

**Customisable EHR Views –
Using Portal Technology to Exploit Existing
Electronic Patient Data**

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Electronic Patient Data**

By

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in partial fulfilment of the requirements for the degree of
Master of Science in Health Informatics

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Declaration

I declare that the work described in this dissertation is, except where otherwise stated, entirely my own work, and has not been submitted as an exercise for a degree at this or any other university.

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Dedication

This dissertation is dedicated to my grandparents,
living and looking down on me.

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This dissertation would not have been possible without the excellent guidance of my supervisor, Bill Grimson, Dublin Institute of Technology.

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Summary

The National Electronic Healthcare Record has been the focus of so many peoples' efforts for such a long time. Considerable work has been carried out in this area and as the realisation of this entity draws ever closer, this dissertation highlights some of the obstacles that still remain. Huge volumes of patient, health and care information already exist in many forms and in many systems, both electronic and paper based. More and more new approaches and technologies are being embraced by the healthcare industry, all with the same goal of improving patient care. As increasing amounts of these new systems come on line, the ability of the healthcare worker to potentially capture, analyse and share increasing volumes of data is greatly enhanced. There now exists more information than ever before and demands for access across every discipline are constantly increasing.

With so many specialist areas in healthcare and existing systems to cater for, a highly adaptable approach is needed to fully meet the information needs of the healthcare professional. This dissertation examines the use of portal technology and its potential role in fulfilling some of these needs. The work carried out also explores the subject of content management and the difficulties of delivering domain and user specific information to the point of care. The information exists, having been captured and stored, but every discipline potentially requires a different view of this data. The portal approach is grounded in the success and capabilities of the Internet and the standards on which it was built. Portal technology looks to exploit certain aspects of this proven method of information delivery through improving information accessibility, interoperability, portability and device independence. These all exist as powerful assets to delivering efficient care delivery.

The final part of the dissertation focuses on a case study within the Adelaide and Meath Hospital Dublin, incorporating the National Children's Hospital. The study looks at what portal technology can offer the specific area of chronic disease management. It specifically looks at the area of Diabetes Mellitus and the added capabilities and improvements to patient care a Diabetes Shared Care Portal might offer.

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Abbreviations

A&E – Accident and Emergency
AMNCH - Adelaide and Meath Hospital incorporating the National Children's Hospital, Tallaght
CEN – European Committee for Standardisation
CMS – Content Management System
CSO – Central Statistics Office
CSS – Cascading Style Sheet
CT – Computed Tomography
DDC – Diabetes Day-care Centre
DHC – Department of Health and Children
DIT - Dublin Institute of Technology
DM – Diabetes Mellitus
DNS – Domain Name Service
DSS - Decision Support System
DTD – Document Type Definition
ECG – Electrocardiogram
EEG - Electroencephalogram
EHR – Electronic Healthcare Record
EJB – Enterprise Java Bean
EPR- Electronic Patient Record
EU – European Union
FPG – Fasting Plasma Glucose
GP - General Practitioner
GUI – Graphical User Interface
HIPE – Healthcare Industry Partnerships with Education
HIQA - Health Information and Quality Authority
HL7 – Health Level 7
HSE – Health Services Executive
HTML – Hypertext Markup Language
HTTP- Hypertext Transfer Protocol
ICP – Integrated Care Pathway
ICT - Information & Communications Technology

ICU – Intensive Care Unit
IE - Integration Engine
ISO – International Organisation for Standardisation
IT - Information Technology
J2EE – Java 2 Enterprise Edition
KBS - Knowledge Based System
KMS – Knowledge Management System
LAN – Local Area Network
LIS – Laboratory Information System
MRI – Magnetic Resonance Imaging
OCS – Order Communications System
OGTT – Oral Glucose Tolerance Tests
OMG – Object Management Group
PACS – Picture Archiving and Communication System
PAS – Patient Administration System
PDA – Personal Digital Assistant
PiMS – Patient Information Management System
RIM – Reference Information Model
RIS – Radiology Information System
RMI – Remote Method Invocation
RPI – Remote Process Invocation
RPG – Random Plasma Glucose
SJH - St. James's Hospital
SOA – Service Oriented Architecture
SOAP – Simple Object Access Protocol
TRiPS – Test Request Protocol System
UDDI – Universal Description, Discovery and Integration
VoIP – Voice over Internet Protocol
VPN – Virtual Private Network
WAN – Wide Area Network
WAP – Wireless Application Protocol
WHO - World Health Organisation
WML – Wireless Markup Language
WSDL – Web Service Definition Language

XML – Extensible Markup Language

XSLT – Extensible Stylesheet Language Transformation

1 Introduction

The overall objective of the work reported in this dissertation is to explore the potential of modern portal technology in the context of healthcare and patient information. Portals in essence provide a gateway to data access and transactions. Hazra (2002) describes them as a single point of entry, a single point of access, and a single point of information exchange. The specifics of this dissertation will look at critical patient health data and explore the improved access and capabilities this approach could potentially provide to those who need to view patient information.

A number of observations can be made of the healthcare environment. The most notable one which provided encouragement to complete this work was the pronounced lack of interoperation and integration between the disparate and departmental IT systems within a single hospital site. It is daunting to even consider these issues on a national basis. Few systems currently seek to exploit relevant data currently residing elsewhere on similar systems. Exceptions in this case are the larger centralised hospital repositories like those used for patient demographics and laboratory results. There are a number of reasons for this lack of interoperation and data exploitation; cultural differences, 'go it alone' projects, inadequate architecture (legacy systems), cross platform integration issues, specific site based issues (management, facilities, budget), etc. The portal approach aims to provide a solution to many of these problems; common interfaces, customisation, advanced integration capabilities, standards, reduced costs and many more (Murray, 2002). This dissertation aims to look at how the portal solution might approach these issues in a manner specific to the hospital and moreover in the context of the healthcare domain.

It is widely accepted that portals with their internet backbone will have a huge part to play in the future of healthcare on a worldwide basis (Kosińska and Słowikowski, 2004). Within Ireland, the 'National Health Information Strategy' (DHC, 2004) reserves a significant section to focus on the use of portals. During this dissertation it will be investigated as to what this means to healthcare in this country. There will be a strong focus as to what extent the concept of the National EHR can be realised using portal technology as its underlying approach. Also to be investigated are the specific issues in the health domain that would arise through embracing portals centrally to

healthcare practices in this country. There will also be an examination into what portals can offer the healthcare management function and what issues might arise. This dissertation aims to introduce the reader to the capabilities, limitations and available approaches currently used by the technology. There will also be an inspection into relevant key areas in the context of this work, with regards to IT capabilities and the EHR, interoperability issues and content management. With all this in place, a case study will be completed within AMNCH to see what Portal Technology might offer a specified discipline within that hospital.

1.1 Background

Chin (2000) noted how healthcare is an information intensive area and the management of this data presents workers at every level many complex but often interesting challenges. The popular IT term ‘information everywhere’ is quite relevant to what is being investigated and how to make this data available to those who need it. An expression like ‘information everywhere but not everyone’ might be more fitting for the health industry. This is because of the sensitivity of the data being dealt with in the healthcare domain. The goal is to make information available anytime anywhere, but with only a desired subset of people allowed access to specific areas of this information. In its simplest form, two main problems exist here. The first of which is the need to share the data in a form everybody can understand. With this in place, a mechanism needs to be implemented that controls exactly who has access to the data once it has been made accessible. These requirements are known as semantic interoperability and access control (Zhu et al, 2004).

The principles of data accessibility are the same within a hospital. People have information relevant to another department’s work that they are often required to provide access to, e.g. the shared care required for a diabetic patient. There are multiple sites and sources of information within a hospital alone. As is a common occurrence, this information may be stored in a system specific to the department it was collected in. The department that requires access to this material may also have a system of their own but there are no guarantees the data can be easily exchanged. There are a number of issues involved here, explored later and throughout this dissertation.

Work currently being carried out within AMNCH includes a pilot project called TRiPS, which stands for Test Request Protocol System (Berry et al, 2002). This system is one of the few within the hospital that makes use of multiple information sources to carry out its work. It ‘pulls’ together information from different systems within the hospital, transforms this data into a common format, correlates it and presents decision support information to the user. This could be seen as a simplified version of a portal, integrating existing data to produce another specific view. The technology now exists to produce such a system on a much larger scale. The interface for TRiPS, while it is Java based and platform independent, it is not completely portable and this is a significant drawback. Remember the concept centres on location independence, to make relevant material accessible throughout the entire hospital. This is the central point to this dissertation, information accessibility and what portal technology can bring to the table.

1.2 Aims & Objectives

The main objective of this dissertation is to investigate in detail precisely what portal technology can offer the area of the EHR and the complex area of patient data management.

Critical healthcare data exists in every health department, ward, system and employee around the country, the view would be to make this information available through a single point of access. The aim is to look at one approach that could potentially make this possible without having to throw out all the previous good work and investment that has come before it.

Previous approaches to health application development often employed too much segregation between departments and systems, interdepartmental relations and user involvement are key issues (Anderson, 1997). A more universal and standard approach is required that is easily accessible to the majority. The portal approach currently may or may not be the way forward but the aim is to investigate how far it can potentially go to realising the EHR. This investigation will aim to draw together numerous different areas and issues that will be encountered by employing this approach and will then try to put these specific issues into the context of manageable healthcare.

1.3 Overview

A good starting point is to explain in full the title. Central to the work is the concept of the EHR, one overall patient record, potentially encompassing information from multiple area specific records. This is the perceived notion of making all existing data on a patient available at one point through one virtual record. ASTM (1996) defines it as a “a comprehensive, structured set of clinical, demographic, environmental, social, and financial data and information in electronic form, documenting the health care given to a single individual”.

The idea of the customisable EHR is that different healthcare professionals in a hospital have different needs. They should be able to access whatever information is relevant to them whenever necessary, in a view that is suitable for their work. This could be seen as tailoring content needs per employee or content management.

A portal or portal technology is an approach used to make large amounts of related information available to a specific audience, using similar technology to that which made the Internet so successful. A very generic definition of a portal is a single gateway connected by a server that connects people with information (HCG, 2002). New powerful and evolutionary computer practices evolve all the time, the aim is to see what this family of technologies can contribute to the development of EHR systems.

Exploiting existing electronic patient data is quite a general statement, to some it means using what is already known, data previously collected on a patient to aid in their treatment or diagnosis. This is of course already a natural practice in patient care today, but what can this technology offer to make the process more efficient and improve the level of patient care. This is where system integration and interoperability has a big role to play, making existing sources of data work together, combining proven systems to enable the sharing of their information with relevant parties to produce positive outcomes.

1.3.1 Portal Technology

The challenge is to enable real time access to all critical clinical information available for a patient, regardless of where the information resides or what system was used to

capture it. Portal technology looks to provide the platform on which to provide the necessary horizontal flow of data to make this existing data instantly available. There are multiple options regarding which vendor, architecture and model to use, or what combinations are available for implementation.

The portal approach centres on providing improved access to vital information and where else is information more accessible than on the Internet? Underlying portal technologies are the principles used by the web, common browser interface, messaging standards, portability and many more. The browser interface (portal) provides a screen most computer users are familiar with or one they can become familiar with after a relatively short period of familiarisation. Throughout this dissertation, the possibilities of migrating existing patient data to a web browser for presentation and manipulation will be investigated. Portal technology provides the background tools required for integration and communication of the required data. This means that there is no need to throw out existing systems and the good work that went with them. In basic terms, portal technology provides another level to encompass existing systems and provides the potential for developing new systems due to the availability of new data.



Figure 1. Introducing Portal Technology

1.3.2 Healthcare Issues

In considering the portal approach in relation to the healthcare domain, there are some specific issues that need consideration. The first issue to consider is the diversity of available sources of information. Consider a hospital and the number of different departments that exist, all generating and storing patient data, though not all necessarily in the same way. The sheer volume of data in healthcare is a major issue. Until recently and even today, healthcare institutions continue to invest in and develop proprietary IT solutions in their workplace. This has led to a major issue, that without any guidelines in place, a huge range of different approaches and breeds of systems have emerged, often carrying out similar functions in entirely different ways. The format of data capture and storage in all these systems presents another problem, the exchange and integration of data between separate systems can prove troublesome. Guidelines are needed for information sharing and messaging, standards like HL7 and popular technologies like XML need to be embraced.

The history or culture of many healthcare agencies is also an issue. Mistrust can exist between certain parties and differing priorities and data usage can lead to reluctance to cooperate in many cases. Many institutions are only interested in what is going on in their own workplace and look to gain the most possible from their own IT investments. They do not always like to have to take others into account. There is a need to instil an information culture to remove these barriers for the successful implementation of the EHR (Fields and Duncker, 2003). The privacy and confidentiality of patient information is also a very important issue. Without an agreed set of guidelines on a national basis, it is difficult to move on in a cooperative manner.

IT capacity to deliver such a large scale project with the current trend in investment is also a major healthcare issue that is very central to the theme of this dissertation. In 2004, the capital spend on Healthcare ICT was estimated to be just over €70m. While that figure represents a very significant increase on previous years, it remains small relative to comparative international levels (HISI, 2004). It remains to be seen whether the technology and frameworks exist to make a national system viable. Many approaches exist to facilitate the delivery of health information but it remains to be seen if any of these are robust or flexible enough to deliver the concept of the national

EHR, in conjunction with other e-Health services. The information exists in both paper and electronic format, healthcare now needs to see if the technology exists to fully exploit its potential and bring the EHR together.

1.3.3 Content Management

With information available from so many different sources in a hospital and the multitude of patient and user categories to cater for, it is a difficult task to ensure that everybody is being exposed to their required, relevant and permitted content. Clinicians have to take substantial amounts of information into account from patient to patient. There is a resulting need to have the required mechanisms in place to help make what is relevant available, in the shortest possible time. Tarczy-Hornoch et al (1997) noted that in a time of managed care, increased patient load and decreased clinician time, an integrated tool to access panels of patients, medical knowledge and patient specific information would be particularly valuable.

Content management is one part of the tool that makes this all possible. The management of what a large system displays on a screen to any one user can be split into a number of significant areas. 'Presentation' deals with the delivery of different data formats to the different devices the content may be viewed on. 'Generation' deals with the data and information itself, the dynamic and static content produced by the users in the system. 'Customisation' is based on the role of a user, modifying content or the level of detail provided based on a user's profile. 'Personalisation' is user specific again, offering the mechanisms for clients of the system to modify views based on their needs, user history, access rights, preferences, etc. 'Assimilation' is the final of the major areas of content management, this is the merging and combining of static and dynamic information from different sources to provide new content views. This leads to increased reporting and interpretation capabilities (Hazra, 2002).

2 Portals

2.1 The Internet – Underlying Technology

It is fully acknowledged that internet technologies are having an important impact on healthcare and medical informatics (Briggs and Early, 1999). Lin and Umoh (2002) noted how the healthcare system stands to become one of the largest beneficiaries of internet technology, stating that its strength was its ability to deliver quality care irrespective of where it was sought. The strengths of the Internet are the standards and protocols it employs. The success of these technologies has led to the natural evolution of new approaches grounded in their proven performance. Portals have emerged as one such approach, building upon and extending the capabilities and performance of these standards and protocols, and exploiting the scalability offered by internet technology. Kapur (2001) noted that as a global cooperative network of university, corporate, government and private computers all communicating together, the Internet can go a long way in meeting the WHO goal of ‘Health for All’.

2.1.1 Overview

The Internet brings with it a lot of important functionality, file sharing and transfer, remote access and invocation, messaging capabilities and the one most will be familiar with, the view or the browser window. It is through this window, or portal, that powerful information delivery becomes accessible. The browser brings together the final product or view that is a combination of complex and extensive work carried out in the background. Web browsers gather together and present information from the Internet, portal technology should in theory be able to do the same for a patient’s information, regardless of where it resides.

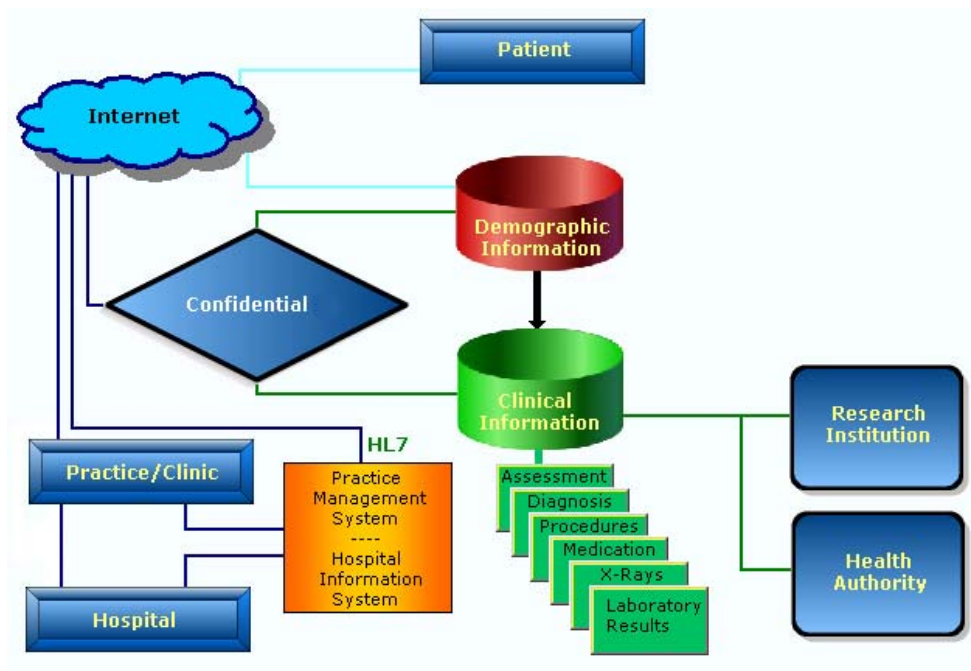


Figure 2. Using the Internet to Deliver Healthcare Information

To make this possible, internet technology has the capabilities to enable the requisite levels of information exchange and communication. It can act as a type of integration platform (Alt and Klein, 1999), made possible with popular standards like HTML and XML. Increased availability of information is a strong point with the use of platform and device independent approaches. Real time information and the ability to perform instant analysis also make it well suited to the medical domain. It also brings with it useful facilities such as instant messaging, discussions forums, online communities and Voice over Internet Protocol (VoIP). Internet technology and the portal platform enable a modular architecture allowing the development, implementation and deployment of independent components, making iterative and prototyping strategies a possibility (Murray, 2002).

