forego the best security practices. This may mean that the security of the device can be compromised.
- Since many mobile devices are sold as consumer goods, the "rush to market" may also cause short-cuts in design to be made that compromise security. It also means that attackers can examine a device for its security flaws by the simple expedient of buying one themselves to experiment with.
- The small size of a mobile device is both a security advantage (in that it can be concealed easily when not in use, or even when in use) and a disadvantage (in that it becomes easier for a thief to conceal it after stealing it). It is also easier to inadvertently lose a smaller device, which may mean that the information stored in it becomes accessible to an opportunistic attacker.
- The lack of a keyboard on a mobile device may mean that its designers opt for a short password (e.g. a 4-digit PIN) as the primary means of user authentication. Short passwords can be more easily cracked by brute force attacks unless other

counter-measures (such as locking the device after repeated unsuccessful attacks) are taken.

- The variety of auxiliary input devices that can be incorporated into a mobile device may provide opportunities for more secure authentication methods to be implemented. For example, it is possible to use the camera in a device to provide a rudimentary means of identifying its user by retinal imaging or face recognition. A touch screen display can make authentication by image (rather than text) easier to provide. Finally, the mobile device itself can be used as a security token (like a key).
- Wireless devices can be subject to *denial of service* attacks by jamming the wireless signal.
- A ubiquitous device is likely to contain personal information about its owner, and possibly their friends/colleagues. This poses additional threats to their privacy.
- Mobile devices are frequently used for social networking purposes. Social networking systems such as Facebook and Twitter have their own security issues that are magnified by mobile use of them.
- A mobile device that uses GPS (or similar) to establish its location, may transmit that location to other systems. Usually this is done with the user's consent and for a good reason, but some nefarious apps may transmit it without the user's knowledge or consent. This may also apply to personal information stored on the device.
- Law enforcement and the emergency services place great reliance on location and usage data about both victims and perpetrators drawn from telecommunications services to assist them in their jobs. Some personal information is therefore collected for statutory reasons.
- Ubiquitous devices contribute massively to the expansion of a person's *digital footprint* or *exoinformation* (Brunk, 2002). It is now not only the case that digital information is collected about you at your place of work or the premises of an organisation that you are doing business with (e.g. shop or office), but also at your home and in the street.

It is a challenge to find a balance between security mechanisms that seem to require the collection of increasing amounts of personal information to prove who you are (how many people now know your mother's maiden name and the name of your first pet?!), and privacy mechanisms that aim to reduce the amount of personal information collected and stored.

The complexity increases further when we consider "function creep", where technology use extends beyond the initial scope or where extra functions are added a bit at a time. Nunn and Quinet’s (Nunn & Quinet, 2002) examination of police technologies showed how technologies developed primarily for use within military and defence applications are becoming commonplace within urban police departments and used for an extended set of monitoring and policing functions. Another example is given by Katos and Adams (Katos & Adams, 2005), who examined CCTV technologies to demonstrate the evolving use of technology: "Technologies evolve in how they are used: This concept is not new to most developers who have to contend with changing and evolving requirements. So a

CCTV camera can be installed in a shopping space initially under the guise of addressing security issues, but evolves into a store management tool monitoring customer flows and purchase patterns" (Katos & Adams, 2005).

2.8 Powering mobile devices

Most mobile phones are powered by lithium-ion batteries (McDowall, 2000). The ever-expanding range of different functions embedded within mobile phones and similar devices has led to a need for more energy storage capability and more efficient use of energy within the devices. There have been considerable advances in battery technologies over the more recent years (Zhuang, Kim, & Singh, 2010). Along with developments in battery technologies, there have been corresponding developments in producing more power efficient processing chips, storage devices, and other functionality within mobile devices. The devices themselves are becoming more energy efficient. However, given the increased functionality and use of mobile phones they still suffer from severe energy limitations (Vallina-Rodriguez, Hui, Crowcroft, & Rice, 2010).

One of the future predictions in "IBM's 5 in 5" (their annual future scanning of technologies activity which identifies five most likely technologies to impact society over the next five years) is to expect increases in intelligent power generation (Kolar, 2011). Devices are likely to be powered from a variety of sources using micro energy collection devices (think collecting kinetic energy from walking, wind, any sort of movement or even water flowing through a pipe). Many devices will have built-in solar panels (similar to solar powered calculators – but larger capacity).

The trend is towards significantly more mobile devices all requiring power, and at the same time increases in micro power generation capability much of which will be attached to the mobile devices or generated by humans carrying the mobile devices.

2.9 Other mobile technologies

The "Internet of Things" (IoT) is a vision of a future where all objects of daily life are equipped with wireless tags that identify them (by IP address, preferably). If everything in the world was tagged, it would solve a lot of problems of stock management, mislaid or stolen items would easily be found, and objects could be related to the people who use them. The IoT contrasts with the "Internet of People" (largely the present situation), where typically an IP address is associated with an individual person, through the single computer they are using (whether it be a desktop, laptop or mobile).

The IoT raises the possibility of many more different types of mobile devices – particularly monitoring devices. Within healthcare, there is clearly the potential for a range of devices to monitor body functioning and general well being of individuals (R S H Istepanian, Hu, Philip, & Sungoor, 2011). Some of these may be embedded devices – embedded within existing technologies, such as personal mobile phones or computer tablets, or embedded within the human body.

Many of these devices will require communication and co-ordination functions – indeed, the volume of device-to-device communication activity may outstrip that of device-to-human and human-to-human communication.

The devices are likely to require interaction with other devices within the local environment, such as road furniture or building and home devices.

3 Technology predictions

Predicting the future pathway(s) of a technology is a complex task. However it is unlikely in the short to medium-term that mobile technologies will diverge wildly from the evolutionary path they have taken over the last 20 years or so.

3.1 Measuring the past

Let's first of all look at what has happened to the mobile phone in the past 20 years. The following table summarises some of its key attributes and how they have changed. (Sources: http://www.cntr.salford.ac.uk/comms/ and http://www.mobilephonehistory.co.uk/index.html.)

