Healthcare Compunetics

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Abstract

Changes in life expectancy, healthy life expectancy and health seeking behaviour are having an impact on the demand for care. Such changes could occur across the whole population, or for specific groups. Changes for specific groups will be particularly affected by policy initiatives, while both these and wider changes will be affected by people 's levels of engagement with their health and the health service itself. Levels of education, income and media coverage of health issues are also important. These factors could also encourage an increase in people caring for themselves and their families or community.

People are now expecting a patient-centred service with safe high quality treatment, comfortable accommodation services, fast access and an integrated joined-up system. The uptake of integrated Information and Communication technologies (ICT) will be crucial. Healthcare Compunetics, the combination of computing and networking customised for medical and care, will provide the common policy and framework for combined multi-disciplinary research, development, implementation and usage.

1. Introduction

During the last 5 years telemedicine has utilized developing technologies and matured into a now usable service acceptable both by patients and medical staff. In essence telemedicine supports the remote application of healthcare services. Isolated medical centres can be connected to hospitals, ambulances can transmit vital sign data to awaiting emergency units, General Practitioners can be kept informed of hospitalised patients and outpatients can be monitored whilst at home. By utilizing the latest wireless technologies a new collection of "wireless telemedical" services can be developed targeting self-care and well-being applications. These new services will support not only home care services but also mobile care services for example an outpatient may go about their daily business but still have the confidence they are being continuously monitored.

Patients and public expectations of future healthcare are changing. Further enhancements to quality beyond those presently planned will be required and patients will demand provision of greater choice. Additionally, there is the changing needs of the population including demography. Over the next 20 years, the changing age structure is likely, especially for the older people, to demand more from the healthcare service.

> "*The balance of health and social care is still skewed too much towards the use of acute hospital beds. More diagnosis and treatment should take place in primary care. There is scope for more self-care*"
>
> Derek Wanless (Securing our Future Health: Taking a Long-Term View, April 2002).

In the future patients will be at the heart of the health service with access to better information, involved fully in decisions – not just about treatment, but also about the prevention and management of illness. The service will move beyond an 'informed consent' to an 'informed choice' approach. In this vision, patients receive consistently high quality care whenever and whoever they are. Different types of care are effectively integrated into a smooth, efficient, hassle-free service. With support from the medical institutions, people will increasingly take responsibility for their own health and well-being.

The degree to which self-care becomes more important over the next 20 years will depend on the degree to which the public engages with health care. It is therefore closely linked to some of the other trends associated with rising knowledge, such as improved public health and increased health seeking behaviour.

Self-care is one of the best examples of how partnership between the public and the health service can work. The health service can support a pro-active public in promoting self-care by, for example, helping people to empower themselves with appropriate information, skills and equipment or supporting people to take a more active role in the diagnosis and treatment of a condition followed by rehabilitation and maintenance of well-being.

A comprehensive strategy on self-care would attempt to incorporate a wide range of approaches and models of self-care, to be combined to provide safe, high quality treatment patient centred services with integrated joined-up systems with fast access.

Healthcare Compunetics, the combination of computing and networking technologies customised for healthcare, can provide the supportive underlying platform, facilities, equipment and technology to support self-care development. Healthcare compunetics is not just about home monitoring with handy, wearable devices. The most significant innovation is that, at all time, it will bring together the medical professionals with the patient and their family and carers. Healthcare compuentics will open new ways for collaboration and information sharing in health provision, something which is now barely available. Healthcare compunetics will manage the information flow and the necessary actions of all people involved in an unprecedented way for medical and care services. And all this will be achieved in a user-friendly virtual environment, within the reach of all actors, including and above all the patients, whether at work, at home or on vacation – indeed everywhere at anytime – while maintaining the privacy of all actors and the confidentiality of the medical record.