Internet technology does have its drawbacks. There have always been issues with security when considering any approach in healthcare (Luxenberg et al, 1997). The emergence of wireless computing adds to this. Along with these factors, the speed of access to some data sources can be a cause for concern but advantages and disadvantages exist with every approach. Special considerations are especially needed when dealing with sensitive health data. Portal technology is continually evolving and

maturing and issues that continue to plague the Internet are a constant focus for improvement across all domains. Security for example is a special concern in the financial world too.

2.1.2 Web-based or Web-enabled

A web-based system is one that from its conception is designed to exploit the use of internet technology (Hu and Lauck, 2004). It is specifically engineered and written with attention given to the specific standards. They are hosted on standards based application servers, J2EE and .NET for example, always with the intention that access is gained via the Internet through a web browser. The design model used and the adherence to globally accepted standards provide extensive flexibility. Web-based designs are also very modular in nature and the systems are easily extended with additional components. The hosting application servers that are used also provide access to numerous additional features that can be used by the systems, for example, security and integration mechanisms. The final element, and that which users will see most of, is the browser interface, designed from scratch to be user friendly with appropriate web design conventions in mind. It is not an interface made to fit but one that is custom built for the purpose.

A web-enabled system really only shares one major similarity with the web-based system, they both use a web-browser to display information. These systems are often applications originally designed and implemented for client-server and mainframe environments, these are the legacy systems. Vendors are under constant pressure to exploit the power of the Internet and often look to 'bolt on' the capabilities offered. Such systems often have to be partly re-written and a new layer of software added to existing structures to make web access possible. It can be worth the effort if the systems have a proven track record of performance or if the existing investment in a system is substantial or prohibitive to a fresh start. The result is usually that the original system operates as before but now with the additional benefits and capabilities of enabling input and output through HTML and XML. New approaches are reducing performance degradation, cost and complexity. Web enabling provides a reduced risk of totally rewriting a proven system and can extend the lifespan through the introduction of web capabilities. It often depends on the long term direction of a

system and its requirements as to what decision is made regarding web-enabling or a green field web-based approach (Snell, 2002).

2.1.3 e-Health

Goran and Stanford (2001) explained that the idea is not to merely electronically enable the current care delivery care process but to use the connectivity offered by the Internet to change the process of complex delivery care, in a way that benefits the patient without increasing overall costs. It is not merely a case of looking to move forward for the sake of it, there has to be a return on investment in the shape of improved healthcare delivery. This can be achieved throughout the healthcare domain through the use of improved communications capabilities in areas ranging from supply chain management and product delivery in a hospital, to the exchange of electronic patient information for shared care practices, or even the advancing technology used in surgical procedures. The advances being made under the umbrella of e-Health are continuous and at times impressive; the challenge is to embrace and manage these approaches to an advantageous end.

e-Health encompasses a wide range of significant areas, it is a broad term used to generalise a complex and expansive set of services, technologies, methodologies and devices for healthcare. It has enriched direct communication capabilities, patient – physician, physician – specialist, etc. From the emergence of email to the growing use of mobile technology and telemedicine, it has never been easier to meet communication needs. More and more data is being made available to those who need it and systems are being developed to find new ways to put this data to good use. Decision support systems have emerged to support the need for evidence-based medicine, intelligent programs which look to maximise existing health data's potential. One of the main areas in e-Health to flourish is the PACS, picture archiving and communications system. The volume of diagnostic imaging produced is immense, X-ray, CT, MRI, ultrasound images all have to be stored, managed and accessed in an intelligible way, needing new approaches and advanced technical capabilities. Significant savings and care process efficiencies can be gained through the use of PACS (Silber, 2003). Test request and laboratory information systems are also sizeable developments, with such considerable throughput of critical information from their related departments.

e-Health can be viewed as a resource to the healthcare employee, and like any resource it requires strict management and thoughtful allocation. It also makes more resources accessible than ever before to support the work being carried out (Podichetty and Biscup, 2003). Increased availability of reference materials, journals, case studies and multimedia is evident, to name but a few. In conjunction with this, there exists the combination of e-Health and e-Learning, using it as a device to educate the current and future workers in the industry. This is referred to as Healthcare Industry Partnerships with Education or HIPE. The provision of simulations and virtual environments in which to expose subjects is a useful tool, which continues to be developed. The introduction of mobile devices and the emerging monitoring capabilities being made available will provide increased access to streaming real-time information. This may prove immensely important when considering the diabetic and cardiac trends evident in Ireland today. e-Health will strive to achieve what can be viewed as a culmination of all that has gone before in this area. When all its capabilities are realised and successfully combined, e-Health will produce the fully functional EHR. A lifetime of healthcare history made available at a single point of access. The portal makes up just one aspect of this, the final delivery mechanism.

2.2 Design

2.2.1 Introduction to General Principles

The design process contains a number of key steps regardless of the domain being dealt with. The first is to identify the features required; this will result in a requirements specification being produced. Every single screen, button, option, etc. that is desired will have to be accounted for. The next step is to evaluate what is currently in place, to learn from any mistakes and to carry over anything that already functioned appropriately. After learning all about the problem domain, the next steps are to choose and implement a solution (Wald et al, 2001). Even at this final stage, a number of options remain, ‘big bang’ or iterative, single vendor or ‘best of breed’ approaches and open-source standards based methods.

When dealing with portal design and topics that include system integration, there are many factors to take into consideration throughout the design process. Heterogeneity

is inevitable when dealing with health data (Hook and Regal, 1995). This encapsulates the hardware, software, network protocols, data models, semantics, etc. Standards are also critical while methodologies and tools are a necessity; these include different software development techniques, development environments, change management control, testing facilities and many more considerations.



Figure 3. Portal Design Considerations

2.2.2 Issues & Challenges

As stated previously, there are two distinct methods in which to approach the design of a large distributed system. One option is to focus on one comprehensive and integrated solution offered by a single supplier. The other option is to focus on solutions related to one or more specific features of the system, each implemented by a niche supplier. Each approach brings with it advantages and disadvantages. There is the threat of being tied to a single supplier and removing the threat of competition for the most part, or the challenge of integrating and managing multiple systems from multiple vendors. The goal is the same in either respect, producing a system that does the job it was designed to do. Considering the vast number of disciplines in medicine and the amount of money already invested in existing systems, it is hard to envisage one single solution. At the same time, it is hard to fathom the work that is required to make all these applications work together to appear to deliver a unified healthcare record. Hazra (2002) points out that in the portal industry alone there are niche players

in areas such as content management, security, XML frameworks, knowledge management, integrators, adaptors, connectors, server vendors, J2EE or .NET architectures, etc. Each claims to provide the best solution for their area. Designers have to sift through the buzz words, the streamlined presentations, endless documentation and determined sales people to select the product that best fits the requirement specification presented to them. This in itself is a challenge to the designer.

Regardless of what approach is taken when designing a portal system, there are some key requirements on the designers' part, as identified by Hazra (2002). Strategy development is a very important place to start. Every project needs a definite direction with aims and objectives, methodology and expected outcomes. A clear strategy on how to achieve these things needs to be clearly stated, this is a prerequisite management deliverable. The next step is to prioritise the different design and implementation phases, put a definite order and timeline on things. People need to know what they are supposed to be doing and when, this makes progress easier to monitor and manage, resource and delivery planning needs to be well managed. One of the more difficult steps is to then identify and specify the requirements for the system. There is a need to pinpoint the components, services and processes that will require reengineering, automation or a transitional phase. A roadmap is then required to develop, integrate and provide the transition and deployment of the systems needed to meet these requirements. Another key requisite in design is the selection process, putting in place the appropriate techniques, tools and technologies required to implement the design efficiently and effectively.

Portal technology is by nature modular and component based, it allows flexible development techniques to be employed (Murray, 2002). These include rapid prototyping, gradual or modular rollout and open standards. This approach allows for incremental investment, which can be very important with budget restrictions in the healthcare domain. In the design phase, prototyping allows an evaluation of the various development options and solutions available. It is also very important to interact, educate and inform everybody involved in the development and deployment of large scale systems. Javitt (2004) notes how user involvement during the design phase is likely to produce a better result. Everybody has to understand what it is they

are trying to achieve; a type of community effort is required. The process and result will impact everybody so they should have the opportunity to have their say. This is especially significant when trying to identify the needs of all the user groups, partners, patients, vendors, employees, developers, etc. Such a coordinated effort improves the dissemination knowledge in any project. A team that works together can better exploit the potential of these portal technologies, have a better understanding of system and process interactions, recognise crossovers between disciplines and exploit the capabilities of a device independent architecture.

2.2.3 System Integration & Existing Infrastructures

Legacy system is a term that is often used when system upgrades and reengineering are the topics at hand. It refers to the existing systems that currently provide the services and processes an organisation might be seeking to improve. Very often they carry out the task they were designed to do efficiently and effectively. Often if they have had a significant lifespan, it means they have been embraced by the workers and fully integrated into existing workflow practices. Some often question the need to change such systems and throw away the good work and money invested in these systems. Change is inevitable in any industry and none more so than healthcare at the moment. This sector is seeing the advantages and results of embracing new and improving technologies. Computer based records alone offer improved access, legibility, views, structured data, decision support, data analysis and exchange and shared care support (Van Bommel and Musen, 1997). With new approaches today, it is not always a requirement to throw out the old to make way for the new. Very often the data required already exists in some format. The problem then remaining is to provide improved access to this information using whatever methods that are available. Portals offer one solution which enables greater access to data currently existing in multiple locations, exactly what many healthcare applications are trying to achieve. Using web technology, the basis for portals, as an integration platform, provides a powerful and flexible approach to data access, system integration and interoperability.

Many common issues exist when dealing with the integration of multiple diverse systems. There are a lot of factors to consider when trying to achieve seamless interoperability. Difficulties exist when approaching the integration of record systems

with other information resources in the healthcare setting (Shortliffe, 1998). The amount of different computing platforms available and the difficulties in making these communicate effectively with each other. Data interpretation and semantics is a huge area. Just because two systems have data items of the same name does not mean they are describing the same thing. There is a lot of work involved in organising the metadata required to ensure there are no misinterpretations of data being passed between systems. The base functionality of any system has got to be thoroughly understood before introducing its workings to another system's environment. Proprietary solutions can often present significant challenges, through lack of detailed documentation and non-standard based approaches. Integration insists data is comparable, consistent and compatible to enable it to be interchangeable and understandable.

System behaviour needs to be fully understood but unless program code is well commented and comprehensive documentation is supplied, then this is often not the case. Systems in general can be unpredictable by nature. The unexpected and unexplainable has been experienced by most people at some time when systems are integrated and interdependent. This is a huge concern, especially when dealing with healthcare data and the considerations of data privacy, confidentiality and security (Shortliffe, 1998). The behaviour of systems and ensuing results cannot be considered isolated in this regard. If there is a 'knock-on' effect or direct troublesome result in one system as the result of a process being carried out in a connected system, it is a serious problem. These problems can initially be difficult to detect and the solutions can be expensive and time consuming. It is a huge factor to consider in system design. Leading on from this is the management of change in these large systems. Separate systems will evolve, needs will change and capacity will often be stretched. Distributed systems needs to be designed with evolution in mind (Warfield, Coady and Hutchinson, 2001). New and modified functionality must be easily introduced. The introduction of new hardware with added capabilities should be encouraged with no major barriers in prevention. Ease of migration if the need arises, new databases, backups, redundant systems etc. When dealing with healthcare data, all this must be achieved with efficiency, quality and safety in mind. These issues relate to the topic of Change Management, a key function within healthcare systems management, but further discussion is outside the scope of this dissertation.

2.2.4 Standards

Adherence to standards is one of the most important requirements when considering the design of any large scale system such as the EHR (Forsslund and Kilman, 2000). Standards exist all around; they can be seen in measurement, electricity supply, mechanics and communications. Computers, applications and portal design are no exception. The portal approach is founded on the ideals of cooperation, integration and interoperability. To achieve this, all parties involved must have a definite framework and specification to follow. This ensures systems are developed to allow seamless process interaction regardless of the number of systems involved or boundaries crossed.

Specific to software and hardware compatibility, there are a number of key areas where standards are required. Data exchange relies heavily on predefined standards to allow systems to operate and share data. This makes it possible to design and implement processes that rely on functionality and data made available through different applications. Messaging standards are central to this, this represents the format in which data is packaged and then interpreted by systems. HL7 is a significant example when dealing with messages involving healthcare data. Coding and Classification standards are another important consideration when trying to integrate and exploit existing computer systems and data in the health domain. It provides a definitive categorisation model for the information being captured and stored for future use. Standards in connectivity are also important. More and more new machines and devices are being harnessed by the healthcare industry in the pursuit of data capture, access and analysis. Standards ensure these devices arrive on the market with integration into existing practices in mind. The purchasing function within any organisation is also made easier through the use of accepted standards and best practices. With so much choice available and potential suppliers, knowing the needs of the organisation before approaching the market makes the procurement process much easier. If one vendor cannot meet these needs where standards are involved, simply find one who does. A market leader will know what its potential customer will be looking for and at what industry accepted specifications. Interoperability is a recognised key requirement for the EHR and this process is completely reliant on a

standards-based approach; this requires standards to be fully embraced in healthcare (Broom and Loonsk, 2004).

Many healthcare standards organisations exist today, with more attention now specifically being afforded to technological advances in the sector. They provide a level of control and focus for further development. Standards bodies like ISO, OMG and CEN are there for industry suppliers to cooperate and work together with, to improve their product offerings. Having such regulators available ensures a certain level of conformance is required by everybody involved in the design, implementation or supply of components for large scale systems. This is good for competition within an industry as it drives down cost and increases quality at the same time, as companies strive for competitive advantage, resulting in the purchase of their product. The push for more standards makes system integration easier and designs more flexible (IEEE, 1996). There is less market fragmentation as users begin to demand standards. This demand trickles down from the users to the designers, to the procurement and policy makers. Suppliers are left with no choice but to embrace standards and subsequently fully incorporate and make use of these standards.

2.2.5 Security

As already mentioned, security is a significant consideration when designing any system. When the use of web technology is added to the equation, there are always concerns on the part of the user; data hacking and interception, identity fraud, spam mail, etc. Add to this the dissemination of healthcare data through the EHR and the data protection and confidentiality issues involved (Gordon et al, 1998), and there is quite a lot to consider when deploying a large scale system of this nature. Security is such a large area, most of which is outside the scope of this dissertation. In relation to portal system design there are some specific themes that will be introduced. Another key element to security and traceability is the existence of a national unique identifier, both for the patients and the users. This is a huge consideration again outside of the scope of this dissertation. This work will proceed on the assumption that it will become a reality in the near future.

The need to tightly control portal access is paramount. On the theme of customisable views relating to access rights, the mechanism required to tailor individual views of

healthcare data falls into the category of user and account management. An example of this is evident in the everyday use of computers in the work place. Some peoples' system logins allow them to access more functionality than others. Design must incorporate this idea of flexible and configurable user groups. While belonging to a certain group, it should be easily recognisable as to what parts of the system are accessible and the specified level of access rights in operation. The concept of a single sign-on is central to making this work on a large system (HIPAA, 1996). Users must be quickly and easily recognisable and hold a significant amount of responsibility for all the work carried out under their identity. Many different options exist to implement this, smartcards, value-based security, biometric data, the simple username and password or a combination of all of these.

User management relies on the mechanism of being able to assign an individual profile to every user on the system. Specialist servers and applications are put in place responsible for this function alone. System design must ensure they manage the identification, authentication and authorisation required to keep the system secure (Westphall and da Silva Fraga, 1999). Identify if the user has approved access to the system, authenticate to prove the user is who they say they are and authorise exactly where in the system the user can enter. Restrictions are often there to protect the user from the potential results of their own actions. Validation of the information entered is also a design consideration and the provision of backup systems is a requirement, in the event that something unexpected does happen. In the event of such as occurrence, traceability is required to get to the cause of a problem. A system of logs and an audit trail are mechanisms that should be put in place and should be powerful and detailed enough to be easily utilised when needed (Landwehr, 2001).

Protecting the exchange and communication of confidential data also needs to be addressed. In large distributed and cooperative systems, large amounts of information are continuously on the move. The medium of there exchange often differs largely but in the context of portal technology, the medium is the Internet and the web-based approach. This is not entirely appropriate for the nature of data healthcare deals with. There are too many people with access to this medium. Encryption and public key infrastructures are methods often mentioned when trying to send data securely over the Internet. The VPN or Virtual Private Network for healthcare data is required

(Jones, Bults and Konstantas, 2001). This is a designated and dedicated internet medium for the industry which is discussed in a later section. The portal approach is based on the fundamentals and protocols of what has made the Internet so successful, this does not mean the same lines of communication have to be used as everybody else though. A reserved channel of communication between the selected systems is needed.

2.2.6 Scalability & Extensibility

The scalability describes the level of a system's ability to grow smoothly and economically as requirements change or increase. The goal in design is to produce a system an organisation will not outgrow. The design must consider many factors in this regard; platform, architecture, applications involved, networks, databases, etc. The focuses within these factors are invariably on the volume related requirements. These are transaction volume, data input and output volumes, stored data, number of users, etc. When extra capacity is required, system design must allow for the increase at an acceptable cost while still meeting the desired system requirements (Winter, 1999). System upgrades are disruptive, system replacement even more so, good design and planning will keep these to a minimum. The increased capacity must also be delivered without degradation of system performance and response time. Increased data size, speed, workload and transaction numbers must be catered for. While it may be impossible to produce a design that will never be outgrown, it is important to plan for the future to ensure ease of transition when the day does come.

Extensibility describes a system's flexibility to keep pace with constantly changing business requirements (Jaenicke, 2000). This covers the ability to add new features, functionality, fields, attributes, etc. to the system without the fear of disruption, system failure and data corruption. A good design allows for future change with efficiency and cost factors as serious considerations. Extensible systems allow the building of new features from the old, and improving existing features without difficulties cascading through the different functions. It is good to adopt the belief that a system will never be finished and to allow for future modification with minimum disruption. Healthcare is a good example; new applications are constantly being introduced into the environment. If a unified structure such as the EHR is to become a reality, the impact and integration of new additions has to be seamless. Design for

growth because it is inevitable. Implement the concept of open ended structures because new platforms, functionality, data sources and specialist systems are inescapable. If everybody shares the same extensible, 'built on top of' approach, more data can be accessed and exploited and more new systems enabled.