	1992	1992	2002	2012+
Definition	Analogue 1st Generation	Digital 2nd Generation	Digital 2nd Generation	Digital 3rd Generation
Era brand	Rabbit, Nokia & Motorola	Nokia & Motorola	Nokia, Sony Ericsson, Motorola, Siemens	Apple and Google
Weight	260-320g	230-470g	92-250g	140g
Shape	Candy Bar	Candy Bar	Candy Bar, Flip, Clamshell	Slate/Tablet
Cost of handset	£199-700	£250-700	£25-200	£300-500
Monthly subscription cost	£55	N/A	N/A	£5-£40
Textual display characteristics	1 x 10 numeric monochrome	4 x10 numeric monochrome	6 x 10 alphanumeric 256 colours	Multiple alphanumeric 280x720 High Definition
Dimensions	160x60x35mm (Average)	140x60x27mm (Average)	99x45x21mm (Average)	115x58.6x9.3mm
Screen size	<=1in	<=1in	2-3in	3.5-4.7in
Operating system	N/A	N/A	Symbian, Palm OS, Windows CE	iOS, Android, Windows Mobile, Blackberry
SIM Card	N/A	86x54x0.76mm (Credit Card)	25x15x0.76mm (Mini)	15x12x0.76mm micro / 6x5x<1mm embedded
Processing Speed	N/A	N/A	52MHz	512MHz-1.5GHz
Storage	N/A	125 names and phone numbers	10-40MB 250 names and telephone numbers	16-64GB Unlimited names and telephone numbers
Mobile Internet	Nil	Nil	WAP	Mobile Broadband
Connectivity long-range	ETACS	GSM 114Bit/s-22.8Kbit/s	GPRS 48-56Kbit/s	3G/4G/Wi-Fi/WiMax 1.2-4.5Mbit/s
Connectivity short-range	Nil	Nil	Infra-red	Bluetooth /NFC
Camera phone resolution	N/A	N/A	1-3MP	8MP
Battery Life	45 mins-1hr talk time	1-2.5 hrs	3-10 hrs	8-14 hrs

	1992	1992	2002	2012+
Definition	Analogue 1st Generation	Digital 2nd Generation	Digital 2nd Generation	Digital 3rd Generation
Sensors and Media	N/A	N/A	Radio, games, polyphonic ringtone, audio player	Multimedia video & audio playback and recording, games, mobile TV, radio, GPS, accelerometer, gyroscope

+ Based on the iPhone 4G and HTC X smart phones

The following table gives some measure of the uptake of mobile phones and the corresponding decline in landline usage. (Sources: Ofcom and http://www.cntr.salford.ac.uk/comms/mobile.php.)

	1992	1992	2002	2012
SMS messages sent	N/A	N/A	14 billion (2004)	37 billion (2011)
Mobile voice calls (total minutes)	N/A	N/A	6 million (2004)	30 million (2011)
Landline voice calls (total minutes)	N/A	N/A	335 million (2003)	28 million (2011)
Residential landline voice calls (total minutes)	N/A	N/A	224 million (2003)	19 million (2011)
Mobile subscribers	20,000 (Rabbit)	700, 000 (1992) (Vodafone) 7% of the UK population	1.6 million (2004) (Vodafone)	81.4% of the UK population (2011) Approx 82 million subscriptions (2011)
Landline broadband subscriptions (including business use)	Nil	N/A	N/A	18.4 million (2011)
Mobile broadband subscriptions	Nil	N/A	N/A	6 million (2011)

3.2 Predicting the future

We can make some observations based on the different types of mobile devices that are currently on the market.

- There is considerable diversity in the range of devices available.
- Each group of mobile devices could be classed as ubiquitous – the more so if you always have it with you and never switch it off (as is often the case).
- The majority of the population have at least one of these devices, though their ubiquity means that many people don't need more than one type.
- A majority of the population are carrying around personal mobile devices with significant storage capability. This storage capacity is frequently under-used and provides potential for future exploitation.
- Similarly, people are carrying around devices with processing power that is not used to maximum level for the majority of the time. This is another potential that can be exploited by new uses in the future.
- The phenomenon of people carrying powerful computing and storage capability is global. Market penetration is extremely high in developed countries, but is also significant in developing countries.

- The expectation is for the user to upgrade periodically to a newer mobile device with increased bandwidth, functionality, processing and storage capabilities.

We can anticipate that in the future:

- There is much potential to interact with a wider set of senses such as smell and touch.
- High bandwidth could make possible a virtual presence almost indistinguishable from the physical presence.
- The actual technology in the mobile phones, even the basic models, is quite sophisticated including relatively powerful computer processing units, and will become more so.
- Devices will be increasingly capable of working "disconnected", i.e. while a wireless link is not available, with data stored on the device ready to be uploaded to a network once connectivity is restored. Devices with multiple networking links will also be more common.
- Convergence of wireless channels is resulting in a trend towards mobile devices having seamless access to the Internet and wider systems. There could well be competition in providing different Quality of Service (QoS) and pricing models based on the specific mix of wireless channels offered.

Certainly, we can anticipate that there will be increasing convergence between devices and their functionality, their applications and the communication channels they employ.

What do we see as the significant trends over the next 10-20 years? We expect:

- hardware to get smaller, more appealing to look at (or more out of sight), less power-hungry and more connected
- software to become more personalised, adaptive, context-aware and more easily upgraded
- software applications to become more integrated between mobile devices and the web, with more pictorial interfaces and increased use of video and sound as inputs
- devices to be more capable of interaction and interoperability with each other, without human intervention
- infrastructure (e.g. networks) to have higher capacity, reduced latency (in making connections), better integration, for it to become more flexible and adaptable in its use, and more prevalent in places it does not yet reach
- more and better quality sub-devices (e.g. cameras, sensors) to be incorporated into devices that themselves become more ubiquitous and more hybrid
- services to become more location-based, more focused on what you are doing and less interactive (because the service will know enough about you, where you are and what you are doing that it will not require to ask you so many questions)
- communication interactions to become shorter but more frequent, with data replicated in more places (e.g. "the cloud") and for longer
- human interaction to be mediated by technology to a higher extent

- everything to get cheaper, with many basic services provided either for free or packaged together for a flat fee

For the particular purposes of healthcare, devices will be hybridised with biotechnology, nano-medicine, genetics and other medical technologies. Specialist medical devices (such as a glucometer) are likely to become accessories to existing consumer devices (such as a mobile phone), but the reverse is also possible.

An outstanding issue concerning the integration of medical devices and communication devices is one of regulation. Regulation can be seen as a barrier to market entry for new devices with medical applications. To date, regulators such as the US Food and Drugs Administration (FDA) have taken the view that a combination medical/communication device takes on the classification of the medical device standing alone. This seems reasonable from a purely local point of view, but if the combined device relies on its communication links to provide its service, consideration also has to be made of whether the device is "safe" if its communication links are broken. In the UK, the Medicines and Healthcare products Regulatory Agency (MHRA), working with EU partners, may take the same approach.

4 Mobile HCI and the user experience

4.1 Mobile human-computer interaction

In sections 2 and 3, we looked largely at the "hard" technology developments that have made mobile devices more ubiquitous. In this section, we look at the equally important "soft" side of the technology and how these devices interact with the user.

Mobile Human-Computer Interaction (HCI) is a research area that aims to study design of useful and usable applications, as well as interaction models via mobile devices. Mobile devices have several characteristics that afford some type of use and hamper others. Gibson’s theory of ecological psychology (Gibson, 1979) first introduced the term “affordances”, which since then has been used continuously in HCI and most recently in *mobile* HCI.

Gibson asserts that all objects in the environment afford some kind of behaviour that users can perceive explicitly just by looking at them, e.g. holding, talking, eating and so on. In order to realise the full potential and "affordances" of mobile devices, it is important to look at some general characteristics of this evolving technology that affect users' experiences (Raudaskoski, 2003).

