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# Mobile Healthcare Information Systems: Thru' the Ant Lens

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## ABSTRACT
Deployment of mobile technologies and applications in healthcare are becoming prevalent worldwide. As mobile innovation and standards in wireless continue to evolve, so does the mobile health care information systems framework. In this paper, we explore this evolving framework by synthesising current technologies, applications, issues and examining this through the actor-network theory (ANT) which seeks to understand socio-technical change by adopting a symmetric treatment of people and technologies.

## INTRODUCTION
Mobile devices are being adapted in every industry sector, including health services (Tessier, 2003) across the world. From the perspective of health services provisioning, shortening of cycle time in patient diagnosis, by simplifying daily routines and providing emergency health care are leading factors in the progressive deployment of mobile health care applications (Tessier, 2003).

In this paper, we explore few mobile health care applications, related issues and an appraisal of some worldwide initiatives. Subsequently, we seek to understand the mobile healthcare frameworks through the lens of Actor-network theory (ANT) – an approach to socio-technological change developed by scholars such as Latour, Callon and Law (McLoughlin, 1999; Law 1999; Tatnall and Gilding, 1999). We offer insightful knowledge to mobile application developers and health care providers while offering academia an opportunity to further knowledge in this area via an open framework.

## METHODOLOGICAL FRAMEWORK
Every field of academic investigation is outlined by a preferred set of research methodologies. Tatnall and Gilding (1999) found that a common approach to researching innovation in the information systems field is to focus on the technical aspects of the innovation and to treat 'the social' as the context in which its development and adoption takes place. They advocated the actor-network theory (commonly known by the ANT acronym) – an influential approach in dealing with socio-technical changes in information technology research (see e.g., McLoughlin 1999; Law 1999). The main attraction of this theory is its controversial element i.e. its symmetric treatment of people and technologies as members of actor networks. "*Contrary to the claims of those who want to hold either the state of technology or that of society constraint, it is possible to consider a path of innovations in which all actors co-evolve*" Latour (1991:117).

ANT is based on three principles: *agnosticism* which is the analytical impartiality demanded towards all actors involved in the project under consideration, whether human or non human; *generalised symmetry* which offers to explain the conflicting view points of different actors in the same terms by use of an abstract and neutral vocabulary that works the same way for human and non human actors; and *free association* which requires elimination and abandonment of all preset distinctions between technological or natural, and the social (Callon,1986).

A major focus of ANT is to explain how stable networks of sociotechnical relations are created and maintained by human and non human actants (Akrich 1992). The actants tend to form a network or *black box* by gathering a mass of silent others giving it strength and credibility. 'The black boxes can be opened due to entry of new actors, desertion of existing actors or changes in alliances' and the contents reconsidered (Callon, 1987). This aspect of ANT, in essence, makes it suitable for Information systems research.

In this paper, we have attempted to use ANT in trying to understand the adoption of mobile health care technologies, which seem to surpass geographic boundaries and social contexts.

## MOBILE HEALTH CARE: A BRIEF SYNOPSIS
Mobile health care encompasses the range of mobile technologies as they are applied in health care such as wireless network infrastructure, mobile devices and applications (Tessier, 2003). The key functions of mobile health computing include: accessing data at any location, recording information with stylus, keyboard, speech, touch or other mechanisms at the point of care, and transmitting/receiving information wirelessly. A plethora of devices are available for use in the wireless healthcare market ranging from traditional pagers, mobile phones, PDAs to the new mobile healthcare computing devices such as handhelds, tablet computers, laptops, sub-notebook computers, smart phones, computer mounted mobile carts.

Tessier (2003) categorised four general types of mobile hardware i.e. handheld (point of care) information accessing devices such as a micro chip which can be updated; intermittently connected computing devices which provide access to patient information through periodic downloading and synchronisation; locally (always) connected computing devices such as hospital wide point of care applications; and long-range connected computing devices – such as handhelds, mobile phones etc. Benefits of mobile health computing included the provision of point of care communication, ease of information access and exchange, elimination of paperwork, improved accuracy/efficiency.

