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Healthcare Compunetics: An End-to-End Architecture for Self-Care Service Provision

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Abstract – Extending healthcare to the community introduces a number of new challenges for the development of information technology infrastructures. A core component of the new self-care infrastructures will be wearable or implantable sensors and actuators that monitor vital signs and take proactive actions to respond to observed clinical conditions. In this paper, we introduce the three core elements of the Healthcare Compunetics architecture developed with a view to support the new self-care services: i-notes is a system that extends the electronic patient record to include non-verified data collection by the sensors; i-WAND is a wearable device that offers pluggable body area connectivity, local storage and processing and remote communication to the diagnostic service centre; and the VMW Protocol which allows sensors to communicate effectively with remote healthcare servers. Finally, we conclude this discussion with a brief overview of our current work on interaction design.

Key words – self-care, extended electronic patient record, biosensors, self-care services.

I. INTRODUCTION

Public expectations of future healthcare are changing. To meet the new demands, significant enhancements to services well beyond those planned at present will be required as patients increasingly demand greater choice of service provision alternatives. Further, population demographics are changing rapidly. Over the next 20 years, the changing age structure is likely to create new demands from healthcare services. Indeed,

> *"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, 2002 Health Trends Review at the request of the Chancellor of the Exchequer, April 2002).*

Indeed, in the near future patients will be at the heart of the health service with access to better information and will expect to be fully involved in decisions that affect their welfare – not just about treatment, but also about the prevention and management of illness. Thus, services will need to move beyond 'informed consent' to 'informed choice'. In this vision, patients receive consistently high quality care whenever and wherever they are. Different types of care are effectively integrated into integrated, efficient, and hassle-free services. With support from medical institutions citizens will increasingly take responsibility for their own health and well-being.

Adoption of self-care by the public as a viable healthcare alternative depends critically on the degree to which the public engages with health care over the next 20 years. Adoption of self-care practices is therefore intimately related to changes in attitudes towards healthcare and is associated with increased patient knowledge about their condition, improved public health and active health seeking behaviours.

Self-care is one of the best examples of how partnerships between the public and the health service can develop. Indeed, health services 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, to create synergistic environments for the provision of safe, high quality patient-cantered services with integrated systems and fast access.

In this paper, we outline three of the core components of Healthcare Compunetics, an end-to-end architecture

developed by MVW Solutions Ltd and its partners designed to provide the basis for the provision of self-care services. In particular, we discuss a device that acts as the hub for pluggable body area networks for self-care systems at home, an XML-based language for the augmentation of electronic patient records with sensed and unverified data, and a protocol to support communication between the sensor area network and the healthcare professional. We show how using these components we can develop self-care services, for example a server architecture for the collection and processing of patient collected measurements and clinical diagnosis. Finally, we will conclude the discussion with ongoing work on the evaluation of this approach in user studies.

II. Architectural elements

Current networking and communication technologies allow for a sustainable distributed and hyper-linked Electronic Patient Record (EPR). This EPR contains the entire patient medical data collected by qualified medical institutions and verified by medical staff. The introduction of automated medical data collection without the intervention of medical staff that can verify its validity or correctness takes the current state-of-the-art a step further. In fact, this is a critical distinction since unverified data cannot be trusted in the same way as the usual EPR and must thus be treated differently. Nevertheless, such data, hereafter referred to as patient *notes* rather than patient records, provide valuable information of historic trends and are of considerable assistance to the clinician – in fact, they are the basis for any self-care system. For example, regular monitoring of blood pressure at home can help identify a predisposition to hypertension.

```
<?xml version="1.0" encoding="utf-8"?>
<patientlist>
  <patient id=”125”>
     <temp>38.2</temp>
     <glu>345</glu>
     <bpm>
        <systolic>120</systolic>
        <diastolic>80</diastolic>
      </bpm>
      <act></act>
      <wgt>
      <pul>
   </patient>
   …….
</patientlist>
```

Figure 1. An example of an i-pad, that is a collection of i-notes regarding sensor readings of a patient.

Medical data collection carried out by a person or performed automatically by a sensor should thus be recorded and stored clearly marked as such. Healthcare Compunetics treats each of these information items as an XML document using the *i-note* specification (cf. figure 1). This approach offers extended flexibility since each i-note may be associated with a particular application and may be subsequently viewed from different perspectives. For example, different transformations of the XML document may depend on the role and/or the authority level of the viewer as appropriate depending on whether he/she is a doctor, a patient or a carer. Several notes may be grouped together and used for particular diagnostic tasks. Employing an XML-based approach provides a flexible solution that can address the different requirements of heterogeneous systems and provide an appropriate interface to a wide variety of platforms and legacy infrastructures.