Firstly, mobile devices are perceived as a *portable* technology, meaning that we can use them in different places and context, e.g. on the move. Secondly, the fact that users can carry them means they also serve as a *companion* device that can be used "anytime and anywhere". Thirdly, a mobile device is usually the property of an individual, not the family or organisation (even if they paid for it), so they are more *personal* than computers. Finally, they are *connected*: it is a device that was originally developed for communication purposes.

In addition to general characteristics of mobile devices, it is pertinent to look at more specific characteristics of mobile phones that have evolved over the past years. From purely voice-based communication technologies, now mobile phones are offering advance sensing and multimedia capabilities. New generation mobile phones, smart phones, enable novel ways of interaction, in particular by the evolution of touch, multi-touch and gesture interfaces. Some general characteristics of smart phones include high resolution displays that not only support the display of text, media and graphics, but also enable physical interaction via a multi-touch screen. Some examples of gesture interfaces include swipe, double tap, pinch open, touch and hold, and shake. Device orientation can also change from portrait to landscape and vice versa in order to support different contextual tasks. Finally, different input methods are supported through physical and/or virtual keypads (i.e. numeric and alphanumeric keypads, touch and multi-touch, voice and handwriting recognition). On the other hand, mobile phones are limited, in terms of screen size, memory and battery life, which poses an extra challenge for interaction designers aiming to develop a usable mobile application.

Although mobile devices afford different characteristics to desktop systems, general principles of usability are still the same. ISO defines usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use." (ISO, 1998) Shneiderman’s framework of usability (Shneiderman, 2000) correlates usability to "usefulness" and is composed of factors including learnability, efficiency, memorability, error tolerance, and user's satisfaction. However, many common desktop design patterns and usability principles do not apply in a mobile environment (Fallahkhair, Pemberton, & Griffiths, 2007). Small screens and limited input methods create extra challenges for interaction design, pointing back to the affordances that a mobile device provides. Navigation mechanisms (including searching and browsing) for applications need to be designed for the small screen, and direct data entry carried out via touch and multi-touch interactions. It is important to provide a logical path for the user to follow, making a navigation control consistent and obvious. In addition, in the mobile domain, users will find it difficult if an application relies heavily on text input, so it is important to use alternatives, for instance table views or drop-down menus in order to minimise the effort required for user input. Moreover, mobile users often want to get access to just-in-time information – provision of content in a more efficient manner is required. It is important to elevate the content people use most so as to reduce information overload. Applications of mobile device are often used on the move and in different situations, so context aware support should be provided to enhance the user's experience.

The fact that there are a number of different smart phones available that feature different types of interaction mechanism and functionalities, makes it even more difficult to have general and standard usability principles. There are many mobile usability guidelines available that have been developed in collaboration between industry, academia and platform providers. Some of these guidelines focus on usability, while others focus on interface design and accessibility. For instance, the World Wide Web Consortium (W3C) outlines mobile HCI guidelines that recommend a number of factors, including interaction method and the consistency and accessibility of content for disabled users that affect their experiences. On the other hand, platform providers and/or handset manufacturers provide their own design guidelines, e.g. iOS design guidelines, UI guidelines for Android, UI guidelines for Windows Mobile and more. Proponents in the field of HCI and usability have outlined a number of design guidelines that could be applied to the mobile domain. In particular, the work of Nielsen (Neilsen, 2012) includes a number of guidelines for increasing usability of mobile devices as well as touch-screen application usability. Pemberton and Fallahkhair (Pemberton & Fallahkhair, 2006) proposed a novel approach for evaluating "beyond usability", focusing on usefulness and desirability as *de facto* requirements for design of mobile application.

While interface design and usability guidelines focus on the detailed look-and-feel of a system, interaction design covers a broader range of endeavours: it is about understanding the users, their goal and experiences to use the technology, which need to be realised in the context of different applications (Fallahkhair, 2011). This knowledge is required in order to inform a design of a usable and useful system in the m-health domain/context.

4.2 Research in the user experiences of m-health systems

Despite the the importance of mobile HCI and usability in the m-health domain, there are only few studies looking at users' experiences (UX) in this context.

A study conducted by Cacace et al. (Cacace, Clinque, Crudele, Iannello, & Venditti, 2004) investigated the use of mobile information systems by students of medicine, nursing and dietetics accessing teaching resources on handheld devices. An evaluation based on user observation, interview and questionnaire revealed that users found handheld devices more efficient than desktop PCs in finding information. Handheld devices also improved information accuracy because data entry on the devices was more efficient than writing on a traditional blank piece of paper.

Hellman (Hellman, 2007) investigated the use of mobile technologies with elderly and cognitively disabled users. The study presents ten categories of accessibility guidelines and accessible user interfaces for an electronic service on a mobile phone.

Putzer and Park (Putzer & Park, 2010) investigated user attitudes towards a smart phone among healthcare professionals, specifically nurses. The study provided empirical support that characteristics such as compatibility, job relevance and internal/external environments were significant predictors of attitude toward using a smart phone.

A study by Anokwa et al. (Anokwa, Ribeka, & Parikh, 2012) focused on the design of a phone-based clinical decision support system for resource-limited settings. Through a formal usability evaluation with the clinicians, they discovered four core themes that should be considered to inform the design of similar systems, including:

- the impact of the phone on time with patients should be minimal
- the desire to shift summary retrieval and patient data entry to clinicians
- the user's experience of using smart phones and the size of the phone screen both affect interaction speed
- clinicians are concerned about the means by which phones are distributed to their users and the security of the system

New directions in this research area should consider issues beyond usability and go deeper into the realms of users’ experiences and user-centred design (UCD) in the m-health domain. ISO 13407, the standard providing guidance on the UCD process, describes this methodology as "a multi-disciplinary activity, which incorporates human factors and ergonomics knowledge and techniques with the objective of the enhancing effectiveness and productivity, improving human working conditions, and counteracting the possible adverse effect of use on human health, safety and performances." (UsabilityNet, 2003). Sharples, et al. suggest "usability is a necessary but not sufficient condition for the design of good human-centred technology. Technology should also be useful, elegant and desirable (people should want to use it, rather than being compelled to do so as a condition of their learning or work)" (Sharples et al., 2002). Further research towards user centred development of m-health systems will enable the development of more usable applications that are derived from the actual needs of users rather than motivated by the technology available.

5 Social trends and mobile technologies

5.1 E-government and m-government

The trends in technology capability and functionality highlight that mobile technologies can change significantly what people do in regard to their everyday lives, including health. This has the potential to move the boundary between what government does and what citizens do. At the same time as citizens are changing what they do, there has been a ripple of change across governments in their use of technology – governments are transforming themselves driven mainly by technological change.