According to Tessier (2003) improved clinical decision making, in real time, in multiple locations is the key benefit. However, conflicting of standards (Bluetooth, IEEE 802.11 etc), interference with other systems, authentication, secure transmission, user acceptance and application development/integration are some of the many issues with the provision of mobile healthcare.

Smart cards are being used as a storage medium in the health care sector, for storing patient records in hospitals, to confirm identity in respect to health care insurance etc. They cover authorisation, authentication and transaction processing and are able to store text as well as image based medical records. Therefore, they are very suited to the health sector (Fulcher, 2003).

The most popular mobile health care device seems to be the Personal Digital Assistant or *PDA*. Patients who need to record data frequently are required to use PDAs (e.g. Palm) which are small wearable computers that contain small operation systems (e.g. Palm OS) and different applications (Buchauer, 1998). They are also called Personal Information Manager (PIM) as this small handheld device has pre-installed functions for personal organisation, such as time and address management, a note pad, task management tools etc. Recent PDAs are equipped with an Internet browser and provide email functionality (Buchauer, 1998).

PDAs are mainly used for the administration of address data and for notification of dates (Bludau et al., 2001). Data exchange with a personal computer is possible and the collected data can be stored by a serial interface or can be transferred wirelessly via infrared, Bluetooth or wireless networks. PDAs come equipped with a touch screen that facilitates identification of handwriting and/or virtual key boards. Data can also be entered via a special pen (Bludau et al., 2001). However, the energy consumption restricts this activity to few hours. Yet another interesting aspect of the PDA is the integration of loud speakers and microphones. Buchauer (1998) sees significant advantage in this, as the need for voice recognition and dictating functionality for patients are growing. PDAs can be used to support the daily work of doctors and nurses – as they provide a wireless link to the hospital's network and its information systems (Pleumann 2003).

Subsequently, they provide access to patient's clinical records. It is possible to transfer patient information directly into the computer based systems of doctors and hospitals. Errors occurring due to unreadable handwriting are eliminated. Foundations of handheld usage are the easy form of inputs, storage, and query of patient data. Dodero et al (2001) argue that this small device provides all features of the personal computer, extended by the fact of being mobile.

Pleumann (2003) also discusses the concept of patient diaries. Some illnesses such as hypertonicity, diabetes, allergies etc demand twice a day progression recording and out of hospital patients need to record their progress themselves. While the conventional form of diaries oppose themselves against electronic registration, processing and excludes automatic storage into patient databases – electronic diaries enable patients to not only records their progress, but also offer the advantage of implemented communication means of sustained data transfer to the doctor in charge (Quenter et al, 2002).

Kennedy (2003) discusses the benefit of handhelds in the control of medication. In line with the improvement in quality care and error reduction, control of medication is necessary. Nurses using handheld equipped with barcode scanners assure the right medication by identifying the patient and drugs by scanning the barcodes. Bauer (2003) argues that the traditional process of prescribing and dispensing drugs accounted for the biggest sources of error in medication causing wrongful deaths each year amount to tens of thousands. With the introduction of electronic prescription software used in mobile devices, such as PDAs, physicians can create or transmit electronic prescriptions, anywhere, anytime. This improves prescription accuracy; eliminate illegible prescriptions and possibilities of dangerous drug interactions (Motsay, 2003). A reported saving of USD3.20 per prescription is reported by Turisco and Steinichen (2002) while comparing paper alternatives.

In addition to handhelds, other mobile devices used include vital sensors which monitor body functions of patients or emergency call applications. Although similar to usage of mobile phones, these handhelds are used by risk group patients (Rugge, 2003). Patients suffering from heart disease, diabetes and hyperpiesia as well as the haemophiliacs are strongly dependant on fast reacting emergency systems. They are equipped with a mobile device, similar to a mobile phone. It features an emergency button, and a global positioning system (GPS) receiver. In case of an emergency, the push of the button starts locating and rescuing the patient, so to speak. The vital data measuring systems provided with the devices help the rescue team (Rugge, 2003).Mobile devices such as these enable the surveillance in domestic environments. As the appliances are wearable, and sustain mobility of patients – they feel more comfortable in giving information. One of the issues in mobile health care – namely patient acceptance – is diminishing as they facilitate access to patient's data at the point of care, in the patient's presence, without being intrusive (Tessier, 2003). Data gathered is more meaningful than in an artificial clinical environment. The drop in long stays at hospitals – especially with patients needing emergency care – has the propensity to decrease therapeutical costs.