2.2.7 Availability & Reliability

Availability can be expressed as the probability that a system is operating properly when requested for use (Weibull, 2003). The service has to be delivered promptly without failure or the requirement of repair. In healthcare, current information is necessary for accurate decision making, it is of no use if this information is not available at the critical time because a system is down. MIT (2004) lists two approaches in design to ensure this does not happen. One method is to build the system out of components that seldom fail, it sounds simplistic but if it is possible to achieve, then it is an option. The second method would appear more suited to the healthcare domain; built in redundancy. This can be divided into two distinct categories, retry or replication. Retry incorporates the idea of a system 'timing out' and then trying again. The use of timeouts are a critical consideration in availability, providing a definite timescale before the need to use plan B. Replication is a more familiar concept to most, the primary backup or duplicate system, designed to take over when the main system fails. This can exist unknown to the user where a background system fails and another simply takes over. In design there are many factors to consider when maximum availability is required. Failure of any number of things will bring a system down; power supply, network infrastructure and access, servers, data storage, etc.

Reliability and availability are strongly interrelated. Reliability can be expressed as the probability that a system can perform its required features for a desired period of time without failure in specified operating conditions (Weibull, 2003). Unlike availability it does not account for maintenance or repair actions. Reliability does not factor in the time required to return the system to full working order. Availability can be considered a function of reliability. In design terms reliability is increased with systems that provide ease of inspection and maintenance, simplicity and damage tolerance. Poor reliability can be the result of poor solution design and selection. Other factors include human error, manufacturing defects, poor maintenance and

monitoring practices, exceeding design limitations and various environmental factors. There needs to be contingency embedded in design to account for such issues.

2.2.8 Usability

Jakob Nielsen is recognised as an expert in the field of user interface design. In 1990, he and Rolf Molich developed a set of usability heuristics which he followed up with some revisions in 1994 (Nielsen and Molich, 1990. Nielsen, 1994). They are a general set of guidelines to be considered when designing any interface with ease of use in mind. This is very important to portal design as the interface is its main component, offering the point of access to the system itself. What follows is a brief summary of the main points.

A user should always be kept informed of system status, exactly where they are in the system and what is going on. Feedback messages should be clear, appropriate and delivered within a reasonable time period. The system, should as much as possible, match the real world. This can be achieved by speaking the user's language, using appropriate words, phrases and concepts with information appearing in a natural and logical order. This is made possible with the portal approach with customisation and personalisation techniques available to present each user with familiar language and workflows. It is important to support the concept of undo and redo providing the user with a level of control and freedom. Users invariably make mistakes and should be able to navigate easily away when this happens, without committing to an unwanted state of persistence. As in all areas of design, standards and consistency in usability are imperative; this includes syntax, semantics, processes and actions. Good usability incorporates error prevention, its better to avoid having to provide error messages by avoiding the problem in the first place. Interfaces should provide users with validation and a confirmation option before they commit to an action.

Nielsen recognises the necessity of having all the information required visible when it is needed. There should be no need for 'recall' during navigation, an interface should be intuitively designed to have all that is required on hand; this includes user instructions for the system. Flexibility and efficiency of use is very important, a system must be able to cater for all levels of user ability. Frequently used actions by a user should be adaptable and configurable to their preferences. Never bombard a user

with too much information, keep it relevant to the purpose of the dialog in use, irrelevant data reduces the visibility of what is relevant and detracts from it. Nielsen recommends the aesthetic and minimalist approach. When problems do occur and error messages are necessary, explain using plain language and avoid codes, be precise and suggest a solution. This allows users to help themselves and empowers them to a certain degree. Nielsen's final heuristic of usability refers to help and documentation. Although a perfect design could be used without documentation, not many of these exist so it has to be provided. This information needs to be focussed and relevant, easily searched, presented in easy to follow steps and should be precise, not vast and cumbersome. Following these general principles will lead to a user interface design of considered usability.

2.3 Architecture & Models

2.3.1 Service Oriented Architecture

Portals are designed to deliver multiple different information services through one single access point. Common everyday portals like Yahoo and MSN, deliver a selection of services that require information from multiple sources. These include news, weather, finance, markets, email, games, shopping, etc. all brought together through one web space. Portals are about bringing the services and their information to the target audience when they need it. Apply this to the patient record and the care personnel are equipped with a powerful tool. The required architecture has to be put in place to deliver this concept; this is a service oriented architecture (SOA). The most important aspect of this architecture is that it separates a service's implementation from its interface (Ong et al, 2004). The consumer of a service sees it as an endpoint and is not concerned about how a service executes their request.

A software architecture describes the components of a system and how they interact with each other at a high level. The configuration of these components and these interactions or connections, defines the structure and determines the behaviour of the system. A service oriented architecture is made up of components and interconnections that stress interoperability and location transparency, the architecture is about building systems using heterogeneous network addressable software components (Stevens, 2002). Network addressable means that any client must be able

to invoke that service over a network connection. A component can be viewed as a small group of objects working within a system to provide a function. They provide a way of hiding complexity, with functionality only accessible through specific interfaces; other functions in the system do not need to know how the work is carried out, just that it is. This reduces dependency in a system because of this loose-coupling (Chaudron et al, 2001). Other parts and functions of the system might not need to know that a component even exists. This component model allows developers to create more complex, powerful and higher quality systems because of the built in mechanism for managing complexity and dependency. SOA is a design method and way of thinking about building these software components to provide services.

A service as mentioned before has to be invocable over a network and this depends on two things, its transport type and its payload format (Stevens, 2002). The most common technologies used for both functions today are HTTP for transport and XML for formatting. Services also need to be interoperable, having the capability of being invoked by any potential client of the service. Services also carry the requirement of being dynamic on both discovery and lookup. A client needs to lookup the services it requires to carry out a task and a service has to make itself known to any potential user, including other services, it is known as ‘publish, find and bind’ (Schaeck, 2001). Web Services is one specification used for implementing a services oriented architecture, arguably that which made the architecture popular in the first place. Web Services is also just one of many methods used to invoke these services, it does not specify any business logic or functionality for a service. It is the method used with portals so there will be a further look at web services later in this dissertation.

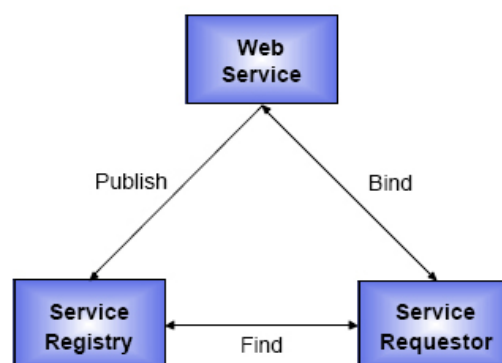


Figure 4. Service Oriented Architecture

2.3.2 Strategic ICT Framework for the Irish Healthcare System – Technology

This national ICT framework (HEBE, 2004) contains a section describing the characteristics of the technological approach required to implement the national plan. It is not specific in its vendor or solution provider but it describes in general the desired capabilities. It describes the need for Enterprise ICT Services and an Enterprise Service Oriented Architecture. This is also the architecture upon which portals are based, with web services central to the portal model. There are a number of interesting topics within the framework.

Modernisation Agenda

There is a modernisation agenda within the framework to lead the industry away from fragmented organisations towards a single patient-centric health system, with the processes of healthcare delivery needing extensive review followed by either replacement or redesign. There is a need for every element in care delivery to interoperate; this includes the agency, people, processes and technology as the enabler. An enterprise architecture provides an architectural view of these elements within the system, allowing the modelling of new and existing inter-relationships, processes, services, co-operation, interconnections and interoperations. The architecture description in the report describes how “the ICT products and services that comprise the legacy will be integrated as appropriate with the products and services acquired in the future.” This approach allows the leveraging of existing investment and continued development and spending in an incremental fashion. There is the need for such a flexible and adaptable architecture to be adopted and then to be used under best practice guidelines.

Migrating to Service Oriented Architecture

To facilitate greater integration between ICT systems in healthcare, the migration towards the modern concept of enterprise ICT services is needed according to the report. It mentions the use of web services as one example for possible adoption. The concept of ‘define once and use many’ is facilitated by such an architecture because of the standards framework involved. These ‘loosely coupled’ components also allow flexibility and ease of maintenance. The Irish health system is currently dependent on single product sets to provide enterprise-wide applications and meet as many user needs as possible. When this approach is not appropriate, the combination of multiple different systems is required, with interoperability relying on the conformance to

approved standards. Where a number of different products are needed to meet needs or a considerable ICT base already exists, there are a number of system management issues such as interfacing, integration and data migration. An appropriate development approach is needed to tackle all circumstances arising from both single vendor and 'best of breed' approaches. Any solutions chosen today must be capable of migrating to enterprise-wide services when required to do so in the future. The framework describes how organisations need a broad strategic direction that is not overly prescriptive to individual technologies. In certain circumstances there is a need for strategic alliances with suppliers and there is an ongoing need for the adoption of standards and best practices. Products and services will come and go in the healthcare sector as they always have. Data and knowledge remain for future use and improvement.

Supporting Communications

There are many different data structures and sources involved in healthcare. There is a requirement for structured messages to deal with digital imaging, telemetry streams, ECG and EEG traces, sound recording, EPR and EHR extracts. There is a greater demand now for real-time information regardless of location. New devices and technology allow for seemingly endless communication webs and increasing location independence. There is also increased demand for shared-care communities and networks and the advanced intercommunication infrastructures required to make these possible. There is also a national emphasis to relocate appropriate care services away from the hospitals and closer to the home, bringing care back into the community and developing specialised centres of excellence. Communications wise there is an issue with infrastructure capabilities and availability to make this possible. These considerations include broadband availability, appropriate LAN capabilities and perhaps a dedicated healthcare WAN. The current communications infrastructure does not currently support the required level of communication envisaged. On top of all this, highly secure layers of communications are required when dealing with healthcare data. A resilient and cost effective national network is a pre-requirement to implement the architecture required.

Current ICT Infrastructures

In such a budget conscious and topical funding subject, healthcare has a need to maximise the value of existing ICT investment. There is a need to build upon the

current systems within healthcare where possible and also to exploit any opportunities to share intra-development with public and even private sector organisations. For example, the idea of a Government Virtual Private Network has been mentioned before; a health specific holding within this might be investigated. Extra security, authentication and authorisation could be built on top to provide the required secure and confidential ICT infrastructure.

Health-IE Net

This conceptual network would bring together all the required components including internetworking, services and presentation. The ICT framework (HEBE, 2004: 109) states that “in order to develop the required infrastructure, a set of technology components will be identified and amalgamated on agreed criteria, becoming the basis for delivering secure and confidential ICT.” In the past agency specific infrastructures of varying morphology and topology have appeared. Some have been standards based, some tightly tied to vendor or supplier cooperation. With long term planning, there is a need to avoid obsolescence. Therefore, in certain cases strategic relationships are required to maximise any investment benefit. There has always been a trend towards Microsoft solutions and platforms within healthcare. The current trend in larger corporations and public sector organisations has been towards open source solutions. All future options and possibilities will require significant analysis before a solution is chosen. This includes networking, service and computer centre components. There have never been so many options and niche suppliers, the solutions are out there to make Health-IE Net a possibility, with portal technology strategically placed to exploit the capabilities it would offer.

2.3.3 Common Approaches

J2EE and .NET are the two main competing technologies used in the development of large scale portals and the services they provide. The choice made in choosing between them will be critical in the ensuing evolution of the resulting software. In the end it should be noted that the tools used are only going to be as good as the developer yielding them. The choice comes down to the use of an open standard, J2EE, operational on any platform or the seeming reliability of a Microsoft regulated solution. The driving factor behind both technologies was to provide a mechanism through which raw data can be transferred. An easier approach was needed to convert data into a standard form for delivery. This resulted eventually in the Web Service

Strategy, which influenced by trends in the industry, exploited existing proven standards. These included HTTP delivery and HTML interfaces, and harnessed new powerful approaches, XML formatting and XSLT rendering. This produced a standard way to retrieve data without the use of proprietary hardware and software (Lurie and Belanger, 2002). These are two approaches used to provide these web services. How they differ technically is outside the scope of this dissertation but the two most significant distinctions are that J2EE offers a multi-platform solution while .NET offers multi-language support. The recommendation is to use whatever one works best.

J2EE

This solution can be seen as a single language (Java) approach which is operational on multiple platforms. It comes from Sun Microsystems (java.sun.com) and is not a product but a set of specifications. Each of these specifications dictates the operation of a particular function. Sun provides reference implementations of these to allow checking for compliance. Sun makes its money from the technology by licensing out these specifications to multiple independent software vendors. This allows them to implement this standard in their products and sell them to the market. It is therefore possible to purchase multiple implementations from different vendors without having to worry about compatibility issues. It is therefore possible to buy the J2EE solution which best meets the requirements specified. Many aspects of J2EE, like Java Servlets, precede the emergence of web services but many view these as the technologies that enabled the concept and were responsible for its emergence in the first place. A basic summary of how J2EE operates is as follows. Servlets provide the data processing capabilities in J2EE; they receive calls from the client and in turn make calls to Enterprise Java Beans (EJBs,) whose responsibility is to return the requested data back to the servlet, data source connectivity etc. The servlet then formulates the response and packages it in XML for return to the client application (Kao, 2001).

.NET

This solution offers a single platform approach (Microsoft) whose functionality is accessible through multiple programming languages. Originally Microsoft was very late into the Internet game, eventually using massive marketing strategies to outstrip Netscape with Internet Explorer in the web browser market. Around the same time a

big effort was put into the delivery of Active Server Page technology (ASP) to counter the Java Servlet approach. The result was a useful technology but it lacked sophistication because it was solely a scripting based approach. Microsoft's initial attitude was a 'wait and see' approach, launching often unsuccessful solution options to rival approaches already establishing market recognition. In many respects .NET could be seen as another reaction to the success of J2EE. J2EE introduced the concept of web services and Microsoft then built a technology devoted to the development and deployment of them. .NET holds an advantage where organisations want to leverage their existing expertise; it allows non-Java developers to create web-services in their native programming language with minimal training. The strategy aims to relegate Java to just another programming language. Sun would argue that it is not just a language but an entire platform. Microsoft promoted the concept of web services to developers excellently, even to the extent where they are inaccurately credited with the concept of web services. Microsoft, like J2EE, now offers a full development environment, ASP.NET, a move away from their previous scripting based environment. A new programming language called C# was developed for .NET, very similar to Java in many ways including the compilation and the use of runtime environments. Microsoft reacted to a trend and did it well, providing a very powerful and usable solution (Microsoft, 2005).

2.4 Components of a Portal Environment

2.4.1 Single Browser Interface – The Portal

The standardised web browser offers one of the most familiar views available in the world of computing. From laptops to PDAs to WAP enabled mobile phones, browsers in whatever guise are commonly available. Familiarity is a key strength when providing a system GUI. If users feel comfortable or familiar with the information views made available to them, regardless of the underlying functionality, acceptance is made more likely. This is one of the simpler but yet powerful features of this technology, the actual portal or access point to information. Schaek (2001) describes them as focal points for users to access information and applications from multiple sources, both local and remote, aggregators of information into a compact and easily consumable form.

The browser provides the point of user interaction for the system. It can be viewed as the portal client that accesses the portal through the use of protocols such as HTTP in browsers such as Internet Explorer¹, Navigator² or Firefox³. Mark-up languages are also required to present data in the required format, HTML for computer based web browsers and WML for WAP applications, are two common examples. The browser interface also handles the data structuring capabilities of XML and the useful facility of CSS. Other useful browser technologies include Java based approaches such as applets and the graphically appealing availability of Flash⁴ components. As a mature technology, the web browser interface is a key attribute in the implementation of powerful portal enabled systems, allowing access to data in an integrative and personal way (Germonprez and Collopy, 2004).

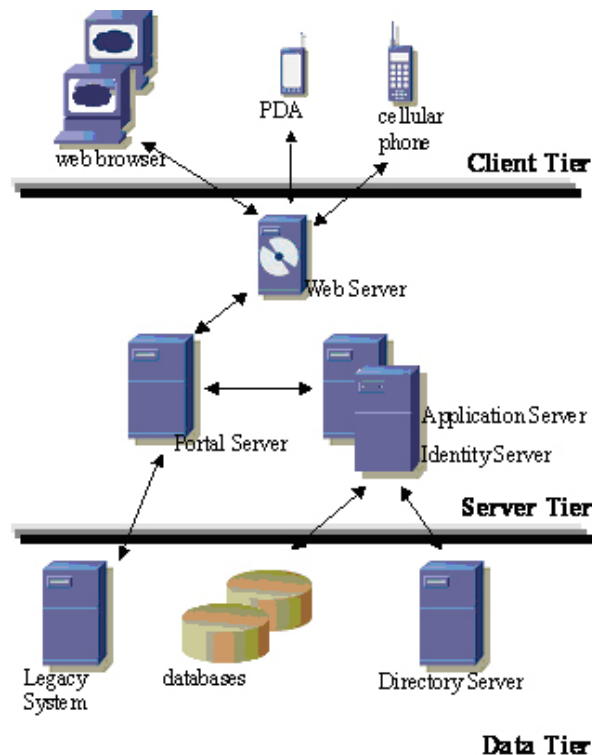


Figure 5. The Portal 3 -Tier Environment

¹ Internet Explorer – Microsoft web browser

² Navigator – Netscape web browser

³ Firefox – Mozilla web browser

⁴ Flash – Macromedia – Authoring environment for interactive web, digital and mobile content

2.4.2 Portlets

Healthcare is a good context in which to explain portlets. A patient's medical history can consist of information residing on multiple independent computer systems. Each of these systems could be from a different vendor, platform or a different era for that matter, so each would have differing user interface requirements. For each system, an entity called a portlet could be designed and implemented, an individual access point fitted specifically to that application but viewable in a web browser. In theory access to multiple systems could be made possible through the one browser at any one time, using specific portlets for each system. A variety of systems could potentially be combined into one portlet where suitably related. One browser window could provide access to multiple sources of healthcare data from anywhere.

The concept would be, where possible, to produce one generic portlet for each major category of healthcare system. This portal would encapsulate all the base functionality required and provide a mechanism through which interfacing with distributed systems was facilitated. An example might be of medical imaging PACS; they all have common functions and options, regardless of vendor. Using a common user interface, the portlet, and an agreed messaging and data structure, regardless of location or supplier of the PACS, its stored information could be made available through this one point of access. If this can be achieved for all major healthcare computer application families, then a virtual EHR could be accessed for every patient present on any system through the generic interfaces.