The market prospects for healthcare compunetics are very significant. The concept of healthcare provision at the point of need has expanded dramatically of the past quarter of century. Nowadays, and thanks to the advances of medicine and medical apparatus, it is common practice for long-term patients to live a normal life and be catered for by specialised staff at their home. Remote monitoring is already part of some people's daily routine – for instance cardiac patients, who may take an ECG of themselves and transit it to their doctor across a regular line. Certainly today's systems look primitive compared to what is achievable even with current technology.

Healthcare Compunetics consists of *intelligent* EPR's, *intelligent* compunetics and *intelligent* services. Presented in the next three sections, the concept of an advanced Electronic Patient Record (EPR) is introduced in section 2 and in section 3 the movement of the patients data with leading edge computing and networking technologies is presented. By adopting advanced networking and computing technologies and interoperable data representations the foundations are provided for the development and implementation of advanced services as addressed in

section 4. For worldwide acceptance of the potential and benefits of healthcare compunetics it needs to be based on standards with well-defined interfaces. This issue is addressed further in section 5.

2. The Intelligent Electronic Patient Record (*i*-EPR)

Advanced networking and communication technologies have provided the platform to sustain an Electronic distributed *hyper*-linked version of the Patient Record. Containing all the patient's medical data (collected in medical institutions and verified by medical staff) this concept can be taken one stage further to include health data that has been collected by the patient themselves i.e. has not been verified by medical staff. This data, referred to hereafter as notes as opposed to records, can provide valuable information of historic trends and present more information for the doctor's decision, for example a regular home monitoring of blood pressure could identify a trend towards hypertension.

A personal medical data reading, such as blood pressure, collected by the patient can be regarded as a packet of information. Each of these packets can be stored in XML format as an "intelligent note" or *i*-Note for short. The note is intelligent because it can have an application associated and stored with it and it can also be viewed from different perspectives depending on the viewer's characteristics (i.e. doctor, patient, carer). Intelligent notes (*i*-Notes) are data items (blood pressure readings, temperature readings, etc.) either collected under the patients control or automatically recorded through intelligent interfaces to measuring devices such as weighting scales. *i*-Notes are not restricted to ASCII characters and may contain multimedia data such as movies and pictures. *i*-Notes, analogous to files in a traditional computing system, can be grouped together and referred to collectively as *i*-Pads. *i*-Pads are analogous to folders in a traditional computing system, however the process of creating *i*-Pads depends on the viewer's characteristics. Different viewers may view the same i-Notes as different i-Pads. Each *i*-Pad can have an application associated with it to pre-process data. Designed originally for healthcare purposes, *i*-Notes and *i*-Pads are equally applicable in any remote monitoring environment. The concept of *i*-Notes provides the flexibility to interface to a wide variety of platforms and legacy systems.

Additionally, since a major trend nowadays is to have a personal mobile phone it makes sense also to have a limited amount of emergency information (allergies, blood type etc) stored on a predefined area of the SIM card located in the mobile phone which in the case of an emergency could be accessed by medical staff.

The intelligent Electronic Patient Record (*i*-EPR) therefore consists of three data records linked together:

- The *i*-SIM, stored on the patient's mobile phone, which contains the patient's emergency information such as blood group, allergies, insurance details etc.
- The traditional EPR that contains the patient's medical records that have been verified by a medical organisation.
- The *i*-Notes, that contains data items collected by the patient and 3rd party services stored on the patient's *i*-WAND (see section 3.1).

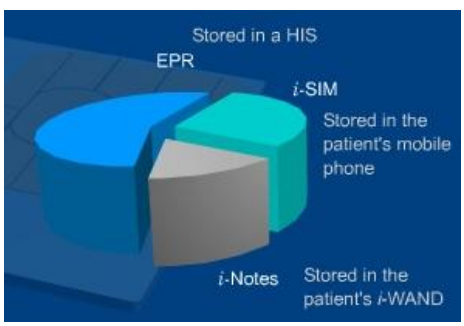

Figure 1: *i*-SIM

As introduced in the next section advanced communication and computing technologies can be employed to collect, transport and analyse the patient's data in a transparent unobtrusive manner.