However, the issue in wireless transmission cannot be overlooked. Wireless usage for transmission of medical records as such raises concerns of security and safety (Cox, 2002). Since wireless transmission is airborne, it is not as safe as traditional wired communications. Wireless networks tend to have fuzzy boundaries and data transmission tends to be available to anyone within the range of the transmitter with an appropriate antenna (Gast, 2002). The WEP protocol was designed to provide minimal protection to wireless networks and is not exactly suited for the medical environment as the issue of privacy and security of confidential medical information becomes significant. There are also concerns on system failure (crash or virus) that may cause data loss, as well as outside forces (hackers) or disasters (natural, terrorist) that may damage data (Tessier, 2003). Therefore, backup systems must be carefully planned and designed with low downtimes.

Grygo (2002) suggests compliance with relevant laws (such as the US Health Insurance Portability and Accountability Act or HIPAA) need to be understood by health care providers. Joch (2002) suggests the use of Internet Protocol Security (IPSec) with allows establishment of virtual private networks between sender and receiver. Communications are encrypted and much more secure than WEP. Turisco and Steinichen (2002) suggest additional security measures by careful configuration of Windows operating system with password control, personal firewall and ensured current definition of anti-virus software. Goodman (2003) proposes built in security features for PDAs.

Bluetooth was developed to help communication between mobile devices (Senese, 2003). However, the range of data transfer is restricted to a 100 meters. Despite this, Bluetooth can be used to transfer data serially from a device to another which is very useful in the medical sector (for example, defibrillator[1]), where infrared has been used for data transfer with the necessity of all devices being right positioned (Senese, 2003). BAN or Body Area Network consists of wireless transmission technique via Bluetooth which is worn on the body. Medical sensors and actors gather human data and send them via Internet to medical computer based information systems (FrauenhoferGesellschaft, 2002).

The issue of electromagnetic compatibility or EMC is a significant issue in this area (Tessier, 2003). Mobile devices emit radiation which causes electromagnetic interference or EMI which can affect medical devices and other wireless communication devices nearby. Cox (2002) also referred to radio signals of wireless mobile devices causing potential interference with hospital equipment, such as cardiac monitors. Turisco and Steinichen (2002) suggested that to address the EMI problem, healthcare providers could conduct controlled tests in a lab environment prior to deployment. The long term solution however involves separating frequency ranges for different devices and providing guidelines for electromagnetic compatibility.

In the next section we provide an appraisal of initiatives that have been proven to work, and on the anvil – which accounts again for the heterogeneous networks or the environment in which the actors network from the ANT lens.

## MOBILE HEALTH CARE INITIATIVES: A BRIEF APPRAISAL

A study of the US Institute of medicine in 1999 revealed that nearly 100,000 American patients die annually due to hospital administration errors, pharmacists misreading the handwritten prescriptions and patients getting wrong medication (Silicon Trust, 2004). Similar statistics are also reported from other countries. To address this issue, many initiatives have begun in several countries as reported by Silicon Trust (2004).

In the USA, the health passport project managed by Siemens provides for a *multifunctional smart card* with the functions of storing personal demographics such as social security number, address, essential health records, test results, information about physicians and Insurance, and information about participation in state sponsored welfare programs.

The European Union is discussing the introduction of a uniform health card – mostly enforced by Germany, to reduce costs. The new card is to include an electronic prescription and drug application, projecting a saving of 500 million Euros only by reducing medication failures and hospitalisation (Silicon Trust,2004).

In Taiwan, a health care project initiative was to equip all the population with their own care card, designed to contain individual medical, administrative and treatment data. The professional cards allow the additional function of digital signature used by health professionals such as doctors, pharmacies and hospitals. In Australia, the national health Insurance Agency initiated a project aimed at transmission of health data over the Internet. A digital signature with credentials is expected to be possible at the end of this initiative. The digital credentials are stored in a hardware token which can be the plastic iKey, which contains the smart card chip or card (Silicon Trust, 2004).