The customisable aspect at its most basic level is the number of these portlets made accessible to a group. If every major discipline has a single entry point to its own specialised data, not everybody will need access or even know such access exists. This in itself enables data control. Those who do need the information can open up the portal and within this open the required view(s) of area specific patient information. This ensures that each user's interface only consists of areas of specified interest (Pierce et al, 2002). One access point exists making information available to those who need it.

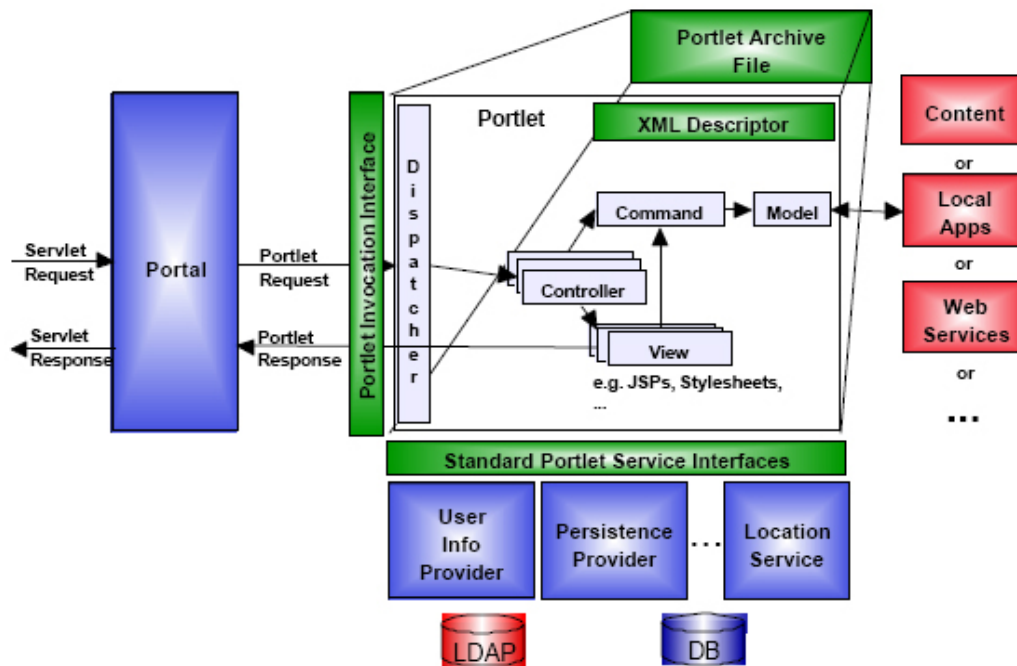


Figure 6. Portlet Invocation – User Request to Portal

2.4.3 Portal Engine / Server

Hosting the portal and its individual service portlets is the portal server, sometimes known as the portal engine. The portal server aims to provide the technology to simplify locating, connecting, presenting, aggregating, communicating (Kosińska and Słowikowski, 2004). For each application, content source or service chosen to be made available through a portal, the information will have to be processed and restructured by the portal server before being dispatched to the user at the browser interface. In very basic terms, the server will import and export data in a defined structure. This data can then be interpreted, processed or restructured by the either the specified portlet that receives it or by the service at its required destination. The portal server acts as a host to interpretive and integrative services.

The portal server on its own is of no use, it is part of a larger family of products used to make powerful distributed systems possible. The portal server itself relies on services provided by the following:

- Web Server
- Identity Server

- Directory Server
- Application Server
- Integration Server
- Messaging Server
- Calendar Server
- Connector Builder
- Content Management System

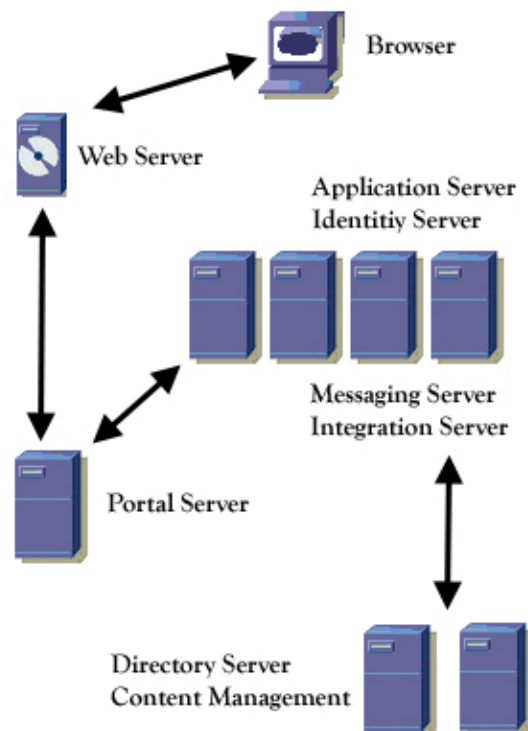


Figure 7. Portal Server Family

2.4.4 Web Services

Portals are central access points to what is often remote information and applications. They access the services offered using the Internet as the medium for communication. The word 'services' is used as these internet enabled systems fall into a category called Web Services. This phrase describes an XML based distributed computing approach which can be seen as a progression from older approaches such as CORBA and Java RMI. Harnessing internet based standards; Web Services provide a standard method of retrieving data without the use of proprietary software or hardware. These services are URL-addressable resources that can be accessed programmatically by a

client using standard protocols such as HTTP and XML (Webster, 2001). The set of defined standards for Web Services include WSDL⁵, UDDI⁶ and SOAP⁷. These provide mechanisms for service description, discovery and invocation. In conjunction with XML, formatted data can be easily transferred from source to requester. XML allows for the conversion and transformation of data without requiring complex parsing programs. A service made remotely available is consumed via the Internet, invoked via HTTP and returns the requested data in XML format.

Microsoft (2005) provides the description that web services allow applications share data and, more powerfully, invoke capabilities from other applications without regard to how those applications were built, what operating system or platform they run on, and what devices are used to access them.

A Sun whitepaper (Kao, 2001) defines a web service as an application that accepts requests from other systems across the Internet or an intranet, mediated by lightweight, vendor neutral communications technologies.

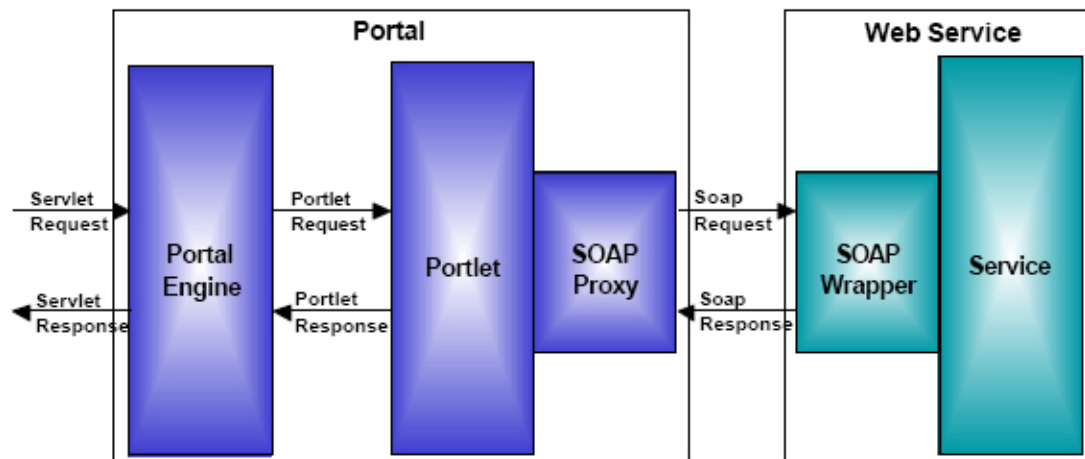


Figure 8. Web Service Invocation

⁵ WSDL – Web Services Definition Language

⁶ UDDI – Universal Description, Discovery and Integration

⁷ SOAP – Simple Object Access Protocol

2.4.5 Backbone Technologies

HTML

This stands for Hyper Text Markup Language, what might be known as common web pages. These are text files containing small markup tags which represent a standard set of features available to these pages. A browser can interpret these tags which describe how a page should be displayed. These files carry .htm and .html extensions and are easy manipulated with common text editors and more specialised web development suites (Raggett, Le Hors and Jacobs, 1999).

XML

This stands for eXtensible Markup Language and is a markup language much like HTML. HTML defines how data is to be displayed, XML describes data structure. Unlike HTML, XML tags are not predefined, they must be produced to specific user needs. XML uses a Document Type Definition (DTD) or the more modern XML Schema to describe the data the XML files will handle; they are designed to be self descriptive (Bray et al, 2004).

SOAP

This stands for Simple Object Access Protocol and is based on XML. It is a communication protocol used for enabling message passing between applications. It provides a format for sending messages and is designed to communicate via the Internet. It has many strengths in that it is platform and language independent, simple to use and highly extensible (Gudgin et al, 2003).

WSDL

This stands for Web Services Description Language. These files are written in and expressed as XML documents. They are used to describe web services and also have a role in finding the location of web services (Christensen et al, 2000).

UDDI

This stands for Universal Description, Discovery and Integration. It is a platform independent framework used for describing, discovering and integrating organisations and their services using the Internet. It is a directory for storing information about web services and web service interfaces described by WSDL. UDDI communicates using the SOAP protocol and other internet standards such as XML, HTTP and DNS (Ariba, 2000).

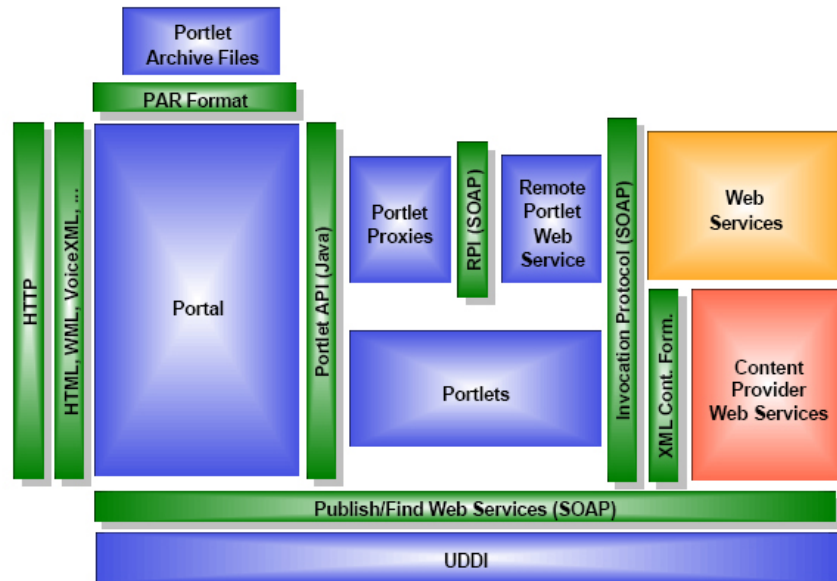


Figure 9. Portal Server Architecture

2.4.6 Grids

The term Grid denotes a proposed integrated distributed computing infrastructure for advanced science and engineering. The health industry adopted the concept by proposing the idea of the HealthGrid (<http://www.healthgrid.org>), a specifically dedicated extension to the concept. It is based on coordinated resource sharing and problem solving in dynamic multi-institutional virtual organisations (Foster, Kesselman and Tuecke, 2001). Grids support this idea of a virtual organisation through a mix of shared data and computer resources, heterogeneous multi-tiered architecture and a wide range of technologies. Grids offer a set of services based on Web Services fundamentals but they adhere to a specified set of conventions. The services are designed to enable cross computation of mechanisms such as authentication, system monitoring, information and resource delivery, status reports, coordination and more. This potentially provides an infrastructure with extensive portal deployment capabilities, perhaps making the EHR possible through the HealthGrid approach. Another opinion describes the Healthgrid as an environment where data of medical interest can be stored and made available to the different actors of healthcare, physicians, healthcare centres and administrations, and of course citizens (Breton, Solomonides and McClatchey, 2004).

3 Portals for Healthcare

3.1 Health Information - A National Strategy - Portals

Health Information – A National Strategy (DHC, 2004) includes a section on portals and mentions in particular how modern internet-based technology provides a practical solution for the delivery and use of health information for those who require it, when they require it and in a format suitable to their needs. It also recommends the development of an internet based health information portal to provide a range of information services for use by the public, professionals, researchers and policy makers. This supports in general the work carried out in this dissertation, the work being more specifically focussed on the technology and its application to the EHR.

The strategy denotes the way ahead as a single point of internet access for both health information and e-Health services. The EHR would conceptually, in this case, fall into the category of an e-Health service, presumably the most complex proposed. The capacity, performance and facilities now exist in ICT to make such a portal available and the provision of such a portal should now be viewed as an integral part of other ICT initiatives within healthcare. In the national sense, the portal will be part of the development of e-Health services in line with the e-Government and REACH⁸ initiatives and the progressive development of national e-Broker services.

The government, in particular the HSE, Department of Health and Children and HIQA recognise the capabilities a portal approach offers and will together look to utilise the technology as a solution to the ever increasing information needs in the sector. The national strategy expresses its expectations that the use of portals will enable the delivery of many useful and powerful services. According to the strategy these include:

- The provision of accurate and timely access to information about health services, healthcare issues and concerns.
- A portal is to provide the point of access for the public to e-Health services, which may include care eligibility checking online, application processing,

⁸ REACH (www.reach.ie) – Government agency established to tackle the integration of public services and the establishment of an electronic government function.

payment of health service grants and allowances, appointment bookings, electronic reminder facilities, email service queries, etc. A national EHR may be categorised as one of these e-Health services.

- The portal should also facilitate and promote the availability of information and services to those without the access or experience with internet applications, alternatives should be catered for and not ignored.
- The portal should support evidence based practice and policy making functions. Access to the National e-Health library should be made available.
- The portal should also be searchable and relevant directories appropriately indexed for use. The active involvement of traditional library services should therefore be promoted.
- Researchers, analysts, planners, etc. should be able to use the portal to access statistical data and databases for their work. This requires intelligent structuring of data, along with comprehensive and interactive metadata. This would potentially be along with the required analysis tools. The meeting of this requirement would promote the idea of a National Health Atlas.
- The design should be capable of linking with other national and international health information systems including government departments, CSO, relevant agencies and academic and research institutes. A public health portal for the EU is currently under construction which should see alignment by the national approach.
- Finally, the strategy also states the portal should also provide for the rapid notification of essential and urgent information (i.e. epidemics, abnormal trends, drug withdrawal) and a related contingency plan should be put in place for traditional communication techniques.

3.2 The EHR

3.2.1 Introducing the EHR

Every section in this dissertation is describing one possible approach to building this significant entity, the electronic healthcare record. It is the goal of so many working in health informatics, to produce an all encompassing system to effectively capture and access all significant healthcare data for all patients in the health system. This is a massive undertaking and something that will take huge effort, cooperation,

management and commitment. There is good reason to seek to make this a reality, as will be evident in the following section.

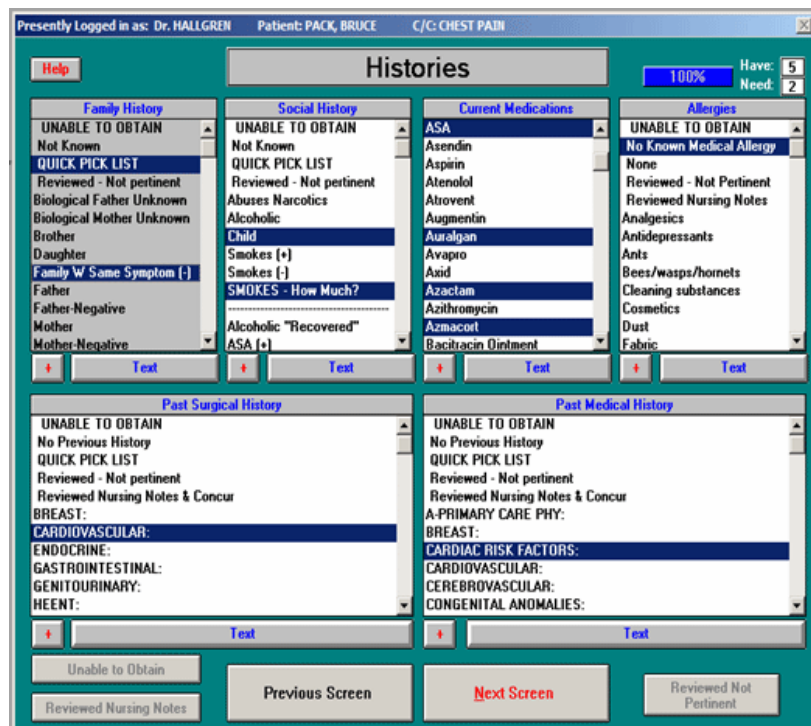


Figure 10. Sample EHR Screenshot

3.2.2 Benefits of the EHR

The EHR will allow for more effective management of clinical care, which is constantly increasing in complexity. It will enable the concept of shared care, connecting the multiple locations required for complete care delivery (Rigby et al, 1998). It will increase the availability of critical information and further contribute to the delivery of evidence based care (Rodrigues, 2000a). It may in time reduce costs but starting now it will reduce errors and inequalities resulting in the main goal, improved patient care. Data entry templates and validation capabilities will make work easier and mistakes harder to make and easier to track. There will be reductions in health data duplication and delays in care delivery, both continuing and the commencement of care, through better communication capabilities, e.g. integrated patient scheduling system and test ordering (Gorden and DuMoulon, 2004). The EHR will also look to empower the patients themselves and get them more involved in the upkeep of their own health. Another powerful deliverable will be its reporting and

analysis capabilities with its access to so much information; population health, epidemiology and research are some good examples (Ebidia et al, 1999). Management will benefit from summaries, tables, graphs, auditing mechanisms and improved resource management. The EHR's main advantage is the accessibility and communications capabilities it will provide for healthcare data. Once the information is available, various customisable and configurable views are made possible, enabling data delivery in the required format.