Osborne and Gaebler (Osborne & Gaebler, 1992) identify several ways in which government activity can be transformed (abridged from (Cornell University, 2006)):

- Catalytic governments separate *steering*, or providing guidance and direction, from *rowing,* or producing goods and services. Osborne and Gaebler give numerous examples such as contracts, vouchers, grants, and tax incentives.
- Community-owned governments push control of services out of the bureaucracy, into the community. Examples show how bringing communities into the picture empowers the people who are the intended recipients of services and results in better performance.
- Osborne and Gaebler believe that improving both the quality and cost-effectiveness of government services can be achieved through competition rather than regulation. Introducing competition does not necessarily mean that a service will be turned over to the private sector; rather the crucial function of competition is ending government monopolies.
- Mission-driven governments deregulate internally, eliminating many of their internal rules and radically simplifying their administrative systems such as budget, personnel, and procurement. They require each agency to get clear on its mission, then free managers to find the best way to accomplish that mission, within legal bounds.
- Result-oriented governments shift accountability from inputs to outputs, or results. They measure the performance and reward agencies, so they often exceed their goals.
- Customer-driven governments are those that make an effort to perceive the needs of customers and to give customers a choice of producers. They use surveys and focus groups to listen to their customers, and put resources in the customers' hands.
- Enterprising governments stress earning rather than spending money. They charge user fees and impact fees, and use incentives such as enterprise funds, shared earnings, and innovation funds to encourage managers to earn money.
- Anticipatory governments seek to prevent problems rather than delivering services to correct them. They redesign budget systems, accounting systems, and reward systems to create the appropriate incentives.
- Decentralized governments transfer decision-making authority to those individuals and organizations at the bottom of the organizational hierarchy. They

restructure organizations and empower employees and create labour-management partnerships.

- Market-oriented governments utilize a market mechanism instead of an administrative program to provide goods and services to the public. They reinvent themselves through the application of market-oriented incentives.

It is interesting to note that Osborne and Gaebler’s work is based on examples of innovation, entrepreneurship and changes to government that pre-date the wide spread adoption of the Internet. Each of their dimensions of government transformation can be applied to mobile technologies. Mobile health has potential for significant transformation in processes, changes in roles and responsibilities, changes in support information provided, changes in monitoring activity and in health data collection.

E/m-government technologies and thinking give national governments the ability to provide their services more effectively (e.g. more cheaply or more quickly). It also provides an opportunity to reconceptualise the very nature of government (Jaeger & Thompson, 2003). This includes transforming relations with citizens, the private sector and/or other government agencies so as to promote citizens’ empowerment, improve service delivery, strengthen accountability, increase transparency, and/or improve government efficiency. According to Silcock (Silcock, 2001), "For the first time since the creation of the modern welfare state, there is now a real opportunity to ‘reinvent’ government".

Sweisi et al. (Sweisi, Adams, & Soliman, 2007) argue an effective transformation to e/m-government services should result in significant improvements in the long-term as well as some tangible results in the short-term, mainly in the following areas:

- simplifying the delivery of government services to citizens and businesses
- eliminating layers of government management (i.e., gradual elimination of bureaucracy and hieratical structure and empowerment of government employees across layers)
- enabling collaboration and interaction among government employees to create synergy utilizing all available resources
- making it possible for citizens and businesses to easily find information and get services from the government
- simplifying business processes and reducing costs through integrating and eliminating redundant systems
- streamlining government operations to guarantee rapid response to citizens' and businesses' needs
- enabling the achievement of the government’s development of goals and objectives

A further aspect of e/m-government transformation capability is the "Open Government Data" (OGD) initiatives – where governments and public bodies around the world are opening up official datasets for public and commercial use. For instance, in the UK there are currently over 5,400 datasets available from central government departments as well as from a number of other public sector bodies and local authorities (see http://www.data.gov.uk). Large numbers of datasets are also emerging across much of Europe. M-health is a particularly interesting area for OGD since it offers the opportunity to collect and collate lots of personal data from individuals as well as providing individuals with access to healthcare information resources. Particular issues that will need to be addressed include standards, formats and metadata for OGD projects. There are a variety of potential standards, for instance the European Data Model (EDM), XML and others, but standardization is needed across projects for the full potential of OGD to be achieved. A key requirement of OGD is the ability of people and corporations to be able to interpret the datasets, hence the need for some common standards.

5.2 How mobile technologies change things

There are a range of proposed models and theories trying to capture the impact that mobile technologies and mobile working provide. For instance, Siau and Shen (Siau & Shen, 2003) have identified 3 key drivers towards mobile technological change:

- **Mobility** – Mobile technology provides workers with the opportunity to be online anytime and anywhere in order to carry out their tasks, meaning that workers can function to their full capability outside the office.
- **Reachability** – Mobile technology allows workers to be able to be in contact or contacted by anyone at anytime and wherever they may be.
- **Personalisation** – The ability for users to filter what information they receive, and to only access the information they need from remote locations.

Similarly, Keen & Mackintosh (Keen & Mackintosh, 2001) refer to the "Freedom Economy" and a set of "freedom" rules towards mobile technological change:

- **1st Rule – Relationship freedoms** – Mobile technology adds value to customer relationships – e.g. by allowing workers to be mobile and to visit customers personally to provide better service. By combining the internet with telephone services, workers are better equipped to provide service to customers, enhancing business relationships.
- **2nd Rule – Process freedoms** – Value is added along the entire supply chain by making as many processes as possible mobile based from logistics to business partner relationships.
- **3rd Rule – Knowledge freedoms** – Enabling mobile workers to retrieve information remotely in order to present it directly to a customer instead of them having to refer "back to base" (because there may not be a base!).

Fitch and Adams (Fitch & Adams, 2006) explored the application of mobile support to community healthcare workers and possible changes to working systems. They found that community healthcare (CHC) offers much potential for socially important mobile applications and services that could increase patient care and improve working practices for healthcare workers. For instance, district nurses visiting patients in their homes could access the patient's notes kept by their GP or hospital. The technology could also provide a means of getting real-time guidance from the GP or a specialist. However, to go down that route would involve significant process and operating changes by the GP and hospital. Benefits in one area may well raise problems in another.

The same authors raised the issue of an "expectation gap" emerging, where new technology raises expectation of new treatments before they are actually ready. Similarly, the sociologists Beck (Beck, 1992) and Giddens (Giddens, 1991) argue, modern society is getting more risky and technology and science play an important role in this new "risk society" by providing increased diagnostic capabilities, yet are unable to provide immediate solutions: technology enables society to see more risks yet cannot meet society’s demands to address them. This seems particularly true for the healthcare arena, where new, sophisticated diagnostic capabilities are able to identify an increasing range of ailments. New technology developments are frequently reported as "future" treatments for these ailments, mostly prematurely. Beck and Giddens argue that society is becoming more critical, no longer willing to accept the truth claims of scientific knowledge. "*Science and its claim to truth are at issue in the risk society*" (Giddens, 1991).

6 Health and social care applications of mobile technologies

As we have noted in previous sections, technology is advancing rapidly. In this section, we look forward to see how these changes might be realised in the existing healthcare and social care ecology in the UK, a system which is fragmented, and technically and organisationally conservative (Andalo, 2012).