However, these initiatives have had their issues. Storage of intimate data (such as HIV infection) on chip cards is not liked by people. Therefore, high protection against unauthorised access is necessary. Sceptical patients and reluctant physicians who see the risk of being monitored /accused do not promote the progress of smart cards. The profitability of chip cards increases with the size of the institution planning to implement the new system. In Germany, for example, the health insurance is obligatory and health insurance organisations are very large. Introduction of health insurance cards 10 years ago, was amortised within two years. However, in US, where insurance is not obligatory and therefore, companies are smaller, the same initiative would require longer time to amortise itself. The number of stakeholders involved such as government, insurance providers, and the medical fraternity also make it complex to fund such initiatives – due to them pulling in different directions (Silicon Trust, 2004).

Slepin and Cale (2001) reported the success of implementing wireless infrastructure to collect real time patient information from existing monitoring devices and linking remote facilities to the main facility with wireless infrastructure, by Sutter Medical Centre in Sacramento. The use of wireless technology increased monitoring capacity up to 96 patients; FTE cost savings of one per year; less time in expensive ICU setting and standardised monitoring quality achieved with 98% compliance rate, faster transmission and access to patient information; and improved patient outcomes by being able to intervene earlier.

In 1994, the medical faculty of the Ruprecht-Karls-Universitat in Heidelberg, Germany initiated the MEDINA project in cooperation with the Clinical Centre in Heidelberg (Buchauer, 1998). MEDINA is a portable personal minicomputer which supports physicians and the communication/information processing at different work places. This initiative integrates computer based information processing into the medical daily routine including aspects of personal organisation, medical documentation, and presentation of patient related information and provision of medical know how. The first prototype enabled display of letters from the physicians, test results, patient related progress, email and beeper calls to the mobile client. A second prototype supported the development of further applications (Buchauer, 1998).

The German Fraunhofer Institute initiated the Body Area Network (BAN) in 2001 (Fraunhofer, 2003), a method suited for supervising health status of patients suffering from chronic diseases such as diabetes and asthma. A device that tracks and responds physical stimuli – known as sensory plaster – is a main part of BAN. First, the data are transferred to the Body Central Unit and via a Bluetooth interface, this data is transmitted to a network access unit (NAU) – a local base station – which transfers it to web servers or vital gateways (Fraunhofer, 2003).

Yet another initiative was the MOBTEL project (Schulze et al, 2001), which dealt with mobile devices, wireless communication and sophisticated surveillance systems. PDAs were connected to a base station via GSM, Internet portals allowed access on specific patient information over secure connections. Medical personnel was creating and configuring a daily program for the patient and after fulfilment of the program, feedback was automatically provided to the base station, which further enabled ease of data analysis.

An Intel PCA-based handheld and mySAP healthcare initiative was deployed in 2001 by the hospital of Jena in Germany (Intel, 2003). This initiative aimed at minimising administrative costs, to move the care of patients into the centre of the work, and to optimise communication. All nurses were equipped with handheld devices which could access the central server of the university via a wireless network by a SAP web application server. The initiative has been successful in creating economic advantages and potential optimisation of beds.

The benefit of a sophisticated WLAN has been reported to be providing data mobility and control to the chaotic emergency department in Boston's Beth Israel Deaconness Medical Centre (Joch, 2002). Registration and accessing healthcare information is done away from the desk. The clinical staff packs PDAs and tablet PCs that enable them to call up registration forms and insurance information as well as test results and radiology reports. At St Vincent's hospital, Birmingham, Alabama, the use of wireless wearable computer by physicians to access patient record has reduced paper work and increased doctor time with the patient from 20% to 60% (Gruman, 2003).