Another benefit of the EHR would be the exploitation of good clinical data with the outcome of improved patient care across the board. This can be realised with the use of decision support and alerting systems (Kuperman, Sittig and Shabot, 1999). Systems could be implemented and controlled on a national basis for areas like drug prescriptions, interactions and adverse effects. Alert algorithms and care pathways for laboratory results and contra-indications could also be controlled electronically. The use of mobile devices for alert notification and the constantly improving area of electronic image processing, delivery and interpretation are other areas the EHR can seek to provide. The EHR will seek to deliver and satisfy all the data requirements of the healthcare professional. Accountability is another benefit offered by a single EHR, a very important consideration when dealing with data of such a sensitive and confidential nature (Mandl, Szolovits and Kohane, 2001). There may also be many beneficial outcomes to be discovered post-implementation of the EHR. Feedback from the use of such a system would support evidence based medicine and provide information on areas such as the revision of guidelines and the progress tracking of new treatments. Only time will reveal its true potential.

3.2.3 The Requirement for the EHR

Modern healthcare practices have brought about the need for a more complex and comprehensive solution to healthcare data capture, storage and communication. Improvements in ICT, system architectures and development techniques have seen the concept of the EHR become a realistic goal. The need for such a solution is due to a number of key factors (Kalra, 2004):

- The increasing complexity of healthcare provision
- Requirement to deliver evidence based care
- Shift of care from specialist centres to community

- Increasingly distributed and mobile workforce
- Huge growth of medical knowledge
- Growth of consumerism and patient participation in healthcare
- Critical reliance upon comprehensive patient records
- Increasing concerns about the confidentiality of patient records

3.2.4 Meeting the Information Needs of the Healthcare Professional

The EHR will look to meet the information needs for the day-to-day work of a healthcare professional. These can be summarised as the abilities to record, analyse and share healthcare information.

The recording of data is becoming a far more intensive task than previously seen. To capture and store the volumes of data being produced by all facets of healthcare delivery presents a significant challenge (Shortliffe, 1999). Information in healthcare is becoming more important; patients are receiving more healthcare than ever before and the information being gathered is becoming more complex with new investigations, treatments and examinations. There is also greater use of data in multiple formats, text, sound, images, video, etc. Healthcare professionals are becoming increasingly dependent on the use of this data to carry out their work. Legal and ethical constraints also impose requirements on the need to record many aspects of care delivery (Rodrigues, 2000b). The EHR will look to address these needs.

Analysis of healthcare data is a key requirement in efficient and effective care delivery. It allows for the recognition and interpretation of trends and patterns in a patient's medical history. Analysis is enabled through the use of clinical guidelines and decision support systems in support of evidence based care. Clinical audit needs and the evaluation of clinical outcomes have to be catered for across all specialties. Information gathered can also be used by management functions to better assess and resource the needs of specific functions in healthcare. Analysis capabilities also support key healthcare disciplines such as epidemiology, research and teaching (Ledbetter and Morgan, 2001). The development of a fully functional EHR will embrace the needs of data analysis on a large scale.

The ability to share healthcare data is a major issue that the implementation of the EHR will seek to tackle. The need for interoperability between systems and a mechanism through which to exchange critical information are goals of the EHR (Bird, Goodchild and Beale, 2000). The EHR will endeavour to enable the sharing of healthcare data between clinical teams, healthcare professionals, multiple disciplines and everybody involved in the care delivery process, including patients and their families.

For an EHR to be effective and carry out the required functions, there are a number of criteria it must adhere to (Kalra, 2004):

- Comprehensive
- Faithful
- Life-long
- Medico-legally rigorous
- Educating – those involved in healthcare delivery and the patient
- Supporting diverse cultures and professions
- Capable of evolution
- Empowering and respecting
- Appropriately ubiquitous
- Capable of interoperability

3.2.5 EHR Standards

There is a need for the standardisation of many elements to make the EHR a possibility. These include network infrastructure, messaging standards, information security and quality standards. Vendor specific products offer one solution but it is impossible for one vendor to supply a complete solution for a domain as large as healthcare. Standards have a significant role to fulfil in interoperability and deployment issues within the EHR but they are only part of the process. If the standards issue could be resolved, a significant barrier to the realisation of the EHR would be removed. There are many difficulties standing in the way of this though (Kalra, 2004):

- The comprehensive models required are difficult to agree upon and maintain

- Designers need to respond to the specialist needs of users but the systems must remain interoperable
- It is difficult to standardise the health information requirements of a single health domain, and take into account all other disciplines
- There are rigorous ethical and legal requirements to be considered

The following are a number of evolving EHR standardisation efforts in ongoing development today:

HL7

"To provide standards for the exchange, management and integration of data that support clinical patient care and the management, delivery and evaluation of healthcare services. Specifically, to create flexible, cost effective approaches, standards, guidelines, methodologies, and related services for interoperability between healthcare information systems."

HL7 v3 Reference Information Model (RIM) is a high level model designed to govern the definition of future messages involving healthcare data. It spans the requirements for purchaser and provider messages, hospital sub-system communications, clinical observations, workflow management and knowledge representation. This is a significant undertaking for one model. The RIM offers a large pictorial representation of clinical data with defined data structures that allow for the shared unambiguous meaning of content. The RIM is concerned with templates, vocabulary and the lifecycle of events a message may pass through. It supplies a shared model from which all domains can create their messages. The HL7 Clinical Document Architecture (CDA) defines an XML architecture for the exchange of clinical documents. It operates using defined DTDs and semantics from HL7 RIM and HL7 registered coded vocabularies. (<http://www.hl7.org>)

CEN TC251

"Standardization in the field of Health Information and Communications Technology (ICT) to achieve compatibility and interoperability between independent systems and to enable modularity. This includes requirements on health information structure to support clinical and administrative procedures, technical methods to support interoperable systems as well as requirements regarding safety, security and quality."

The development of this standard is divided into four working groups, each with a specific focus. Working Group 1 Information Models is concerned with the development of European standards to facilitate communication between independent information systems. Their work also centres on standards for the EHR and on messages for the communication of healthcare information. Working Group 2 Terminology and Knowledge Representation focuses on the semantic organisation of information and knowledge for practical use in the health information domain. Work is carried out on the provision of information and criteria to support harmonisation of all functions and entities involved. Working Group 3 Security, Safety and Quality are developing a statutory framework to ensure information systems in healthcare have appropriate security, safety and quality levels in place. To fully exploit the provision of such a framework, their work is carried out in parallel with the other working groups. Working Group 4 Technology for Interoperability is concerned with the development and promotion of standards that enable the interoperability of devices and information systems in health information. This includes attention to intercommunication, integration and communication standards to facilitate EHR provision. (<http://www.centc251.org>)

OpenEHR

The OpenEHR is an independent non-profit community set up to facilitate the creation and sharing of health records by consumers and clinicians, via open-source, standards based implementations. They are involved in the publishing of EHR specifications using multi model approaches and actively contribute to the HL7 and CEN standards. OpenEHR are also actively involved in user and industry liaison and education. Their goals are as follows:

- promote and publish the formal specification of requirements for representing and communicating electronic health record information, based on implementation experience, and evolving over time as health care and medical knowledge develop
- promote and publish EHR information architectures, models and data dictionaries, tested in implementations, which meet these requirements
- manage the sequential validation of the EHR architectures through comprehensive implementation and clinical evaluation

- maintain open source "reference" implementations, available under licence, to enhance the pool of available tools to support clinical systems
- collaborate with other groups working towards high quality, requirements-based and interoperable health information systems, in related fields of health informatics (<http://www.openehr.org>)

3.3 Specific Issues in the Healthcare Domain

Specific to the healthcare domain are a number of issues that offer significant challenges to the implementation of a single co-operative national system in pursuit of the EHR. Using portal technology is an approach which also brings its own issues. Regardless of the final chosen delivery method, some issues will remain common to all. The diversity of systems and sources present in the health domain is significant, to account for everybody's requirements would seem impossible and to deliver a single framework for data access and integration is perhaps unfathomable. It does remain a long term goal though. With so many sources of information, there is a pronounced lack of awareness of its scope, depth of availability and methods to access it. Information remains only partially analysed and exploited and external interpretation can prove difficult (DHC, 2004). Proprietary systems, site projects and 'Frankenstein' type systems also means standards in the past have not been a major issue, just as long as systems worked. Therefore information is not available or distributed in a relevant format. It can be of poor quality and unclear to those not familiar with its structure, if these people are even still around today.

History and culture play huge roles in medicine and healthcare. This is often to the detriment of ICT, it may be one of the underlying factors why the industry, in comparison to others such as banking and insurance, has been slow on the uptake of advanced information technologies (Jung, Grimson and Grimson, 1999). The paper and the pen, the chart and the written prescription are all mainstays of medical society but they have been proven to be flawed and at times dangerous. The solutions are there but they are often not being embraced. Things are of course improving with e-Learning becoming more of a part of the education process but very often the people in power are of an older generation, alien to putting their trust in an electronic device.

Different health agencies have different roles and priorities and many show hesitancy towards the sharing of health data. Cooperation is a key requirement in making any large scale integrated system function efficiently. The DHC (2004) also recognise that there is a general absence of agreed mechanisms and guidelines for this sharing to take place. The strong influence of the privacy and confidentiality issues along with ethical-legal requirements are also barriers to success that will need extensive management. There is no effective mechanism for national integration and the use of all available sources of information. There are many challenges in meeting interoperability needs. Great work is being done in the area of standards and this is a crucial starting point but much more will have to follow. This will include supplying the required IT capacity to facilitate the delivery of this information and the other e-Health services. This area remains underdeveloped for both the healthcare professionals and the patients. The security and reliability of information access and the conformance to security policies are pressing issues in healthcare, while the clinical acceptance of the concept of shared records and pathway structured healthcare will all have to be addressed. Patients will also have issues with respect to the sharing of their information across multiple sites and there is also the impact that giving them access to their own health record might have (Carter, 1998).

3.4 Management Requirements

An informed decision is the conclusion reached based on the best possible information made available at a given time. The more accurate and timely the information received the more decisive and prompt a response can be. Therefore, increased information availability has a positive effect on healthcare (Win and Cooper, 2004). Effective healthcare is about making the right choice for the patient, be this at a management or clinical level. A manager's job is to plan, organise, lead and control (Drucker, 1974). Each of these tasks are labour and information intensive, ICT can only do so much to make any work easier but it does have the capabilities of getting the information required to a suitable destination at the appropriate time. With the information at hand a manager can potentially exploit their management skills. In healthcare this should translate into improved patient care. Portals can complement the skills of a manager in a number of key areas. Technical knowledge can improve by providing the information resources necessary to accomplish or understand the tasks relevant to the organisation. Diagnostic skills can benefit with increased

availability of information and the tools to carry out analysis, enhancing a manager's ability to formulate the most appropriate response to a situation. Communication skills are an area that benefits most, using portal capabilities to convey ideas and information to others and to receive the same back in an interactive fashion. Improved communication often helps with interpersonal skills also. Decision making skills also thrive with increased information and data availability, increasing a manager's ability to recognise an issue and select an appropriate course of action. Time management is another obvious function that benefits from advances in ICT. The ability to schedule, prioritise, work efficiently and delegate appropriately is aided significantly through specialised software applications. The conceptual skills of a manager or their ability to see the 'big picture' can be aided with an organisational wide information system. Software in its nature is abstract and very often a manager has to think in this way to understand their environment. Having the appropriate information on hand can only help with this task (Griffin, 1997).

Information is not only used to support the decisions of the manager but of the healthcare worker also. Entire systems in healthcare are devoted to help make the correct diagnoses, avoid mistakes and complications, drug interactions, validate results, trigger alerts etc. These systems have many different approaches and such phrases associated with them include expert systems, rule and case based systems, artificial intelligence, knowledge based systems and decision support systems. In healthcare it is often a shared decision made by many professionals. Portals aim to bring the appropriate information to the user to help make the best possible decision. Therefore, Decision Support Systems are an important feature in the context of portals for healthcare. The topic of Decision Support Systems will be discussed in greater detail in a following section.

McKemmish et al (2002) noted how access to information is a fundamental component of shared decision making, and improved medical, social and health outcomes. They saw the challenge as providing information that is relevant, timely, accurate, and as far as possible meets the dynamic information needs of the user. Health information also needs to be dependable, reliable and of high quality and there are many different user groups to cater for; patients, family, friends and carers. With such a volume of information available and an extensive list of requirements relating

to both the data involved and the users, appropriate mechanisms have to be implemented in a portal to make it easy to get the information being looking for. There is a need for intelligence to be built into portal design. This could possibly be viewed as a new class of expert system. There is a need for adaptation and personalisation for individual users and groups. A detailed system of information classification, indexing and prioritisation is also needed. There is also a requirement for intelligent information retrieval through the use of metadata and the development of a knowledge repository and an explanation facility for the portal. Many of these areas are outside the scope of this dissertation but some will be discussed further on.

3.5 Guidelines, Protocols & Care Pathways

A definition by Field and Lohr (1992:27) states that clinical practice guidelines are:

“Systematically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances”.

They are carefully chosen pre-approved steps to be taken in a given situation and can offer significant improvements to the process of care delivery when introduced. For guidelines to be effective, it is important to include the users in their development. Implementation must also be patient specific when called upon at the time of consultation and the information dissemination they offer must be specific and precise and the time of intervention (Grimshaw and Russell, 1993). Guidelines specify what is required; they are the detailed framework of what is required in a specified area of clinical practice. To put their theory into practice, they are implemented through protocols and integrated care pathways, which will now be investigated.

Protocols are detailed descriptions of the steps taken in delivering care or treatment to a patient. They are designed at local level to implement national standards and guidelines. Protocols seek to utilise the best evidence available to determine the care that is to be provided. To achieve this, healthcare delivery is multi-disciplinary and cross functional. Protocols are designed to match this requirement and to reflect local services and staffing arrangements. They look to integrate fully the care delivery provided by the different groups and teams involved. Protocols are also required to be specific in terms of personnel involved in the treatment, specified steps involved and the location of delivery. To aid in their implementation, protocols are usually

incorporated into Decision Support Systems. This helps the practitioner to make more informed decisions on care for specific clinical circumstances (UK DoH, 2002).

Integrated Care Pathways (ICP) and Protocols are closely related. An ICP describes a process within healthcare which maps out a pre-defined set of activities, and records the care delivered and any variations that exist between planned care and the actual care delivered (OBS ICRS, 2003). A Protocol can be viewed as an ICP if it meets a certain set of criteria; it must be local, agreed and multidisciplinary, form part of the care record and have the ability to capture variances away from the approved set of steps. ICPs already exist widely throughout the healthcare system but mainly as a paper based approach; checklists with embedded rules and exception recording. These are locally developed systems that focus on one task, in one place, for one time period. There is a lack of integration and cooperation with the paper based approach, something the interoperable portal approach would have the capabilities to rectify.

There are many reasons as to why the pathway approach is attractive. For health functions in governments and managers, it offers a patient centred approach. It is a multi-disciplinary and flexible approach and being evidence-based, it provides a means to put guidelines into use. Care Pathways fit neatly into the vision of integrated health management and care delivery and are another tool which can be used to enforce quality management and risk reduction. To the healthcare professional, pathways support shared-care and joined-up working between different disciplines and departments. They offer decision support techniques and important mechanisms such as reminders and potential alert capabilities. They support the concept of the shared patient record and also support clinical audit through their recording of variances in care delivery. Pathways are key information resources as they map the processes of care delivery, and data usage at each stage is well defined (Campbell et al, 1998).

3.6 Decision Support Systems

Decision support systems are designed to support the decision making process, not to replace the people who make them. They encapsulate knowledge extracted from human experts but not all knowledge is easily adapted for use in a software application (Bobrow et al, 1986). Hence their role exists as a support mechanism.

There are many different approaches employed in the implementation of these systems. Rule-based, case-based and model-based are the main classification which will be discussed further on. Decision support systems attempt to emulate the experts' methodology and performance through encoding both their theoretical knowledge and practical or heuristic knowledge. This encoded information is then made available for interpretation by such a system. In general the roles of these systems are in information management, attention focus through the use of alarms and alerts, and a consultation resource for specific domains (Shortliffe, 1989).

There are measurable benefits for both patients and healthcare staff in using decision support systems. They promote the efficient use of information resources and can improve the quality and efficiency of work carried out in conjunction with their use. They are designed to be highly configurable and aid in preventing the problem of data overload when decision making. There are two main components in the structure of these systems; the Knowledge Base and the Inference Engine. The knowledge base consists of data storage such as a database, rule lists if required and comments and interpretations relating to the data. The inference engine is made up of the user interface and any rule handling procedures. Information from the knowledge base is processed in this component to produce a response to user requests. Other components of these systems include a knowledge base editor and an inference translator to provide the information in an easily understandable format (Nikravesh and Azvine, 2002).

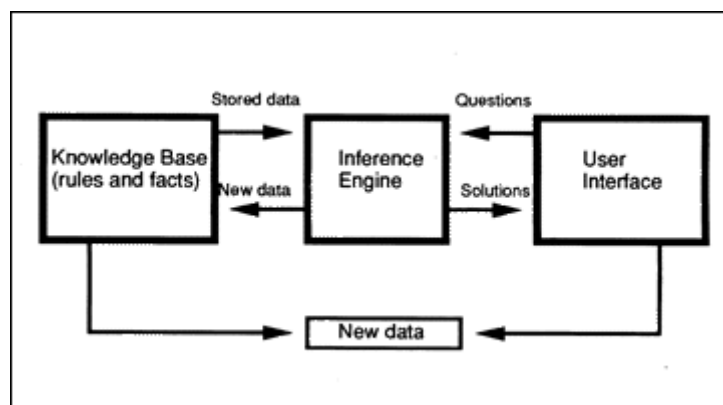


Figure 11. Basic Expert System Architecture

There are a number of general classifications used for decision support and knowledge based systems (Hederman, 1999), as follows.

Rule-Based Systems encode the expert knowledge in a set of well defined rules. The concepts of 'event – condition – action' or 'if – then – else' apply to these systems. An event occurs in a system or a piece of information is received, this is then matched against a set of rules or conditions, if a condition is satisfied then a pre-defined action is carried out. When multiple conditions are met and more than one possible action could be chosen, this approach uses confidence measures to deal with the uncertainty. Different values are attached to different criteria, providing a level of grading for their selection. If all criteria are met, the one with the highest confidence rating will be chosen.

Case-Based Systems use the knowledge captured in instances of solutions provided for previous similar cases. The new case or problem is matched as closely as possible to one that has been encountered previously. The matching result is then used as a starting point to finding the new solution. This approach requires the features that best characterise a case to be chosen. It is a similarity measure used to find a similar case that is either most applicable, easiest to adapt or possesses a high confidence rating for re-use.