The NHS is already embracing m-health. The National Mobile Health Worker Project (Department of Health, 2011) is one a number of initiatives that designed to pave the way to larger and larger-scale deployments. It has found that:

- it is useful to keep metrics about daily activities so that issues such as productivity and the time spent with patients can be analysed
- clinical effectiveness (e.g. reducing referrals) is an important means of financial saving
- users will get frustrated with the technology (especially wireless network coverage), and developers must experiment with different approaches to seek the best solution
- clinicians are not resistant to change or innovation, provided they are supported and engaged
- mobile devices are key to bridging the information gap that community care suffers from

In our view, there are a number of prerequisites without which the potential improvements offered by m-health technology cannot be fully realised. These include:

1. a shared, comprehensive electronic patient record that is immediately available to healthcare (and social care) practitioners in every setting, allowing joined-up care
2. better integration of health and social care – fundamentally, the patient should not be able to see the joins
3. evaluation of health and social care on the basis of patient outcomes

If these prerequisites start to be realised, then we foresee that technology will make the following potential scenarios into reality.

6.1 Chronic conditions

The lifetime management (not cure) of sometimes multiple chronic conditions will be the largest effort for future healthcare (Davies, 2012; Kings Fund, 2005). The way these conditions are handled can greatly improve the wellbeing of individual patients as well as controlling the costs and therefore sustainability of the system. Patients will vary in their willingness or ability to participate in their own care, and a number of different care management tracks will need to be made available to allow for these individual preferences and needs.

Example 1: A 68 year old woman, suffers from congestive heart failure. She takes and transmits vital signs at specified intervals to a health hub for trends to be analysed (DukeHealth.org, 2010; E-Health Insider, 2010, 2012b). She receives visits from her health co-ordination team, who organise Skype consultations with specialists where required, using Google Body (Open Source at Google, 2012), and protocols for patient to indicate problems. The health co-ordination team (GP, community nurse, physiotherapist, counsellor, social worker, pharmacist, etc.) will mediate where necessary. Medication will be dispensed from an implant, with its dosage adjusted according to vital signs analysis (Cookson, 2012). She is an actively engaged patient, feeling well cared for and in control of her condition (News Letter, 2012). The result is a reduced incidence of crises – problems are identified in good time to fix them before they exacerbate.

Example 2: Her daughter, 37 years old, has learning difficulties and diabetes. She is living independently in a telecare assisted home (Alzheimer's Society, 2011; Brownsell, Aldred, & Hawley, 2007; Disabled Living Foundation, 2008) with some monitoring as worked out in her agreed care plan – GPS tracking in case she gets lost and confused (Personal GPS Trackers, 2012) medication implant for better compliance, alerts in case of changes to normal sensor traffic (e.g. no movement, no use of kitchen). She agreed to these conditions to allow greater independence, in consultation with her care team and family carers.

Example 3: A 48 year old man suffering from diabetes and depression. Regular clinics are provided at his workplace for diabetes offering advice and support. There is the opportunity for him to transmit daily vital signs measurements to his primary care team for trend analysis. There is also the opportunity to consult at intervals from the workplace with an emotional wellbeing coach (for example, mi-wellbeing (mi-wellbeing, 2012)). His employer recognises that facilitating employees' health maintenance (both physical and mental) is advantageous (Black, 2008).

6.2 Emergency medicine

The mobile phone has already changed the way that the emergency services respond to requests from the public. There is now almost never a need for someone to have to look for a public telephone, so the request for assistance typically comes much earlier than it would previously have done.

New technology will therefore be used to further enhance existing provision. For instance, the patient's medical history will be accessed immediately through the electronic patient record. Handheld ultrasound (Walsh, 2010) and other diagnostic devices can be used in transit (Bowdler, 2012; Burns, 2011; Medtronic Ltd, 2012; Wauters, 2011). The nearest accident and emergency department with the shortest waiting time can be located (Gaglani, 2012). Guidance can be given on resuscitation techniques (Gaglani, 2012). In congested city centres and remote locations, volunteer first responders can be quickly located and alerted and despatched to provide a limited number of learned techniques (CPR for instance) that can make a crucial difference in the interval before the emergency team arrives (Diagnosaurus, 2009; Resuscitation Council (UK), 2010; The Economist, 2012). More mundanely, shared portable scheduling technologies allow a more flexible and immediate response by emergency teams (Ridden, 2011).

6.3 General medicine

The scenario below is based on the premise that the balance of healthcare delivery will be weighted towards primary and preventive care, as envisaged in the Health and Social Care Bill, with hospital reserved for accident and emergency treatment, and planned treatment of specific problems, the patient then being returned to the home or community setting for convalescence and follow-up treatment (Department of Health, 2006; Munton et al., 2011; Singh & Ham, 2006). We envisage primary care organised with the GP as the hub of a network of different health workers, co-ordinating the care of his patients. Better communications and workflow co-ordination software on easily-used devices (tablets, smart phones, toughbooks) reinvigorate community teams and make community healthcare workers pivotal (E-Health Insider, 2012a; Ridden, 2011). Generally, process and structure changes enabled by the new technology will allow more responsive, patient-centred care.

In the primary care setting, the Health Co-ordinator checks the trends of her 3000 patients: 30 have been prioritised for attention according to the protocols (Kedward & Dakin, 2003; Marshall, 2008). These will be attended to by the most appropriate members of the team today (for instance, midwife, community nurse, pharmacist). The scheduler allocates the visits or calls in the most efficient way and co-ordinates shared visits with other members of the team (physio, geriatric consultant) where required (Ridden, 2011).

Results of yesterday's submitted tests are received by electronic transfer (Caldwell, 2011; Park House Medical Centre, 2012) and automatically added to each patient's EPR. Further actions required by the medical team are included in the priority scheduling.

The co-ordinator checks emails received from patients (40 received today) and responds (2 hours), using Internet access to the latest medical information to answer queries (Hartzband & Groopman, 2010). Any further actions resulting are added to the priority scheduler. The remaining 6 hours are spent on the 8 patient visits and 5 patient phone consultations allocated to her (Chase, 2012).

Other actions she might take are:

- providing monitoring equipment for home use with selected patients (to measure blood pressure, ECG, blood glucose, etc.) and monitoring the input readings (NICE, 2011)
- participating in a ward round for discharged hospital patients in a virtual ward (Lewis, 2012; Lewis et al., 2011)
- attending a video conference with a surgical team to prepare for forthcoming planned hospital procedures for patients
- further health education campaigns – sending flyers out electronically (email, SMS, etc.), offering new apps for weight control to selected patients
- receiving alerts by email/SMS on changes to medical practice, new research, technologies

Any relevant hospital will utilise m-health technology to provide the following:

- full medical history on EPR shared with patient and with primary care team
- more mobile outreach clinics utilising better workflow co-ordination software
- workflow, bed management and diary scheduling improvements facilitating better co-ordination of clinical effort
- more automated prompts and reminders to aid safety (e.g. the drug trolley "knows" the patient's prescription and can reinforce correct dosage and alert if there are contra-indications for additional medication; this also improves stock management (Enovate, 2007)).