3. Intelligent compunetics

Modern and integrated information and communication technologies (ICT) can be used to full effect, joining up all levels of health and social care and in doing so deliver significant gains in efficiency. For example, repetitive requests for information can be avoided as health care professionals can readily access a patient's details through their EPR. As depicted in figure 2 and detailed further in table 1, *i*-Compunetics combines 21st century computing and networking technologies to provide a platform to support advanced *intelligent* healthcare data collection and communication devices, such as the *i*-WAND, *i*-Port and *i*-Server.

Figure 2: *i*-Compunetics

Wireless Hospital Area Network (WLAN)	The interconnection of Hospital Information Systems (HIS), Picture Archiving Systems (PACs) and medical devices within the hospital environment. Medical staff can have wireless access to medical services and patient data whilst in the hospital environment
Wireless Medical Area Network (WMAN)	Medical staff can access patient data outside the medical establishments (telemedicine). Fast access can be used to support movements of patient data and tele-monitoring services
Wireless Home Area Network (Home WLAN)	Outpatients can be monitored in their home with a local network of connected monitoring devices
Wireless Personal Area Network (PAN)	Short-range wireless communications can be used to collect personal i-sensor data whilst the patient is on the move
Satellite	Digital Television (DTV) and GPS services can be employed to support homecare and patient on the move services
GSM/GPRS/UMTS	Mobile telecommunications technologies can support patient on the move services and remote access
Intelligent sensors	Miniature disposable wireless transmitting sensors can collect personal vital signs data.
Intelligent devices	Medical devices can perform on-the-fly analysis of patient data related to a patient's profile.
Intelligent Clients	Client applications customised for the patient can be monitoring vital signs data trends.
Intelligent PDA's	PDA's can be used to provide customised viewing of patient data.
Intelligent Servers	Servers can be used to perform trend analysis and data mining analysis of patient data
Intelligent Mobile Phones	Long-range communication of patient data can used whilst the patient is on the move.

Table 1: *i*-Compunetics joining together the puzzle of ICT technologies

By associating intelligence with the patient notes the respective devices can also be made to be intelligent, for example an *i*-WAND can perform analysis and diagnostics as it collects and stores the patient's data, an *i*-server can archive the patients data that has been sent by SMS,

check for alarm conditions and perform more extensive data analysis and an *i*-port can transmit data directly from a measuring device, such as a blood pressure meter directly to an *i*-server.

3.1. *i*-WAND

Figure 2: *i*-WAND

An *i*-WAND (Intelligent Wizards for Analysis, Note-taking and Diagnostics) is a hand-held intelligent storage and processing device with fingerprint authentication. Personal data stored on an *i*-WAND are in *i*-Note format. Each *i*-Note can have an associated Java wizard to process data on the fly and check for alarm conditions. All data saved on the *i*-WAND is automatically encrypted and hidden making it secure and unexposed. The Java wizards automatically detect which device the *i*-WAND is connected to, automatically analyse the data as it is being recorded as *i*-Notes and automatically performs diagnostics for alarm conditions.

3.2. *i*-Socket

An *i*-Socket provides intelligent access to supported medical devices. An *i*-Socket allows the *i*-WAND to be connected to a variety of data collection devices including:

- Biocompatible sensor chips in ingestible capsules
- Flat padded water resistant hypoallergenic dermal patch
- Homecare monitors

3.3. *i*-Server

Figure 3: *i*-Server

The *i*-Server designed originally for healthcare tele-monitoring, but applicable in any remote monitoring environment, provides a stand-alone server with the capabilities to send, receive and process SMS messages. The *i*-Server provides a complete interface to specify, request, record and view the tele-monitored data. The *i*-Server can transmit alarms to support its tele-ambulatory *i*-Services and reminders to support its conformance *i*-Services. Messages are automatically stored in device folders per message type. A copy of the received messages can also be copied automatically to a removable flash drive.

3.4. *i*-Port

Figure 4: *i*-Port

The *i*-Port is an intelligent GSM modem that when receiving a data value from a connected medical device can automatically inform a server via SMS of not only the reading but also an indication of which person the reading belongs to. Homecare devices are connected to the *i*-Port directly or via a Home Area network. Designed originally for intelligent personal health-care services the *i*-Port is equally applicable in any tele-monitoring environment.