Model-Based Systems use reasoning based on a model of a device or system. They provide a representation or simulation of a real-world situation and a set of known interactions. They look to predict the performance of a system and are constantly optimised by comparing against actual performance.

4 Content Management

4.1 Introduction

The challenge presented is to deliver appropriate content or data to those who require it at the desired time. There is a need to differentiate between the different classes of users and present information appropriately, based on assessed requirements of healthcare professionals. Content needs to be highly adaptive, new interfaces and devices are emerging constantly, the diversity of users is increasing and machines are acting more and more on the user's behalf (Meliksetian et al, 2001). Content therefore needs to be both managed and highly manageable. Content management encapsulates the complete process required to capture data, process it accordingly, store it securely, deliver it in a timely manner and terminate it when appropriate. While carrying out these tasks, content management systems aim to deliver these services with many gains in mind. These include the increased capture and sharing of information, reduced delivery costs, increased productivity, improved service responsiveness, improved quality of decision making, improved regulatory compliance and an enhanced ability to match the competition. (Gábor and Kő, 2002)

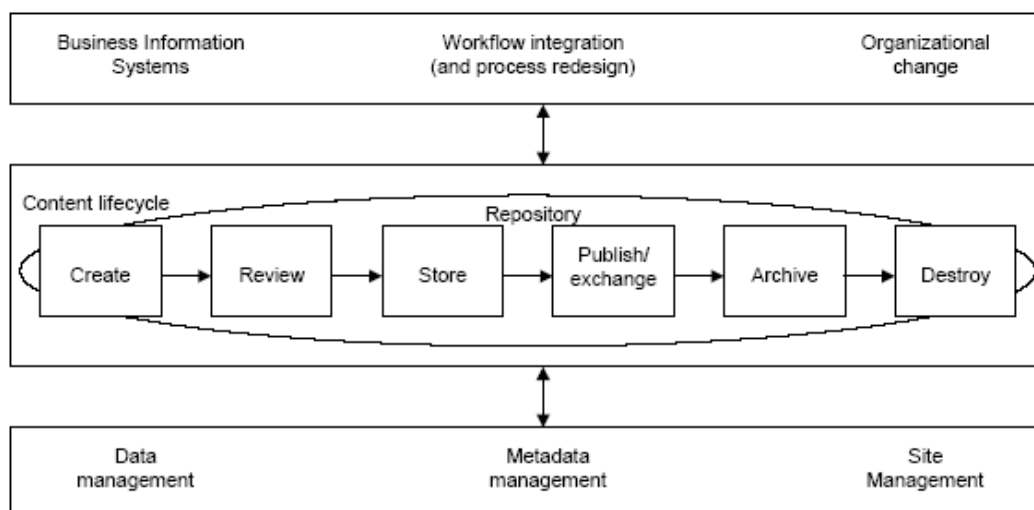


Figure 12. Content Management Framework

Information exists in many forms, structured, semi-structured and completely unstructured. The content management approach used must be equipped to deal with all potential format problems, to a reasonable degree. This introduces the concept of

embedded data or Metadata which can be used to manage information in its various states. Metadata is used to describe the data itself, it helps categorise information under desired headings; source, author, function, format, etc. This enables further content production, intelligent storage, publication and potentially increased utilisation. Päivärinta and Munkvold (2005) state that metadata should provide information about a content element, its configuration, production, ownership and potential utilisation context to facilitate its retrieval or re-use for organisational purposes. Content management also has a role to play in managing the convergence between applications and devices. A large proportion of this function will be handled by the document and file management systems and the databases involved. Structure and interchange standards are central to the success of content management and the related system integration. In the portal and health domains, strong consideration is needed in the areas of web content integration and the requirement for data access using multiple electronic devices.

Content management has many objectives and subsequent significant impacts. It aims to increase collaboration between all parties involved while adding value to their products and services. Reliability and quality of information through well managed data handling processes are significant considerations along with the efficiency, effectiveness and flexibility offered by powerful content management techniques. The overall objective is to put meaningful knowledge to work, to exploit an organisations experience and at the same time cut costs. The conformance to the related regulations and standards is beneficial to an organisation and can put in place the platform required and the capabilities to develop and maintain the organisation's content requirements with future developments in mind (Päivärinta and Munkvold, 2005).

4.2 Key Concepts in Content Management

4.2.1 Customisation & Personalisation

Content management enables the modification of information or the level of detail that is to be delivered to the user. Through a system of designated user rules and chosen preferences, it is possible to provide a customisable approach to data access and viewing. Information can be viewed and tailored based on specific needs, choice or history of access. It is possible for a Content Management System (CMS) to learn

as it works, improving its personalisation capabilities with each user visit. This flexibility also offers the user a mechanism through which to modify their view of information, within the constraints of their roles and access levels. Abidi and Chong (2003) note how portals need to evolve towards being adaptive in nature, to allow for dynamically tailored e-services to meet the diverse needs of its users.

4.2.2 Generation

Generation refers to the ability to compose new data and edit existing data with the view of making it available for use by another function or query within a system. This reuse of data is central to content management, as it allows content elements to exist only once but be usable across many applications and functions in an organisation. This refers to both static and dynamic content and enhances the increased sharing of data both internally and externally.

4.2.3 Assimilation

This concept is similar to ‘generation’ as it is making use of existing content to create new usable data entities. This is the merging of existing data, both static and dynamic, from multiple sources. Some content elements might appear useless when viewed on their own. When these are combined with other complimentary data, they can result in new useful entities in their own right. This is especially useful in analysis and reporting or in system integration.

4.2.4 Presentation

Presentation in content management refers to the mechanism that allows the delivery of the same information to multiple devices in the different display formats required. This is the final product of content management, the part an end-user is exposed to. Data can exist in many file types and formats; text, images, sound, movies, etc. It must be possible to convert and transform these data elements into the format required for effective content delivery. A device independent approach is a key requirement in many environments. This is very true of healthcare with information access and delivery breaking away from the boundaries of location.

4.3 Knowledge Management & Content Management

Knowledge management and content management are closely related management issues. While content management concentrates on the mechanics of information

delivery, knowledge management is a broader concept, dealing with the organisation as a whole and what it can do to make more meaningful data available to those who require it. Knowledge management techniques seek to optimise collaboration within and between organisations, increasing knowledge sharing and analysis. Knowledge management in this way also aims to improve organisational responsiveness through access to more concise and tailored information. It looks to enable the reuse of greater volumes of knowledge, to foster innovative approaches in the pursuit of this goal and ultimately improve the accessibility and dissemination of knowledge on a whole. A key requirement in all this is filled through content management. Content management provides such integral services as customisation, filtering, categorisation, search capabilities, archiving and many more. Knowledge management systems employ these mechanisms to support and enhance the tasks of knowledge generation, codification and utilisation to combine various knowledge technologies and sources, such as repositories and directories (Alavi and Leidner, 2001).

Knowledge management and content management are both concerned with the collecting, managing, systematising, maintaining and usage of large amounts of information. They both embrace the same core function, the delivery of information to the right person in the correct format. Meeting this requirement is increasingly complex and many are realising that knowledge is becoming more valuable to their organisation. Content, knowledge and technology complement each other greatly; content and knowledge have a high correlation which needs to be well managed, often with the aid of technology. The sources of information and knowledge are normally independent; this is visible within the healthcare domain where the systems store the information and the employees, such as the doctors, apply their personal knowledge to this information to formulate a decision. Content management can satisfy many goals in the provision of its common basic function, to provide the opportunity for these knowledge workers to process what is often badly structured and distributed information. Content management links information services to the consumers in a domain specific or personalised way. Therefore, the increasing importance of knowledge usage and its exploitation means that content management is not independent of knowledge management's influence (Gábor and Kő, 2002).

4.4 Metadata

Metadata is information associated with a piece of data, it is descriptive information that refers to meaning, content and purpose of data and is used for the purpose of data organisation and classification (Siegel and Madnick, 1991). Content management is reliant on metadata for its success and effectiveness. It is central to many content management needs such as content validation, transformation, search and generation (Curtis, Foster and Stentiford, 1999). Metadata has needs of its own; it requires standardisation and specification, transportation, storage, security and its own set of management tasks. The need for metadata and metadata's needs can impact on organisational processes, connectivity and collaboration but concurrently offers many advantages to an organisation. It promotes content reuse and provides flexibility through content re-purposing. The use of metadata also encourages content consistency across connected systems. Data quality is also easier to ensure through improved management and constant monitoring of the information. Metadata's strength lies in its ability to enable the personalisation of data (Hicks and Tochtermann, 2001). This allows consumers to access more relevant data and more rapidly, through better codification and categorisation provided by the associated metadata.

Metadata commonly takes the form of a set of attribute-value pairs (Butler, 2002). Content can be viewed as a combination of data and metadata, where metadata exists. It is structured in nature to allow for consistent access and decoding capabilities, in which XML plays a significant role. This will be discussed in a following section. Metadata itself requires significant management and cross functional agreement. The meaning of attribute terms must be standardised to allow for intelligent processing by all connected systems. This allows any content to be interpreted correctly in any given context. Data and metadata, while interdependent, must be possible to physically separate to allow for flexibility, storage constraints, and processing restrictions in certain contexts. Metadata allows for the more effective planning and evaluation of existing information, it can provide a history of use and even be self learning to be more context aware, self validating and increasingly adaptive by constantly updating and adding to its own description. This enables more meaningful data allowing for more amenable and intelligent information retrieval (Lorence and Spink, 2004).

Metadata is used to manage content from creation to deletion so that various applications and consumers have a standardised method in which to understand the information they are accessing. This allows the same content to be used for multiple services and also allows for consistent identification, retrieval, persistence, archiving, version control and modification tracking and accountability (Duff and McKemmish, 2000). Metadata is also used by many different classes of users throughout its existence. These include content providers, application builders, content consumers and even network service providers, who can use the information provided to better design and optimise their service offerings. Metadata provides a flexible approach to enable small and large service provision and it is also scalable in nature to allow for future service expansion. It can be viewed as a key enabler that is central to allowing many different distributed management components work together seamlessly (Curtis, Foster and Stentiford, 1999).

4.5 Ontologies

This is a big topic by itself, most of which is outside the scope of this dissertation. What follows is a brief introduction of the concept. Ontology is the term used to describe a specific set of metadata. It is sometimes referred to as a meta-model and is used to express structured meaning in a specific domain. Ontologies offer a type of controlled vocabulary to enable unambiguous data definitions and a formal logic based language for specifying the meaning of a set of terms. Its goals are to help structure, classify, represent and model the concept and relationships between subject matter in a given domain, e.g. healthcare data. This allows an agreement to be reached to commit to using the same terms in a standardised way. Ontologies in partnership with content management give definite meaning and organisation to the further use and interpretation of data collections (Jasper and Uschold, 1999).

4.6 Challenges in Content Management

There are many challenges to be addressed in producing and maintaining an effective content management system. With so many heterogeneous sources of data available today, effective content creation and capture can prove difficult. The variety of formats, sources, locations, underlying systems, management functions, technologies and access needs all have to be considered (Somani, Choy and Kleewein, 2002). The content itself needs a lot of attention. Editing needs to be controlled, constant review

processes need to be put in place and approval needs to be sought in many cases for content change. All parties with a vested interest in this content need to be constantly informed of any decisions or actions taken. Content distribution practices, permissions, publications and updates are all content management processes that have to be considered and effectively managed.

The storage of content also presents a sizeable challenge. It needs to be tightly controlled with carefully selected data file systems and formats. The considerable challenge of version control has to be addressed along with the management of relationships that exist between certain categories and sections of content (Päivärinta and Munkvold, 2005). Along with the storage of content, there exists the need to maintain information about the functional and semantic role of each content fragment. This relates to the storage and management of metadata as discussed in a previous section. The long-term requirements for content are also an issue. The retention of data and its evolution, its reliable preservation and any format transformation needs over its lifespan are live issues being addressed by the IT community (Reimer, 2002). These relate closely to the long term archival needs and ongoing necessary deletion of content.

In any content management system, the functions being carried out should be transparent to the user. They should be background tasks whose goal is to satisfy the user's needs, they do not even need to know they are being carried out. Therefore the user interface of such a system should be designed so that it shields the content user and supplier from any underlying syntax and complexities of the content management (Mika et al, 2003). The portal approach allows this separation of presentation and content. The final challenge to be mentioned for consideration in content management is the need for the adoption of standards and regulatory compliance. There is a proven understanding, that for a large scale content management system to be successfully adopted and implemented, i.e. EHR, standards need to be embraced as a cornerstone to any approach employed (Päivärinta and Munkvold, 2005).

4.7 The Role of XML

XML technologies are used extensively to support both the re-use of content and context dependent delivery. It is possible to represent content using XML documents

and generate the desired presentation and content through the use of XSLT templates and transformers. Client access through various devices is also supported through the generation of different XML formats like HTML, WML and VoiceXML (Norrie and Palanginis, 2003). The use of XML as a framework for content management provides a highly flexible approach, allowing for the modularisation of data, highly descriptive metadata though customisable tags, reusable content elements and the separation of content and presentation. Content can easily be attached, included within or associated with an XML file. XML is also a powerful approach as it is platform independent and a recognised industry standard.

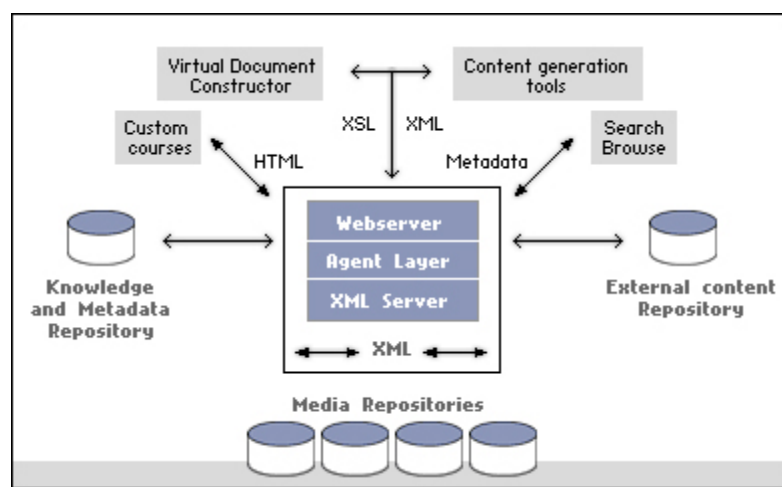


Figure 13. XML & Content Management

Content stored in XML format is easily rendered into a presentation format through the use of XSLT and stylesheets. This allows the selection, integration and composition of pages from elements throughout the collection, enabling customisability in a method that is transparent to the user. XML is easily created, modified and deleted and it also holds the advantage of being easily stored, whether in a file system or database. Dependencies between content and information can also be stored and managed using pre-defined attributes within XML. DTDs and Schema are separate files used to describe the structure of XML. They can be used to specify the expected content and metadata elements of the files. In this manner, XML files are easily searched and categorised using common tag elements such as **KEYWORD** and **CATEGORY**. (Meliksetian et al, 2001) These capabilities are key requirements in effective content management. While being effective in content storage, XML files

can also be found useful in the configuration of content management systems, as they do not require compilation or complicated updating processes.

4.8 Content Management System Components

A Content Management System (CMS) consists of five main components; Data Repository, User Interface, Editorial Tools, Workflow, Scheme and Output Utilities (Kartchner, 1998). Each component is concerned with managing the recognised asset of content data. Working together these separate entities combine to enable output in a number of configurations to multiple heterogeneous environments. A brief description of each of these components follows.

The data repository often exists as a collection of databases and file systems. Its role is in the organisation of data to facilitate its maintenance, updating and redistribution. Storage techniques employed are often dependant on how the data is to be used. For reusability purposes, data at this level usually exists in its lowest level of detail, which is also its highest degree of logical abstraction. There exist a plethora of options when deciding on a data repository solution; commercial database offerings like those available from Oracle and IBM, custom databases, relational or object-oriented models and multiple directory and file system configurations. All must, individually or combined, deal with multiple data formats, various access methods, and the stringent security and control required for what some might view as their most significant asset.

The user interface is a familiar concept, the screens through which interaction with the various data collections takes place. Content management systems are usually an integration of several products who individually might have dedicated interfaces in use. The need often exists to combine these into custom interfaces to fit specific needs. The ability to browse data across multiple products through one interface is a powerful concept. It is also one which the portal approach mirrors, making it suitable for the role.

The editorial tools or content editors are key components in a CMS. They work directly with the system's raw material, facilitating content creation, deletion, editing and preparation for processing. This preparation involves the transformation of data

into a format suitable for content delivery. This set of tools provides a mechanism for authors to output or convert data into the desired format, without the requirement for extensive knowledge of formatting techniques and standards. Such complex tasks can be kept transparent to the author, allowing them to work in an environment they are comfortable with. There is no need for high level tagging knowledge; this can be automated by these tools allowing focus to remain on efficient content creation.

In a CMS, there is a requirement to know what is happening with any content component at any given time. The workflow scheme refers to the path taken by any component of content, the specifics of which must be recorded. For each data entity, this facility allows the system to keep track of information and its use under such categories as: check-in and check-out history, versioning, access information, editing information, change submissions, author information and current status. In large scale systems it is common to have multiple versions of the same information component in existence. It is often desirable to allow accessibility to the different versions but this requires strict management and monitoring about the current users of this data at any given time. The workflow scheme relies on metadata which was discussed previously. This categorisation and information-rich approach also allows for the generation of custom reports and can provide valuable status information, which can be outputted in multiple formats for use externally or by the system. This complements the workflow scheme's role in tracking and controlling content and processes.

The output utilities in a CMS allow users to view different versions, combinations and configurations of the same content. The overall role of these utilities can be viewed as the filtering of the information from the repository into the required format for publishing. This allows for the personalisation and integration of data views. This powerful component populates the user interface with content in response to specific user requests and needs. This personalisation of content is important when trying to tailor to the information needs of user groups, security levels, sensitive and confidential content, power users and individuals.