- vital signs of all patients are regularly measured against metrics to prompt corrective action (according to protocol) if a patient deteriorates (The Learning Clinic Ltd, 2012)
- kiosks to provide information at all levels to interested patients and their families and carers – many entry points to information (Ellison, 2011; Touch4, 2012)
- significant patient safety outcome measures are published so that patients and primary health co-ordinators are able to check (e.g. the number of blood line infections in past x months) for each specified facility at the hospital, before selecting that hospital for treatment (Collins, 2012)
- encouragement for patients and their primary health co-ordinators to post feedback so that the services can be improved (NHS Choices, 2011; Patient Opinion, 2012), and this feedback is regularly examined and acted upon

6.4 Social care

Many social service departments and private-sector care providers have already embraced telecare (the use of information and communication technologies to provide social care at a distance) to help them do their job more effectively and efficiently. The important aims for the future are to further integrate care with health, and the introduction of mobile technologies provides new opportunities to make that happen. The following scenarios show how m-health technology could considerably enhance people's quality of life.

Example 1: A 79year old woman living alone has fallen once before which involved a lengthy hospital stay and recuperation and shook her confidence. She now has a number of safety features fitted in her home: bogus caller alarm at the front door, sensors which test discreetly for absence of movement and raise alerts if necessary, heat and fire controls in the kitchen, flood controls in the bathroom (Dewsbury, 2009; Disabled Living Foundation, 2008, 2012). She also has a personal alarm fitted to her wristwatch, with GPS capability, which she can use to summon help if required, whether at home or out and about (The Carephone, 2011). Sophisticated natural language recognition software allows her to control this device and other home devices such as the cooker and doors, and communication devices such as phone, television and computer tablet, by voice alone (Apple Inc., 2012; Nuance, 2012). This has vastly improved their ease of use for her, given her normal age-related loss of function in eyesight and touch. She makes use of the new interactive features of phone and television to keep in touch with friends and family (Apple Inc., 2012; Looking Local, 2012; Nuance, 2012), and enjoys shared games and exercise sessions with other members of her social network, either in real time or virtually (Pacheco, 2011). When she goes out, she can access useful information through her phone, such as the nearest open public lavatory, or facilities with disabled facilities such as wheelchair access or a hearing loop, should she require those (DisabledGo, 2012; Elbatrop Ltd, 2012; Macmillan, 2011). A careful multifactorial falls risk assessment was made following her hospital stay, and as a result changes were made to the home environment, to her medications, and an exercise routine was established to mitigate the risks (Doughty, 2011a; Gillespie et al., 2009).[2] These devices and systems enable her to live a more independent, fulfilled life.

Example 2: A family with mental health problems or learning difficulties requires daily carer input.

The carers for this family are able to check and update their schedules on the move, allowing more flexible response to need (Ridden, 2011). The homecare check-in is made electronically, allowing better supervision of the care provided, and also allowing input from the clients themselves (Whittle, 2012). Each member of the family's social care and health history is stored on an electronic record, and authorised persons have immediate access to this information.

Help and advice for the adult family members can be delivered as texts through mobile devices – appointment reminders, childcare tips, diet and so on. This has been shown to be a very accessible way of disseminating information (Brownlee, 2012).

The immediacy of interaction has beneficial effects on the confidence of all the members of the family.

6.5 Public health

Advances here utilise the better possibilities for public engagement afforded by the mobile technology to achieve improvements in prevention and education.

Example 1: A young pregnant teenager, at odds with her family. The outreach team send texts to her mobile phone to remind her about appointments and better engage her with the care process (Brownlee, 2012). The mobile pregnancy clinic periodically visits her school and can administer most diagnostic tests there, for example using handheld ultrasound (Walsh, 2010). The care team prompts the girl to health-enhancing behaviour change (smoking cessation, control of alcohol consumption) through game-based apps on her mobile phone (Ferenstein, 2011; Free et al., 2011), and also encourages her to join social networks of mums and mums-to-be for peer support.

Example 2: A cohort of patients aged 30 – 40 with Crohn's disease are recruited to record a selection of their daily data (weight, food intake, alcohol consumption, exercise pattern) on to their mobile phones and transmit that data securely to a research group that aggregates and anonymises the data and uses it as a resource to aid understanding of the factors that ameliorate or aggravate the condition. Similar cohorts are recruited to examine problems such as poor sleep behaviour, ME and so on (Carmichael, 2008; Singer, 2011b).

6.6 Self-diagnosis, self-management

Advances here build upon the consumer-led use of devices (such as FitBit) to track vital signs and statistics with a view to improvement (e.g. increased stamina, weight loss). Data from gym devices is also stored and integrated into the individual's EHR. Gradually this joins up with other health activities (there is already some crossover – for instance is obesity a disease or a result of lifestyle choices that can be

[2] At this time, no usable falls prevention device has been developed, though research continues (Mackay, 2011; Xu, Gong, He, & Sarrafzadeh, 2011).

reversed?). Motivation is a key factor, and the use of gaming features, peer pressure, workplace promotion, helps here. The devices move from being fitness gadgets to be more closely integrated into everyday health plans.

Example 1: A young fit woman aged 35 who is a keen runner, is used to researching and buying products to improve her performance – specialised running shoes, lightweight, sweat-wicking shirts and trousers, supportive sports bras. She extends this to buying apps for her smart phone that can record and improve her performance (Lowensohn, 2009). She enjoys testing herself against colleagues, and setting new targets for herself (Striiv.com, 2012).

10 years later, she has developed a significant medical condition. She researches that condition, and takes her findings to her primary care physician (Allen, Lezzoni, Huang, Huang, & Leveille, 2008; deBronkart, 2012). She locates portable ways of measuring the relevant vital signs for her condition (Singer, 2011a; Wauters, 2011) and experiments in her daily life to find actions that improve her condition (Singer, 2011b), in cooperation with her medical team. She participates in online patient forums, and research groups (Irritable Bowel Syndrome Self Help and Support Group, 2012). She is a fully engaged patient, participating in her care.

Example 2: An elderly man, with some dementia, living in a residential care setting, was withdrawn and did not engage with the other (largely female) residents. Use of a tablet device allows him to participate in competitive games, both against himself and against others, improving cognitive function, social comfort, and general wellbeing (iPadStands, 2011).

6.7 Summary

The NHS has adopted *e-health* to a large extent – every hospital has an electronic patient record system and virtually every GP has a PC on their desktop. But these technologies simply replace paperwork – while they may improve the efficiency of administrative processes, and consequently improve resources directly available for patient care, the user (doctor, nurse, carer) acts as an intermediary between the patient and the system.

The goal of the use of technology in healthcare must be to move the collection of data *nearer to the patient*. As Briggs and Curry observe (Briggs & Curry, 2012), collecting information near to the patient (both in time and space) is likely to result in better quality. For the healthcare information collected about an individual, that patient is usually the best quality checker – they have the greatest motivation for the data to be accurate and have the most complete appreciation of the context in which it is collected. The clinician who records information is probably the next best. The use of m-health can thus make a large contribution to the quality of information stored. It can also contribute to increasing the patient's involvement in the processes of their care – they become an active participant in the process.