4. Intelligent services

The *i*-Services (Intelligent-Services) utilising the *i*-compunetics platform can be divided into three categories:

- The *i*-Safety (Intelligent-Safety) services are a form of the newly developing Mobile Location Services (MLS) but focus on the potential safety implications of location awareness, which include child monitoring, location advisory and third party location monitoring services.
- The *i*-Healthcare (Intelligent-Healthcare) services focus on the collection and interpretation of personal medical sensor data, which include the recording of personal sensor data (for example ECG) for future comparison, a mechanism to check the data for warning signs (for example high blood pressure) and an automated analysis of the sensor data.
- The *i*-Medicine (Intelligent-Medicine) focus on 2-way communication between diagnostic medical servers (supported by medical staff) and the users medical sensors, which support personalised care (for example informing the user, then checking that drugs have been taken with the correct dosage and at the correct time), personalised nursing (for example altering a drug prescription due to updated sensor data) and personalised doctoring (for example modifying a treatment plan).

Intelligent data and devices are only as good as the services that use them. Intelligent services can be developed that integrate a number of respective components for example a drug conformance service can utilise an *i*-server to log compliance to a drug programme and a PDA based pain assessment monitor can be reminded by an *i*-server that a reading is required. Collectively all the intelligent devices, services and data elements can be combined

3.1. Intelligent Drug Conformance Monitoring

Designed originally to support drug conformance monitoring, but equally applicable in any compliance monitoring environment, the intelligent Message Centre (*i*-MC) accepts "Reminder" SMS messages from a service center which then initiates a sequence of audio alarms and LED lights to inform the user that a message has arrived and requires acknowledgement. When the acknowledgement button is pressed the content of the reminder message is displayed on the LCD screen and using the latest Text-To-Speech technology, the user can listen to the message content being read.

Figure 5: *i*-MC

The Drug Conformance Monitoring (*i*-DCM) service combines automated reminding and compliance logging. The rationale being that if a user acknowledges a reminder message then compliance can be assumed. If Non-compliance is indicated the server will automatically initiate an alternative action that may include an alternative means of reminding (friends, family members etc.) or even call-centre intervention.

3.2. Intelligent PDA applications and services

The *i*-PDA, developed in Java, is a complete SMS server running on a PDA. The *i*-PDA toolkit can be used to create applications such as *i*-PAM to support remote tele-monitoring applications and *i*-Profiler to support remote access and control of an *i*-Server. The Intelligent Pain Assessment Monitor (*i*-PAM) is triggered by receiving an SMS reminder, then the user, normally the child carer, indicates by using the touch screen, which picture best

Figure 6: *i*-PAM

describes the child's pain level. An SMS is then sent to the server and the patient's record is updated.

3.3. MERLIN

MERLIN (Medical Electronic Records Logistics Interface to Notes) uses the latest developments in healthcare compunetics to address social care by combining wireless communication technologies, intelligent sensors, intelligent products and intelligent services for improved self-care and non-intrusive tele-monitoring. The patients taking a more active role in their healthcare management for example can use an *i*-SIM card in their smart mobile phone to store an emergency version of their EHCR and also an *i*-WAND (an intelligent data logging device) to collect their physiological data over time as a series of intelligent notes (*i*-Notes) thus providing a movie of their health rather than snapshots. In XML format these *i*-Notes can be used to complement the distributed patient EHCR.

MERLIN addresses not only outpatients but also includes for example patients with long-term illness, disabilities and the "Well-worried" (healthy and health conscious) with three categories of intelligent services namely, *i*-Safety, *i*-Healthcare and *i*-Medicine. The *i*-Safety services are a form of the newly developing Mobile Location Services (MLS) but focus on the potential safety implications of location awareness such as child monitoring and guiding a blind person. The *i*-Healthcare services focus on ambulatory services via tele-monitoring both for at-home and on-the-move users, and *i*-Medicine focuses on automated 2-way digital communication between patients and carers whereby treatment plans can be analysed and adjusted remotely.