5 Case Study AMNCH – The Diabetes Shared Care Portal

5.1 Diabetes Mellitus

Often referred to as just Diabetes, this condition is due either to a lack of insulin production in a person, or the failure of any insulin produced to act normally. This then leads to an abnormally high level of blood glucose (Zaini, Khir and Pheng, 1999). Symptoms of the illness include increased thirst, frequent urination – especially at night, weight loss, blurred vision and extreme tiredness. Diabetes Mellitus (DM) has two major classifications, Type I and Type II. Type I are insulin dependent cases, where there is a lack of insulin production due to the destruction of insulin producing cells in the pancreas. This mainly presents in young people, often as a sudden onset of symptoms and is treated using insulin injections. The exact cause of Type I DM is still unknown. Type II are non-insulin dependent cases, where any insulin produced is not effective or of insufficient quantity. It is referred to as a type of insulin resistance and is strongly linked to both genetic and environmental factors such as diet, obesity / weight gain, lack of exercise and general lifestyle. Treatment comes in the form of lifestyle change, improved diet, weight loss and exercise. The use of Oral Hypoglycaemic Agents (OHAs) is also a popular treatment; these are a family of drugs used to help reduce the amount of sugar present in the blood. Type II is the most common form of DM accounting for more than ninety percent of cases and presents mainly in overweight adults over the age of forty (Aziz et al, 2003).

5.2 Shared Care

Diabetes is a chronic disease which requires continued monitoring and care. This care can include a variety of care disciplines depending on related conditions and the relative health of the DM sufferer. From initial diagnosis to everyday care, properly managed DM will bring the patient into contact with many interdependent healthcare employees throughout the care process. There is a significant requirement among these carers to share and communicate their knowledge and findings with those others integrated into the DM care pathway. These carers can originate from a number of backgrounds; GPs, DM nurses, endocrinology, cardiology, dietetics, ophthalmology, renal, podiatry and pharmaceutical. Each of these possesses valuable information and data required for the complete treatment of the condition. Therefore, an appropriate mechanism is required to enable the dissemination of this information to those who

require it, including the patient. Goldberg et al (2003) state that web-based applications have the potential to support the ongoing care needs of patients with chronic diseases, like diabetes.

Care for DM is usually provided using a combination of primary and secondary care. Secondary care is usually offered within clinics in a hospital in support of the work carried out by GPs. This puts unnecessary pressure on hospitals and staff as some treatments and monitoring could alternatively be carried out by community practices. With ICT there exist the capabilities of returning more of the care delivery back to the community setting. Existing care delivery can be quite distributed and this would only increase this factor. Concurrently, it would help reduce the pressure on the hospitals and the need for people to travel long distances for these clinics. This would however also further distribute the points at which information is collected at each visit. Portal technology has the capabilities of providing a solution to this issue and the problems of multiple disparate computer systems. Tracking down the complete paper record of a DM patient is time consuming if not impossible or impracticable. Making the information available through one shared point of access will combat a lot of the issues in DM care delivery and more importantly the portal approach considers both the health employee and the patient's needs in this respect.

5.3 Structure of Care and Existing Systems

The Diabetes Day-care Centre (DDC) in AMNCH serves the diabetes community in the large catchment area of South West Dublin. It is estimated that this centre alone caters for a population of approximately three hundred thousand people. The DDC itself currently looks after over 5000 diabetic patients from over 700 GPs. This requires a significant amount of administration and co-operative management. Patients are referred to the centre on diagnosis of DM and may return for monitoring or in cases where associated complications arise. DM treatment requires a constant process of information collection; blood tests, glucose meter recordings, patient diaries, medication, information gathered at clinics, etc. It is desirable to make this collection of information available between the different care disciplines and systems in use.

Within the hospital there currently exist many different computer systems which are used in combination with a patient's paper-based record to support the delivery of DM care. These systems are required to store and share a sizeable volume and array of data for each DM patient; demographics, laboratory results, decision support, prescriptions and medication, DM education and information, episode notes, eye care, foot care, cardiovascular care, renal care, dietetics, email, appointment scheduling and referrals. When exploring shared care solutions, external GP systems and the provision of facilities for use by DM patients have also to be considered. The tables that follow show the number of systems potentially involved and their current interactions. There is a significant variety of formats and standards present for information storage, messaging, interfacing, data exchange, etc. The majority of systems interact with the Patient Administration System (PAS) and many have links to the Laboratory Information System (LIS). There still remains potential gain from enabling interoperability between those which do not currently interact and therefore are not sharing relevant data between medical disciplines.

Classification	Product	Discipline	Supplier
Patient Administration System (PAS)	PiMS	Patient Information / Demographics	iSoft
Laboratory Information System (LIS)	WinPath	Laboratory Information	Sysmed Solutions
Order Communication System (OCS)	Key	Test Request Communications	Torex
Radiology Information System (RIS)	PACS	Medical Imaging	Keogh Software
Accident and Emergency (A&E)	Footman Walker	Emergency Medicine	Footman Walker
Intensive Care Unit (ICU)	Critical Care	Intensive Care	AcuBase
Urology	Maisy	Urology	Proprietary
Cardiology	ACAS	Anticoagulant System	Eider Computers
Diabetes	Diamond DB	Diabetes Care	HICOM
Diabetes	TRiPS	Diabetes DSS	Proprietary
Electronic Transfer Service	MediBRIDGE	Secure Health Data Transport	DMF Systems
Ophthalmology	ImageNET	Retinal Photography	TOPCON
Integration Engine (IE)	Cloverleaf IE	System Integration	QUOVADX ISD

Table 1. Relevant AMNCH Systems

Product	Supplier
Healthone	Health Ireland Products
GP Clinical	Quantum Computing
Dynamic GP	Medicom Medical Computer Solutions
Dabl	Dabl – Disease Management Systems
MediX	MediX Solutions
GP Mac	JacSoftware
Easy GP	Dr. F Colohan
Clinical Objects	Apollo Medical Systems

Table 2. Approved National GP Systems

System (From)	Interactions (To)
PiMS	WinPath, Key, PACS, A&E, ICU, Diamond, TRiPS, ACAS, Maisy
WinPath	Key, Diamond, TRiPS, ACAS, ICU
Key	WinPath, TriPS, ICU
A&E	PiMS, Key
Medibridge	WinPath
Diamond	TRiPS
<i>The majority of interactions between systems are via the Cloverleaf Integration Engine</i>	

Table 3. AMNCH System Interactions

5.4 System Potential

5.4.1 Diamond

The Diamond DB is the existing system in use in the diabetes centre in the hospital. It draws patient information directly from PiMS and accesses laboratory information on WinPath via the Integration Engine (IE). Diamond is a comprehensive application, covering many aspects of DM care. There are quite a few sections within Diamond that are not only specific to DM, these could potentially be adapted for use with other conditions. Apart from general DM episodes, there are sections dealing with eye care, foot care, renal care, dietetics, referrals, treatments, coded problem lists, drug database and more. A significant amount of patient data is captured by the system in these various sections; this information can often be relevant to other care disciplines but not always available. Web-enabling the system would make the system more accessible to other areas within the hospital for use. There could also be versions

adapted for GP interaction, improved image handling capabilities and sections for access by the DM patient.

A new audit facility has recently been added to the Diamond system. If adapted and made available to other systems and data repositories, the auditing capabilities could prove very useful in the areas of management and research. Reports, graphs and charts, customised layouts and data export facilities are just some of the features that could be exploited by adapting and implementing such a system with the aid of portal technology. Many management requirements could be catered for and the scope for data analysis and research outcomes in the hospital could be potentially improved.

5.4.2 *TRiPS*

TRiPS is a good example in the hospital of a system that exploits data collected from a number of systems. It is also an example of information that exists in the hospital that is not being exploited for use by other systems. TRiPS is an acronym for Test Request Protocol System. It is a decision support system, developed primarily to aid in the diagnosis of Diabetes Mellitus. The system monitors specific blood results associated with the condition, Random Plasma Glucose (RPG), Fasting Plasma Glucose (FPG) and Oral Glucose Tolerance Test (OGTT). It then automatically alerts the user if any of the results are abnormal; this is carried out by comparing results against a set of rules defined in the system. The user can then decide to register the patient against the diabetes diagnosis protocol that is intended to facilitate decision-making based on WHO recommendations. The aim is to identify pre-diabetic and diabetic conditions, at a much earlier stage than previously possible with clear clinical advantages.

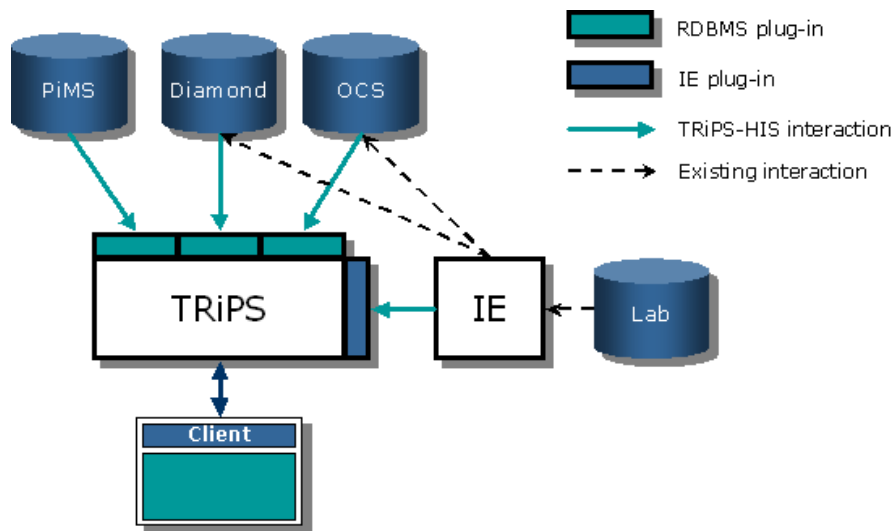


Figure 14. TRiPS Data Sources

TRiPS acts as a portal in many senses by providing a gateway to a number of information resources. The system was developed in co-operation with DIT, as part of the HEA funded Medilink project, and still remains a pilot project as it has not been fully integrated into the clinical pathway in the hospital. A substantial amount of work has gone into the development of the system and it has yet to be exploited. Many valuable lessons were learned throughout the development and subsequent analysis and use of the system, in areas relating to protocol development, data integration, interface design and the analysis and editing of system rules. If these useful features could be adapted and migrated for use with more systems and environments, the work carried out may yet prove valuable.

TRiPS also provides an element of content and knowledge management which could be further exploited in the hospital. These can be seen in the system's use of protocols and its potential integration into clinical care pathways. Knowledge is encapsulated within the protocols and their associated rules in TRiPS; this supports the process of evidence based care by formulating and optimising the rules based on previous rule performance and outcomes. In the area of content management, TRiPS also provides a results screening mechanism, focusing specifically on a specified set of data entities and having the ability to discard or ignore unwanted material. The system has a facility that allows the user to select or ignore the different sources of information being monitored by the system, the current application being diabetes. This screening

process has the potential to identify new candidates for care, at an earlier stage than previously possible, allowing them to commence progress on a care pathway at a sooner stage. The rules in the system currently focus on diabetes but the potential is there to adapt the system for use with other conditions such as thyroid and cardiovascular disorders. There is the potential to provide accessibility to these capabilities through the use of portal technology.

TRiPS remains a good example of what can be gained through the sharing of data between systems. It is also a good example of a system whose information would be useful if shared with others but is currently unavailable. There is significant potential for the sharing of data from existing systems around the hospital.

5.5 Proposed Approach and Potential Benefits

To implement the diabetes shared care portal, it would be a requirement that systems involved adopt a set of standards in their operations. This is necessarily a good thing because there is a recognised need for more standardisation to be enforced. There is a significant focus on the implementation of standards within IT in AMNCH presently. Therefore, implementing more standards through the introduction of such a portal would fit into the common goal. Once in place, portal capabilities throughout the hospital would carry many benefits. If all systems within a hospital, or even the entire healthcare system, are conforming to a given set of standards, the potential scope and capabilities arising from shared data greatly increase.

Standards also allow for greater scalability and extensibility capabilities. Additional users being added to the system, along with new functional requirements and entire new systems could potentially be integrated with greater ease. Should a site-wide adoption of portal technology take place, many possibilities would then exist. A single over-riding system responsible for application security could be implemented. This would make for easier user management and profiling across all systems. There also exists the potential for improved systems monitoring; one system to track problems and provide alerting capabilities. This would help improve availability and reliability of systems within the hospital.

Specific to DM care, a number of issues and requirements in the DDC would be potentially addressed through the added capabilities of the portal. The Diamond system could be complemented with the introduction of added features such as decision support capabilities, increased integration with other hospital systems, a portable web-based interface and increased conformance to industry standards. Improved enablement of bi-directional communications between systems would be a powerful feature; this would for example allow for easily updateable patient information without having to use a specific application. In the DDC it would enable automated laboratory test ordering and eliminate the current paper based form. Currently the Diamond systems handling of clinical images is not satisfactory, a specialised system could be integrated into the portal for this function, such as the new system acquired in the centre for retinal photography. Standalone systems would no longer exist. Decision support functionality could be adapted for use with the portal such as that developed with TRiPS. Decision support features would be a useful addition to the DM care process. As with any condition, new drugs and treatments are constantly emerging for diabetes. It is hard to keep track of these at times and the current system requires constant manual updating. Connectivity with a central pharmacy service to handle this could be a possibility. Coding and classification of problems and specific terminology used, as with ICD and SNOMED, could also be handled by a central service to ensure consistency across the board.

The GP could also make use of such a portal in the support of shared care delivery for DM. From the comfort of their own practice a GP could potentially order patient tests remotely, send in the blood samples and view the results as soon as they become available. This would prevent a lot of unnecessary effort on behalf of the GP and the patient having to travel to the hospital for these tests. It would improve communication capabilities between GPs and diabetes care specialists and give them more information on the care process and on their patients. It would be easier for GPs to refer new DM patients and subsequent follow up visits used for monitoring the condition could then be carried out by the GP, reducing the pressure on the care centres. In the event of complications due to their condition, DM patients could also be easily referred to the hospital for specialised care. A complete history of treatment for the illness would therefore be available to all those involved in the care delivery.

The DM patients could potentially use the portal to help with the self-management of their illness. An information section could be integrated into the portal covering topics such as diabetes education, new treatments and products, health plans, risk awareness, nutrition, exercise, message boards and a support community. Decision support could be introduced to help with treatment, taking into account lifestyle choices and management of blood glucose levels. The portal could also be used by the patient to upload data from their blood glucose meters for remote analysis and advice by trained carers. Increased patient involvement in the management of their condition is a good thing; it helps build relationships with those involved in the care process through more frequent interactions. It can help build confidence or acceptance by the patient in the care delivery process when they see immediate results for their efforts. Diabetes requires a high level of self management, a shared care portal for the illness would help support this.

6 Conclusions

Portal technology is in a position to offer many valuable capabilities to the implementation of the EHR. This is recognised through the inclusion in the ‘National Health Information Strategy’ of the requirement to implement a National Health Information Portal. The strategy envisages a portal that provides an information resource for healthcare related areas and eventually as an access point to e-Health services. The largest of all e-Health services will be the EHR. The portal approach fulfils many key requirements in information delivery in a healthcare setting but there are also some areas that remain immature. Complex user-interface implementation though a web-browser and security concerns are just two examples. Work is ongoing in these areas to evolve and overcome any deficiencies in the technology.

Within AMNCH the integration engine provides the mechanism through which the different systems and applications can interact when required. This proves quite effective when considering this approach on a single site basis. Portal technology may however offer a more flexible and standards based integration approach. The integration engine does not however provide a solution for inter-site communication, which would be a key requirement of the EHR. The Internet exists as the one suitable expansive medium through which this inter-communication could be implemented. Portal technology is one approach which exploits these capabilities; the Diabetes Shared Care Portal is a good example. Considering long term goals and the realisation of the national EHR, it is clearly an ongoing iterative process. The relevant standards are required together with appropriate planning. The portal and web technologies are well positioned in this respect to support the modular rollout of such a system.

References

- (Abidi and Chong, 2003) Abidi S. S. R, Chong Y. H. 'E-Healthcare via Customized Information Services: Addressing the Need for Factually Consistent Information'. Proceedings of the International Conference on Service Oriented Computing (ICSOC) 2003.
- (Alavi and Leidner, 2001) Alavi M, Leidner D. E. 'Review: Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues'. Management Information Systems Quarterly. 25: 107-136, 2001.
- (Alt and Klein, 1999) Alt R, Klein S. 'Lessons in Electronic Commerce – The case of Electronic Transportation Markets'. Proceedings of the 31st Annual Hawaii International Conference on System Sciences. IEEE, 4: 102-111, 1999.
- (Anderson, 1997) Anderson J. 'Clearing the Way for Physicians' use of Clinical Information Systems'. Communications of ACM. 40; 8: 83-90, 1997.
- (Ariba, 2000) UDDI Technical Whitepaper, Ariba, IBM, Microsoft, 2000. Available at: <http://www.uddi.org>
- (ASTM, 1996) American Society for Testing and materials. 'Standard Guide for Properties of Electronic Health Records and Record Systems'. E1769-95, Feb 1996.
- (Aziz et al, 2003) Aziz A. A, Ahdon M. F, Hassin M, Hussin M, Siraj F, Sainin M. S. 'The Design of an Intelligent Community Portal for Diabetes Patient'. Proceedings of Artificial Intelligence Application in Industry (AIAI) 2003.
- (Berry et al, 2002) Berry D, Grimson W, Pardon S, Gaffney P, Boran G. 'A Laboratory Test Request Protocol System'. Studies in Health Technology and Informatics. 90: 804-808, 2002.
- (Bird, Goodchild and Beale, 2000) Bird L. J, Goodchild A, Beale T. 'Integrating Health Care Information Using XML-Based Metadata'. Proceedings of the 8th National Health Informatics Conference, Australia 2000.
- (Bobrow et al, 1986) Bobrow D.G, Mittal S, Stefik M. J. 'Expert Systems: Perils and Promise'. Communications of the ACM. 29; 9: 880-894, September 1986.
- (Bray et al, 2004) Bray T, Paoli J, Sperberg-McQueen C. M, Maler E, Yergeau F. 'Extensible Markup Language (XML) 1.0, 2004'. Available at: <http://www.w3.org/TR/REC-xml/>
- (Breton, Solomonides and McClatchey, 2004) Breton V, Solomonides A. E, McClatchey R. H. 'A perspective on the Healthgrid initiative'. Proceedings of the 4th IEEE/ACM International Symposium on Cluster Computing and the Grid (CCGrid) 2004.
- (Briggs and Early, 1999) Briggs J. S, Early G. H. 'Internet developments and their significance for healthcare'. Medical Informatics and the Internet in Medicine. 24; 3: 149-164, 1999.