M-health can also contribute to "joining up" historically distinct (i.e. separately staffed, funded and managed) services. However, technology only makes integration *possible* – management still have to make the decision to make it happen.

7 M-health in other countries

The adoption and implementation of m-health initiatives is now a global phenomenon, but few are deployed at scale (WHO, 2011). The UK stands to gain by learning from these m-health innovations from both the developed and developing worlds. In the last few years, great strides have been made in m-health innovations in these regions, many of them very simple applications.

In brief, the adoption of m-health in developed countries is mainly patient-centric, with applications for the management of long-term chronic conditions. That puts them as telehealth or remote monitoring applications. Those from the developing world point to how low-cost innovations can revolutionise healthcare delivery at the community-level. These are being developed to tackle the Millennium Development Goals (MDGs) – related to the diseases of malaria and tuberculosis, and to maternal and child health.

7.1 Global outlook

According to a World Health Organization (WHO) report (WHO, 2011), m-health is a globally adopted technology. The report identifies 14 categories of m-health applications grouped under six headings – these are based on the results of a large-scale global survey conducted to measure and benchmark national adoptions. The categories are:

1. Communication between individuals and health services • Health call centres • Health care telephone help line • Emergency toll-free telephone services	2. Communication between health services and individuals • Treatment compliance • Appointment reminders • Community mobilization • Awareness raising over health issues	3. Consultation between health care professionals • Mobile telemedicine
4. Inter-sectoral communication in emergencies • Emergencies	5. Health monitoring and surveillance • Mobile surveys (surveys by mobile phone) • Surveillance • Patient monitoring	6. Access to information for health care professionals at point of care • Information and decision support systems • Patient records

The report identifies the most globally adopted applications as SMS or voice-based public health ones such as health call centres, emergency toll-free telephone services, managing emergencies and disasters, and clinical applications such as mobile telemedicine. Most initiatives are classified as pilots, with few identified as being well-established.

In addition, differences in the nature of m-health technologies are identified along regional dimensions based on the size of the national economy. Generally, high income, developed countries (especially those from Europe), are reported as leaders relative to their low-income, developing counterparts from Africa, for instance. The economic disparity influences the differences in the types of m-health applications adopted in these regions.

7.2 Developed world: m-health for personalised medicine

In developed countries, the tendency is for applications that monitor patients and assist in making decisions about their care.

In the past decade, the European Union under its Framework Programme (FP) has invested in various basic and applied research initiatives in the areas of ICT and medical technologies. These researches combine technologies from mobile telephony, genetics, nanomedicine, biotechnology, sensors and medical imaging to develop patient-centric remote monitoring, therapeutic and diagnostic technologies. Examples are combination of innovations coming from the EU eHealth programmes such as *Personal health systems*[3] and *Risk assessment and patient safety*[4] and technology based ones like *Micro Bio Nano Systems*[5].

The outputs from these researches are now finding their way into clinical usage. Devices and systems are being developed to support personalised and independent management of long-term chronic conditions. Most of these technologies are yet to make it into the healthcare services. Nevertheless, the EU has instituted a road mapping project. The Mobile eHealth for the Vindication of Global Lifestyle change and disease management solutions (MovingLife) project[6] is to assist in fostering service integration and policymaking.

The project is to "deliver roadmaps for technological research, implementation practice and policy support with the aim of accelerating the establishment, acceptance and wide use of mobile eHealth solutions". The project's outputs promise to explore and analyze the available technologies and develop scenarios for integration into chronic disease management and into medical and clinical guidelines for healthcare professionals. In addition, risks associated with technological innovations and clinical adoption, and together with likely socio-economic needs are to be assessed. The MovingLife project could be instrumental in dictating the direction and scope of how m-health innovations should be strategically implemented and adopted within the health systems of the EU member states.

Outside Europe, South Korea's substantive progress and leadership in m-health innovations in telehealth and telecare and hospital-centric applications (mobile telemedicine), and their full integration within its national eHealth programme and infrastructure (Lee, Min, Shin, Lee, & Kim, 2009), is worthy of note.

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[3] http://ec.europa.eu/information_society/activities/health/research/fp7phs/index_en.htm

[4] http://ec.europa.eu/information_society/activities/health/research/fp7ps/index_en.htm

[5] http://cordis.europa.eu/fp7/ict/micro-nanosystems/projects-mnbs_en.html

[6] http://www.moving-life.eu/downloads/events/2012-01-27_MovingLife_agenda_mhealth_scenario.pdf

7.3 Developing world

In the developing world, applications tend to be focused towards supporting isolated health workers.

A United Nations Foundation report published in 2009 (Vital Wave Consulting, 2009) looked at the technologies that were being used to tackle the diseases targeted by the Millennium Development Goals. It identified SMS and voice-based m-health as the applications most commonly adopted in Africa and other regions. Nevertheless, since the publication of this report, innovations that could be classified as mobile telemedicine are emerging. These are driven by the availability of Smartphones. Example of such is capturing clinical and histopathological images for remote teelconsultation and diagnoses. Such re-invention of Smart phones for mobile telemedicine could create ‘Mobile Hospitals’ for community healthcare purposes.

For developing countries, the UK can both learn and support m-health innovations. Support in forms of funds and transfers of clinical and engineering expertise could assist in fostering inventions and in making transitions from pilots into service integration. Learning could come from joint participations in research projects, which outputs could have relevance for healthcare delivery within the NHS, especially for the UK’s ethnic minority populations.

8 Conclusions

8.1 The impact of new technology

Technology moves inexorably forward. Devices are becoming smaller, less power-hungry, and more ubiquitous. At the same time, the wireless technologies that allow them to communicate are providing wider and more continuous coverage, with a greater range and better security.

The best illustration of this is from the television and movie series *Star Trek*. In the original series, Captain Kirk had to take his communicator off his belt and hold it in front of his face to speak to his colleagues, but technology moved on and by the "Next Generation", Captain Picard only had to touch the badge on his uniform to accomplish the same!

How can health and social care take advantage of these developments? The first thing to note is that the technological developments have not largely been driven by healthcare needs. They are often consumer-led, and healthcare has been able to piggyback on that to provide its own applications. It is certainly the case that the widespread and relatively cheap availability of technology is fuelling the supply of solutions to healthcare rather than healthcare problems driving demand.

However, there is a never-ending supply of healthcare problems requiring solutions, and a wide range of people and organisations looking to develop specific applications that address them. Perhaps the biggest challenge is for health and social care commissioners to embrace the new ways of working that technology potentially brings.

The introduction of any new technology is generally disruptive to the industry that adopts it. Being able to see the advantages of a new way of working is one thing, but being able to plot a course from the present to the future that does not result in a failure along the way is difficult. Many organisations will need to sustain the "old" way of working while the "new" way is developed and implemented. Large-scale change does not come overnight, "double running" a new system alongside an old one is expensive, and there needs to be resources available to cover the inevitable bumps in the road.