Data harvested from a variety of sensors need to be processed into i-notes and stored for future use and according to system policy communicated to the appropriate clinician for analysis. Since connectivity to the healthcare systems may not always be available Healthcare Compunetics provides two devices that work together to offer secure storage and seamless communication within the body area network. The first component is the i-WAND, a wearable storage and processing device with fingerprint authentication. Personal data stored on it and structured in i-note format, is processed on the fly and checked for critical conditions locally. Stored data is automatically encrypted. The device employs Java-based wizards to detect the type of sensor transmitting data. Currently i-WAND supports infrared and Bluetooth communication and a Zigbee version is expected later in 2004. The device currently supports detection of a variety of data collection devices including homecare monitors, flat-padded water resistant hypoallergenic dermal patches, and certain biocompatible sensor chips in ingestible capsules. The mobiliser, a smart GSM modem, provides wide area communication.

Figure 2. The i-WAND, a device that acts as a hub for the construction of pluggable body area networks.

To support data communications between mobile devices and healthcare information systems there is a clear need for a common protocol. The Virtual Medical Worlds Protocol (VMWP) developed by VMW Solutions Ltd is used between the service centre and a VMWP enabled terminal [1]. VMWP is carrier independent but its current implementation is employing SMS for cost effectiveness. The VMWP is developed to offer different supplementary services for mobile healthcare users. VMWP supports remote monitoring of vital and physical signs and forwarding to a Service Centre where data is collected by a VMWP enabled terminal is in ASCII format. For more details on VMWP please refer to [1].

Using these three elements and existing healthcare information systems, a variety of services may be developed

to address the needs of self-care. For example, a low cost remote monitoring environment has been developed [5] where a dedicated server at the clinician location collects and process messages. The clinician may specify, request, record and view the harvested data and may make recommendations or take proactive action to prevent adverse situations. To assist the clinician, the server? can accept rules and react to simple or composite events, to notify for observed extraordinary conditions or display simple reminders to help support medication conformance. Messages are automatically archived for accountability purposes. A copy of the received messages can also be replicated on a removable flash drive.

Figure 3. The Mobiliser offers wide area communication capabilities to i-WAND based networks.

III. Self-Care Service Provision

The combination of the Healthcare Compunetics architecture and traditional medical information systems can provide the infrastructure for the development of a variety of self-care services [2]. We are currently investigating two classes of such services in user studies.

The first class of services is focused on the collection and interpretation of data recorded via wearable medical sensors. For example, in the IST project Panaceia (reference?) we have developed an application that records electro-cardiogram (ECG) data, which is subsequently transmitted to an application server. The server software provides mechanisms for data analysis and diagnosis of conditions that require attention as well as an interface for the medical practitioner that can be used to further investigate the recording and research patient progress. On the server, data is encoded in i-note format and stored with the EPR. Simpler diagnostic mechanisms are implemented at a local level on the i-WAND but more extensive analysis is performed at the server where historical data is also available.

A second class of self-care services focuses on bi-directional communication between the sensor area network and the medical diagnostic server, under the supervision of trained medical staff. For example in the IST project e-Care (reference?), self-care services have been developed that provide feedback to the patients about their current condition and supply further information and guidance on actions they need to take. In particular, we have explored the conformance to medication, the alteration of drug prescriptions and modification of treatment plans due to updated sensor data.
Due to space limitations, we cannot fully demonstrate examples of these services here but the interested reader may consult the VMW Solution website for more information [5].

IV. Discussion and Conclusions

The Healthcare Compunetics architecture can support the development of self-care services securely and effectively. Nevertheless, early experience with deployed systems indicates that success and subsequent widespread adoption of such services depends crucially on the design of an appropriate user experience. Moreover, the development of self-care services using wearable sensors also has to incorporate provisions for conformance to existing processes within the health system as well as to take into account practitioner liability issues. In particular, changing treatment plans and its effects on patient health is an area where law has particular implications.

Unlike information systems at hospitals or other healthcare organisations, self-care demands that systems are used in the context of the patient personal space. Similar to other personal systems in related situations [3] if interaction between system and person is not perceived as appropriate (including trusted and under control) the end users will not adopt the technology despite any indications of the objective value of the system for their welfare. Despite the fact that the systems described here have been designed with a clear aim to operate without specialist skills, it is still unclear what the effect of their introduction in the home environment would be. In collaboration with the cardiology department of the Royal Brompton Hospital, we are currently carrying out experiments on the design of suitable interaction paradigms that would satisfy patient requirements regarding their experience. In this work, we favour appliance-based designs, which offer distinct advantages from a usability point of view [4].

After all self-care is all about empowering the patient and for this reason it is most important that interaction caters for exactly this type of empowerment.

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