The Wireless VoIP technology introduced in St Agnes Healthcare, Baltimore also enables health care providers to spend more time with patients and tracking of employees. The ID badge size wireless device allows employees of the hospital to track down key employees quickly when time is critical and to communicate with each other using VoIP on the hospital's existing 802.11b. In St John's hospital (Gruman, 2003), wireless mobile scanners are used to record medication delivery. It is perceived as inexpensive. Patients' wristbands, drug labels, and nurses' badges are all bar coded. A nurse can scan all three so that the system can track which patient is given, what medication, at what time, by which nurse. WLAN is also used to deploy robots, substituting humans at the Ohio State University Medical Centre. 40 delivery robots deliver food, linen and supplies by accessing their task lists and guidance information over the WLAN (Gruman 2003).

Wireless wide area networking (WWAN) has been deployed by Red Cross Madrid in the mobile telecare area to provide efficient support of highly vulnerable user groups who are at risk in distress or people with disability. The systems allows home visit nurses with a portable monitoring unit to integrate with the hospital information systems, by means of GSM connection using a small mobile device. The nurse is able to transmit information about each visit to the hospital patient electronic clinical record and access patient information such as high risk report. It also allows the nurse to request admission at different hospital departments, as needed (Toledo 1999).

It can be well said that there are number of initiatives which have been piloted, tested as successful and yet others under development worldwide.

## MOBILE HEALTH CARE FRAMEWORK: THRU' ANT LENS

As discussed in the methodology section, the ANT declares that the world is full of hybrid entities containing both human and non human elements. Keeping in line with this theory, it can be drawn from the previous sections that, both mobile technological innovations and human requirements have contributed to the mobile health care framework. The usage of mobile technologies in healthcare became strong by gathering a 'mass of silent others' (Callon 1987) who accepted their usage, thus creating a network or rather 'black box' with greater strength and credibility. In this context, we consider 'mobile health care framework' as a black box or a network of heterogeneous actors. When this black box of mobile healthcare technologies or applications are placed in different contexts or moved around, they remained 'immutable mobile' (Latour 1991) or remained unchanged.

However, as Callon (1986) argues, the network can become unstable with the entry of new actors, desertion of actors or change in alliances. In line with this aspect of ANT, we found that although there are certain accepted technologies and applications within the mobile health framework — desertion of redundant or obsolete technologies and standards, arrival of new technologies that replace existing ones, and the continuous developments influenced by the human actors (namely patients as well as medical personnel) — all lead to opening and reconsideration of the contents of the 'black box'.

One of the significant concerns is in the area of privacy influenced by human actors. Security standards for wireless networks are currently not suited for confidential medical data transmission. This aspect is debated in many forums as security standards evolve. An example of a technological issue that is leading to opening of the black box is the issue of electromagnetic interference caused by ration from mobile devices and interferes with health equipment. Healthcare providers or 'human actants' are involved in remedying this problem via controlled tests in labs. In the context of ANT, this again leads to opening of the black box.

However, as Callon (1986) contends, the black box depends on all the actants for their proper functioning and the proper functioning of the network itself. Clearly, the mobile healthcare framework requires all its actants, and a consortium of 'silent others' to function properly. With the dynamism related to this arena, it is almost a critical requirement that there is a certain world-wide concensus in providing health care initiatives using mobile technologies.

## CONCLUSIONS AND FUTURE

In this paper, we examined the mobile health care framework through an appraisal of current technologies, applications, issues – from a socio-technical view point of ANT. We derive that the future of the mobile health care framework – including its practices and application deployment, would depend on a global consensus of medical fraternity, people and policy makers. All of these 'actants', although different in disparate socio-economic contexts, contribute to a stable but efficient futuristic framework for mobile healthcare applications.

We propose an open research framework that would study the evolution of this sector for future academic researchers and also practitioners involved in the progress of this sector.

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## ENDNOTES

1 Defibrillator is a device which administers a controlled electric shock to restore normal heart rhythm in cases of cardiac arrest due to ventricular fibrillation (chaotic and abnormal pumping of the heart which does not allow the heart to pump blood effectively and is due to a disease or medical complication). The defibrillator administers the shock either through electrodes placed externally on the chest wall over the heart or directly to the heart after the chest has been opened surgically (neurolab.jsc.nasa.gov/glosscd.htm).

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