Figure 7: MERLIN

5. Conclusions

Healthcare Compunetics will play an important role in personal healthcare management. Subsequently, the development of supportive products and services will also create a new niche market economy for universities and companies, especially Small and Medium Enterprises (SME's), to develop a range of collaborative technologies.

The necessity of having standards is well understood and highly appreciated. A number of standardisation organisations and committees have been quite active in the development of standards that relate to healthcare informatics:

- American National Standards Institute (ANSI)
- CEN (Comité Europeén de Normalisation) Technical Committee 251
- ISO Technical Committee 215
- American Society for Testing and Materials Committee E31 (ASTM E31)
- Healthcare Informatics Standards Board (HISB)
- Computer-Based Patient Record Institute (CPRI.).

For the successful development of intelligent healthcare services there also needs to be an agreement on what types of categories of services will become available, how different complementary industries can work together to develop these services and how the developed services are certified.

A US perspective

The Health Management Organizations (HMO's), that have supporting legislation, have driven the adoption of telemedicine within the US. Internet based applications are being used to improve access to care and the quality of care, reducing the costs of care and the sense of professional isolation for some healthcare practitioners. In this environment the introduction of wireless telemedicine should be introduced via the HMO's expanding their range of services and therefore compatible with the presently installed systems and envisaged wireless LAN systems. In summary, it is envisaged that the introduction of intelligent healthcare services in the US will again be driven from the HMO's therefore it is essential that some form of standardization and conformance be undertaken in conjunction with existing telemedical services.

A European perspective

Within Europe telemedicine has not been driven so much by HMO's but more by isolated medical institutions and regional trails. The legislation aspect of telemedicine also within Europe is more complex than in the US especially when National boundaries have to be crossed. However, the telecommunications markets in Europe are more focused and standardized than their US counterparts and it is this that is envisaged to be the driving force behind the introduction of intelligent healthcare services in Europe. In summary, it is essential that some form of standardization and conformance be undertaken in conjunction with developing telecommunication infrastructures and services.

The foundations for a Healthcare Compunetics Special Interest Group

By combining the two perspectives above it is clear that for intelligent healthcare services to be generally available and accepted worldwide then there needs to a standardization and/or conformance certification group. Similarly to the bluetooth Special Interest Group it is therefore proposed that a Healthcare Compunetics Special Interest Group (SIG) be established with representatives from both HMO's and telecommunications domains both in Europe and the US. Additionally there also needs to be representatives from a number of supporting industrials including platform developers, compunetics (computing and networking) suppliers, security advisors, medical data sensor developers and service developers.

The objective of a **Healthcare Compunetics SIG** could be to combine 20 areas of expertise:

1. Wireless Medical devices (ERM TG30)
2. Mobile Terminals (PDA, Smart phone)
3. Operating Systems (Linux, Palm OS)
4. Data Storage (M-EHCR)
5. Data Encoding (XML, WML)
6. Programming environments (JAVA)
7. Visualization (MPEG, VRML)
8. Transmission (GPRS, EDGE, UMTS)
9. Collaboration (SMS, WAP, HTTP)
10. Privacy & security (TLS, SSL, PKCS)
11. Compression (JPEG 2000, Wavelet)
12. Archival (HIS, Data warehousing)
13. Knowledge discovery (personalized alarms)
14. Healthcare providers (Doctors, Nurses)
15. Personal healthcare management providers
16. Standardization (R&TTE)
17. Conformance (FDA, EU CE Marking)
18. Legislation (National, EU polices)
19. Service providers (HMO's)
20. User groups (Elderly, Outpatients)

The Healthcare Compunetics SIG will therefore tackle such issues as device availability, possibilities for health with 3G networking, the services that will be required (by health

professionals, ambulatory, patients and citizens), the applications that will be developed, the costs (private and public) and compliance with technical issues, legislation and regulatory frameworks.

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