It takes a special effort to be able to predict all the consequences of a change. Accordingly, most change tends to be evolutionary (solving the problems as they arise along the way) rather than revolutionary. However, we can see from the way in which technology has been introduced into developing countries (where there was nothing to replace so they were starting from a blank slate), that revolution can work too.

8.2 The future healthcare service

The logical conclusion of today's technological development is a healthcare service where:

- humans are "chipped", i.e. everyone has a number of implanted or body-mounted sensors that continuously monitor their state of wellbeing
- the information gathered from those sensors is shared wirelessly with systems that provide advice and warnings about healthcare conditions, and can raise the alarm if the condition is serious and urgently requires attention

- that information is aggregated centrally in order to facilitate the efficient provision of service and the monitoring of its effectiveness
- care can be provided almost anywhere, anytime
- everything is more focused on the individual
- the individual is expected to play a more active role in the maintenance of their health
- individuals are less concerned about the privacy aspects of sharing their healthcare information, accepting that it is necessary for the provision of a effective and efficient service
- the technology is less obvious, and simply seen as a means to an end

The strength of m-health is that it naturally leads to an overall system within which each component is typically small and cheap, and therefore replaceable, both if it gets damaged or a newer improved version comes along. An m-health system is thus easier to introduce incrementally and to upgrade once in place.

The weakness of m-health is that the system is distributed widely, both in geographic terms, and in who owns and controls the components. Centralised management is thus more difficult, and a wider range of stakeholders must be involved in decision making.

M-health is also limited where a big piece of capital investment is required – a current example would be something like a magnetic resonance imaging (MRI) scanner. Until someone invents a portable equivalent, we are going to need a building to house it in, a large-scale energy supply, a team of operators, and a booking system to manage (i.e. ration) its use. Nevertheless, even here m-health could provide a means of accessing the booking system, so integrating the "big kit" into the overall m-health experience.

However, the crucial aspect, as with other technological innovations, rests with the non-technological components that make up the "whole system". Whatever mobile devices are used, and whatever their use, a whole healthcare system needs an infrastructure of people and services that are available to respond to the information that comes in. The true challenge of m-health is to develop that infrastructure.

8.3 Questions for the future

There are a number of issues that remain unclear and are deserving of further study.

1. How do we overcome the apparent reluctance of many *potential participants* to engage with m-health (as found in the results of recent Whole System Demonstrator projects)?
2. How do we overcome the apparent reluctance of many *clinicians* to engage with m-health?
3. How do we fit m-health into the NHS's existing structures and infrastructures (e.g. "Victorian" hospitals, "traditional" doctor-patient relationships)?
4. How do we balance on the one hand the real efficiencies and convenience to patients of remote monitoring / consultation / administration, with on the other the traditional face-to-face, and "laying on of hands" of the healthcare model?

5. How do we make the transition from human monitoring of sensor data, and derived information, to the far more risky and necessarily error-proofed scenario of automatic response?
6. How can m-health address the still knotty and expensive problem of treating long-term conditions?
7. How do we tackle the possibility of patients being overwhelmed, distracted or disgruntled by the complexity of multiple technologies involved in their care?
8. How do we best assure (or at least quantify) the quality of information gathered from multiple sources (including patient-controlled ones)?
9. How do we best regulate the safety of technology used as a component of healthcare delivery?
10. How do we create a new model of healthcare data ownership that allows a citizen to share their information with the people they trust, and keep it out of the clutches of people that they don't?
11. What are the potential consequences of a consumer-driven healthcare market both on the provision of public services and the overall health outcomes?
12. What are the most effective user interface components that allow patients (of all ages and abilities) to record their health status and to receive information, instruction and advice on what to do about it?

M-health provides plenty of opportunities to use technology to join up healthcare. The challenge is how best to do so.

9 Glossary of terms and abbreviations

1G, 2G, 3G etc	First, second, third Generation of mobile telecommunications
Bandwidth	(colloquially), available or consumed data communication resources
Bluetooth	Proprietary open wireless technology standard for exchanging data over short distances
CCTV	Closed-Circuit Television: the use of video cameras to transmit a signal to a specific place, on a limited set of monitors
CDMA	Code Division Multiple Access: a 2G and 3G telecommunications standard
Cellular system	A distributed radio network
CHC	Community healthcare
Compass navigation system	China's alternative to GPS
CPU	Central Processing Unit (of a computer)
EDGE	Enhanced Data rates for GSM Evolution: a pre-3G network standard
EDM	European Data Model
E-health	Healthcare practice supported by electronic processes and communication, often using the Internet
EHR, EMR, EPR	Electronic Health Record, Electronic Medical Record, Electronic Patient Record (terms often used interchangeably)
FDA	Food and Drink Administration (USA)
Galileo	EU alternative to GPS
GLONASS	Globalnaya Navigatsionnaya Sputnikovaya Sistema: Russia's alternative to GPS
GPRS	General Packet Radio Service (2G standard)
GPS	Global Positioning System (US owned)
GSM	Global System for Mobile communications (2G standard)
HCI	Human-Computer Interaction
HDMI	High-Definition Multimedia Interface: an audio-video interface
HTML	HyperText Markup Language (for web pages)
ICT	Information and Communications Technology
IEEE	(formerly Institute of Electrical and Electronics Engineers): a leading professional association (USA)

IoT	Internet of Things: uniquely identified objects represented in an Internet-like structure
IP address	Internet Protocol address: a unique numerical ID attached to a device that links to the internet
ISO	International Organization for Standardization: developer and publisher of international standards
MDG	Millennium Development Goals (United Nations)
M-health	The intersection between the health sector and mobile technologies, such as (but by no means limited to) mobile phones
Mobile device	An electronic device that is small enough to be portable
OGD	Open Government Data
PDA	Personal Digital Assistant
QoS	Quality of Service
RFID	Radio-Frequency Identification
RuBee	Two-way, active wireless protocol
SMS	Short Message Service: text messaging
Telecare	The use of information and communication technologies to provide social care at a distance.
Ubiquitous computing	Ubiquitous computing (ubicomp) is a post-desktop model of human-computer interaction in which information processing has been thoroughly integrated into everyday objects and activities. In the course of ordinary activities, someone "using" ubiquitous computing engages many computational devices and systems simultaneously, and may not necessarily even be aware that they are doing so. This model is usually considered an advancement from the desktop paradigm (Wikipedia, 2012).
Ubiquity	The capacity of being everywhere or in all places at the same time
UCD	User-Centred Design
UI	User Interface
Usability	The ease of use and learnability of a software application, technical device, website and so on
USB	Universal Serial Bus
UX	User Experience
VGA	Video Graphics Array connector
W3C	World Wide Web Consortium
WBAN	Wireless Body Area Network

WEP	Wired Equivalent Privacy: a security algorithm used in wireless communications
WHO	World Health Organisation
Wi-Fi	In effect, Wireless Local Area Network components
Wireless	The transfer of information between two or more points that are not physically connected
WPA	Wi-Fi Protected Access: a security protocol used in wireless communications
XML	Extensible Markup Language
ZigBee	Specification for communication protocols for low-power devices

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