(Broom and Loonsk, 2004) Broom C. V, Loonsk J. 'Public Health Information Network — Improving Early Detection by Using a Standards-Based Approach to Connecting Public Health and Clinical Medicine'. *Morbidity and Mortality Weekly Report*. 24; 53: 199-202, September 2004.

(Butler, 2003) Butler M. H. 'Barriers to Real World Adoption of Semantic Web Technologies'. HP Labs, Technical Report HPL-2002-333. Available at: <http://www.hpl.hp.com/personal/marbut/barriersToRealWorldAdoptRDF.pdf>

(Campbell et al, 1998) Campbell H, Hotchkiss R, Bradshaw N, Porteous M. 'Integrated Care Pathways'. *British Medical Journal*. 316: 133-137, 1998.

(Carter, 1998) Carter M. 'Should patients have access to their medical records?'. *The Medical Journal of Australia*. 169: 596-7, 1998.

(Chaudron et al, 2001) Chaudron M. R. V, Eskenazi E. M, Fioukov A. V, Hammer D. K. 'A Framework for Formal Component-Based Software Architecting'. *Proceedings of Specification and Verification of Component-Based Systems Workshop (OOPSLA) 2001*.

(Chin, 2000) Chin R. 'The Internet: Another Facet to the Paradigm Shift in Healthcare'. *Singapore Medical Journal* September 2000. 41; 9: 426-429, 2000.

(Christensen et al, 2001) Christensen E, Curbera F, Meredith G, Weerawarana S. 'Web Services Description Language (WSDL) 1.1, 2001'. Available at: <http://www.w3.org/TR/wsdl>

(Curtis, Foster and Stentiford, 1999) Curtis K, Foster P. W, Stentiford F. W. M. 'Metadata – the key to content management services'. *Proceedings of the 3rd IEEE Metadata Conference, 1999*.

(DHC, 2004) Department of Health and Children. 'Health Information - A National Strategy'. Strategic Document.

(Drucker, 1974) Drucker P. 'Management: Tasks, Responsibilities, Practices'. New York: Harper & Row, 1974.

(Duff and McKemmish, 2000) Duff W, McKemmish S. 'Metadata and ISO 9000 compliance'. *Information Management Journal*. 34; 1, 2000. Available at: <http://www.sims.monash.edu.au/research/rcrg/publications/smckduff.html>

(Ebidia et al, 1999) Ebidia A, Mulder C, Tripp B, Morgan M. W. 'Getting Data Out of the Electronic Patient Record: Critical Steps in Building a Data Warehouse for Decision Support'. *Journal of the American Medical Informatics Association*. 1093: 645–749, 1999.

(Field and Lohr, 1992) Field M. J, Lohr K. N. 'Guidelines for Clinical Practice: From Development to Use'. Washington, DC: National Academy Press, 1992.

(Fields and Duncker, 2003) Fields B, Duncker E. 'Articulating Resources: The Impact of Electronic Health Records on Cross-Professional Healthcare Work'. Interaction Design Centre, Middlesex University, Technical Report: IDC-TR-2003-002 December 2003.

(Forslund and Kilman, 2000). Forslund D. W, Kilman D. G. 'The Impact of the Global, Extensible Electronic Health Record'. Lauren B. Eder. Idea Group Publishing, 2000.

(Foster, Kesselman and Tuecke, 2001) Foster I, Kesselman C, Tuecke S. 'The Anatomy of the Grid: Enabling Scalable Virtual Organizations'. International Journal of Supercomputer Applications. 15; 3: 200-222, 2001.

(Gabór and Kö) Gabór A, Kö A. 'Knowledge Management in Content Management at the Public Administration'. Proceedings of the 3rd Workshop on Knowledge Management in Electronic Government (KMGov) 2002.

(Germonprez and Collopy, 2004) Germonprez M, Collopy F. 'Designing Tailorable Technologies'. Sprouts Working Papers on Information Environments, Systems and Organisations. 4; 7, Summer 2004. Available at: <http://weatherhead.cwru.edu/sprouts/2004/040307.pdf>

(Goldberg et al, 2003) Goldberg H. I, Ralston J. D, Hirsch I. B, Hoath J. I, Ahmed K. I. 'Using an Internet Comanagement Module to Improve the Quality of Chronic Disease Care'. Joint Commission Journal on Quality and Safety. 29; 9, September 2003.

(Goran and Stanford, 2001) Goran M. J, Stanford J. 'E-Health: Restructuring Care Delivery in the Internet Age'. Journal of Healthcare Information Management. 15; 1, Spring, 2001.

(Gorden and DuMoulon, 2004) Gorden M. S, DuMoulon J. P. 'Enhancing the Quality of Patient Care Through Interoperable Exchange of Electronic Healthcare Information'. American College of Physicians Policy Paper, April 2004.

(Gordon et al, 1998) Gordon D, Geiger G, Lowe N, Jickling J. 'What Is An Electronic Patient Record?' Proceedings of the AMIA Annual Fall Symposium, 1998.

(Griffin, 1997) Griffin R. W. 'Fundamentals of Management; Core Concepts and Applications'. Boston, MA: Houghton Mifflin, 1997.

(Grimshaw and Russell, 1993) Grimshaw J. M, Russell I. T. 'Effect of clinical guidelines on medical practice: a systematic review of rigorous evaluations'. Lancet; 342; 8883: 1317-22, 1993.

(Gudgin et al, 2003) Gudgin M, Hadley M, Mandelsohn N, Moreau J. J, Nielsen H. F. 'Simple Object Access Protocol (SOAP) 1.2, 2003'. Available at: <http://www.w3.org/TR/SOAP>

(Hazra, 2002) Hazra T. K. 'Building Enterprise Portals: Principles to Practice'. Proceedings of the 24th International Conference on Software Engineering (ICSE) 2002.

(HCG, 2002) Harvard Computing Group. 'Portals and Business Functions: New Tools to Improve Operations'.

Available at: http://www.PortalsCommunity.com/library/white_papers.cfm

(HEBE, 2004) Irish Health Boards Executive. 'Embedding the e in Health – A Strategic ICT Framework for the Irish Health System'. Strategic Document. Part B-7 Technology.

(Hederman, 1999) Hederman L. 'Knowledge-based Systems – Alternatives to Rules'. KBS Lecture, Postgraduate Diploma in Health Informatics. March 1999.

Available at: <https://www.cs.tcd.ie/Lucy.Hederman/DipHI/MBR&CBR.ppt>

(Hicks and Tochtermann, 2001) Hicks D. L, Tochtermann K. 'Personalizing Information Spaces: A Metadata Based Approach'. Proceedings of the International Conference on Dublin Core and Metadata Applications, 2001.

(HIPAA, 1996) Health Insurance Portability and Accountability Act 1996. 'Enterprise Single Sign-On and HIPAA: A Best Practice in the "Good Faith Effort" to Protect Patients' Privacy'. Passlogix Whitepaper January 2005. Available at:

http://www.passlogix.com/global/fact_sheets_wp/AssuringHIPAACompliance.pdf

(HISI, 2004) Health Informatics Society of Ireland. 'Standardisation and Standards in the Irish Healthcare System'. Presentation, November 2004.

Available at: <http://www.gpit.ie/presentations/hisi.html>

(Hook and Regal, 1995) Hook E. B, Regal R. R. 'Capture-recapture methods in epidemiology: methods and limitations'. Epidemiologic Reviews. 17: 243-264, 1995.

(Hu and Lauck, 2004) Hu B, Lauck F. 'Prototype of a Web and XML Based Collaborative Authoring System'. Proceedings of the International Conference on Computing, Communications and Control Technologies (CCCT) 2004.

(IEEE, 1996) Halloran M, Harrington J, Seliger R, Beeler Jr, G. W, Mohr D, Khanderia B. K. 'Accelerating the Movement Toward Standards Based Interoperability in Healthcare'. Institute of Electrical and Electronics Engineers Whitepaper, May 1996.

(Jaenicke, 2000) Jaenicke C. 'XML: It's The 'X' That Matters'. XML Journal – Web Services, February, 2000. Available at: <http://xml.sys-con.com/read/40034.htm>

(Jasper and Uschold, 1999) Robert Jasper R, Uschold M. 'A Framework for Understanding and Classifying Ontology Applications'. Proceedings of the 12th Workshop on Knowledge Acquisition, Modeling and Management, 1999.

Javitt, 2004) Javitt J. C. 'How To Succeed In Health Information Technology - Involving a broad community of users at the development stage is likely to result in usable, durable, and deployable health IT products'. Health Affairs Journal, May 2004.

Available at: <http://content.healthaffairs.org/cgi/content/full/hlthaff.w4.321v1/DC1>

(Jones, Bults and Konstantas, 2001) Jones V, Bults B, Konstantas D. 'Healthcare PANs: Personal Area Networks for trauma care and home care'. Proceedings of the 4th International Symposium on Wireless Personal Multimedia Communications (WPMC), 2001.

(Jung, Grimson and Grimson, 1999) Jung B, Grimson W, Grimson J. 'The EHCR – if not now, when?'. Proceedings of Towards an Electronic Health Record Europe, (TEHRE) 1999.

(Kalra, 2004) Kalra D. 'The Electronic Healthcare Record and The openEHR Foundation'. Proceedings of the Eurorec Conference 2004.

Available at: <http://www.prorec.be/events/eurorec2004/eurorec/04-DipakKalra.pps>

(Kapur, 2001) Kapur S. 'The Internet : Its Role in Medicine and Healthcare'. Indian Academy of Clinical Medicine. 2; 3, July-September 2001.

(Kao, 2001) Kao J. 'Developer's guide to Building XML-Based Web-Services with Java 2 Platform, Enterprise Edition (J2EE)'. Sun Whitepaper, TheServerside.com, June 2001. Available at:

<http://www.theserverside.com/articles/article.tss?l=WebServices-Dev-Guide>

(Kartchner, 1998) Kartchner C. 'Content Management Systems: Getting from Concept to Reality'. The Journal of Electronic Publishing. 3; 4, June 1998.

Available at: <http://www.press.umich.edu/jep/03-04/kartchner.html>

(Kosińska and Słowikowski, 2004) Kosińska J, Słowikowski P. 'Technical Aspects of Portal Technology Application for E-health Systems'. Proceedings of the 2nd International Conference on eHealth in Common Europe, Critical Conditions for Development of eHealth Environment in Transforming Economies, 2004.

(Kuperman, Sittig and Shabot, 1999) Kuperman G. J, Sittig D. F, Shabot M. M. 'Clinical Decision Support for Hospital and Critical Care'. Journal of Healthcare Information Management. 13; 4, 1999.

(Landwehr, 2001) Landwehr C. E. 'Computer Security'. International Journal of Information Security. 1; 1: 3–13, 2001.

(Ledbetter and Morgan, 2001) Ledbetter C. S, Morgan M. W. 'Toward Best Practice: Leveraging the Electronic Patient Record as a Clinical Data Warehouse'. Journal of Healthcare Information Management. 15; 2, 2001.

(Lin and Umoh, 2002) Lin B, Umoh D. 'e-Healthcare: A Vehicle Of Change'. American Business Review June. 20; 2, 2002.

(Lorence and Spink, 2004) Lorence D. P, Spink A. 'Semantics and the medical web: a review of barriers and breakthroughs in effective healthcare query'. Health Information and Libraries Journal. 21; 2: 109-116.

(Lurie and Belanger, 2002) Lurie J, Belanger R. J. 'The Great Debate: .NET vs. J2EE'. JavaWorld Article, March 2002. Available at:
http://www.javaworld.com/javaworld/jw-03-2002/jw-0308-j2eenet_p.html

(Luxenberg et al, 1997) Luxenberg S, DuBois D. D, Fraley C. G, Hamburg R. R, Huang X, Clayton P. D. 'Electronic Forms: Benefits and Drawbacks of A World Wide Web-Based Approach to Data Entry'. Proceedings of the AMIA Annual Fall Symposium, 1997.

(Mandl, Szolovits and Kohane, 2001) Mandl K. D, Szolovits P. S, Kohane I. S. 'Public standards and patients' control: how to keep electronic medical records accessible but private'. British Medical Journal. 322: 283-287, 2001.

(McKemmish et al, 2002) McKemmish S, Burstein F, Manaszewicz R, Fisher J. 'Towards meeting the Decision Support Needs of a Community via an 'Intelligent Portal': Breast Cancer Knowledge Online'. Proceedings of Improving Quality by Lowering Barriers: 10th National Health Informatics Conference, Australia, 2002.

(Meliksetian et al, 2001) Meliksetian D, Weitzman D, Dean S. E, Milton J, Zhou N, Davis P, Wu J. 'XML Content Management: Challenges and Solutions'. Internationales Congress Centrum (ICC), May 2001.

(Microsoft, 2005) 'What is .NET?'. February, 2005.
Available at: <http://www.microsoft.com/net/Basics.mspix>

(Mika et al, 2003) Mika P, Iosif V, Sure Y, Akkermans H. 'Ontology-based Content Management in a Virtual Organization'. Handbook on Ontologies 2004. 455-476.
Available at:
http://www.aifb.unikarlsruhe.de/WBS/ysu/publications/2003_ontohandbook_ens.pdf

MIT (2004) Massachusetts Institute of Technology. 'Availability and Replication'. Principles of Computer Systems. 28: 1-2. Available at:
<http://web.mit.edu/6.826/www/notes/HO28.pdf>

(Murray, 2002) Murray M. 'An Investigation of Specifications for Migrating to a Web Portal Framework for the Dissemination of Health Information within a Public Health Network'. Proceedings of the 35th Hawaii International Conference on System Sciences (HICSS) 2002.

(Nielsen, 1994) Nielsen J. 'Heuristic evaluation'. Usability Inspection Methods, Nielsen, J., Mack R. L. John Wiley & Sons, New York, NY.

(Nielsen and Molich, 1990) Nielsen J, Molich R. 'Heuristic evaluation of user interfaces'. Proceedings of the Association for Computing Machinery, Computer Human Interaction (AMC CHI) 1990.

(Nikravesh and Azvine, 2002) Nikravesh M, Azvine B. 'Fuzzy Queries, Search and Decision Support'. *Journal of Soft Computing*. 6: 389, 2002.

(Norrie and Palanginis,) Norrie M. C, Palanginis A. 'From State to Structure: an XML Web Publishing Framework'. *Proceedings of the 15th Conference on Advanced Information Systems Engineering (CAiSE) 2003*.

(OBS ICRS, 2003) Department of Health, UK. 'OBS2 For Integrated Care Records Services'. Part 2, LSP Services. Version 2 August 2003.
Available at: <http://www.dh.gov.uk/assetRoot/04/07/16/32/04071632.pdf>

(Ong et al, 2004) Ong M, Ren X, Allan G, Kadiramanathan V, Thompson H. A, Fleming P. J. 'Decision Support System on The Grid'. *Proceedings of the International Conference on Knowledge-Based Intelligent Information & Engineering Systems (KES), 2004*.

(Päivärinta and Munkvold, 2005) Päivärinta T, Munkvold B. E. 'Enterprise Content Management: An Integrated Perspective on Information Management'. *Proceedings of the 38th Hawaii International Conference on System Sciences, 2005*.

(Pierce et al, 2002) Pierce M, Fox G, Youn C, Mock S, Mueller K, Balsoy O. 'Interoperable Web Services for Computational Portals'. *Proceedings of Supercomputing, 2002*. Available at: <http://sc-2002.org/paperpdfs/pap.pap284.pdf>

(Podichetty and Biscup, 2003) Podichetty V. K, Biscup R. S. 'e-Health: A New Approach in Healthcare Practice'. *The Internet Journal of Allied Health Sciences & Practice*. 1; 2, 2003. Available at:
<http://ijahsp.nova.edu/articles/1vol2/PodichettyeHealth.html>

(Raggett, Le Hors and Jacobs, 1999) Raggett D, Le Hors A, Jacobs I. 'Hyper Text Markup Language (HTML) 4.01 Specification'. Available at:
<http://www.w3.org/TR/REC-html40/>

(Reimer, 2002) Reimer J. A. 'Enterprise Content Management'. *Datenbank Spectrum*. 4, 2002. Available at:
<http://mordor.prakinftu-ilmenu.de/papers/dbspektrum/dbs-04-17.pdf>

(Rigby et al, 1998) Rigby M, Roberts R, Williams J, Clark J, Savill A, Lervy B, Mooney G. 'Integrated record keeping as an essential aspect of a primary care led health service'. *British Medical Journal*. 317: 579-582, 1998.

(Rodrigues, 2000a) Rodrigues R. J. 'Information systems: the key to evidence based health practice'. *Bulletin of the World Health Organization*. 78; 11:1344-51, 2000.

(Rodrigues, 2000b) Rodrigues R. J. 'Ethical and Legal Issues in Interactive Health Communications: A Call for International Cooperation'. *Journal of Medical Internet Research*. 2; 1, 2000.

(Schaeck, 2001) Schaeck T. 'WebSphere Portal Server and Web Services'. *Whitepaper, IBM Software Group, 2001*.

(Shortliffe, 1989) Shortliffe E. H. 'Testing Reality: The introduction of decision support technologies for physicians'. *Methods of Information in Medicine*. 28: 1-5, 1989.

(Shortliffe, 1998) Shortliffe E. H. 'The Evolution of Health-Care Records in the Era of the Internet'. IMIA, Medinfo 1998.

(Shortliffe, 1999) Shortliffe E. H. 'The evolution of electronic medical records'. *Academic Medicine*. 74; 4: 414-419, 1999.

(Siegel and Madnick, 1991) Siegel M, Madnick S. E. 'A Metadata Approach to Resolving Semantic Conflicts'. Proceedings of the 17th International Conference on Very Large Data Bases, September 1991.

(Silber, 2003) Silber D. 'The Case for eHealth'. Proceedings of European Commission's High-Level Conference on eHealth, May 2003.

(Snell, 2002) Snell A. 'Web-Based or Web-Enabled...and ASPs'. Taleo Research – Expert Views. Available at:
http://www.ilogos.com/en/expertviews/articles/technology/20020501_AS.html

(Somani, Choy and Kleewein, 2002) Somani A, Choy D, Kleewein J. C. 'Bringing together content and data management systems: Challenges and opportunities'. *IBM Systems Journal*. 41; 4, 2002. Available at:
<http://researchweb.watson.ibm.com/journal/sj/414/somani.html>

(Stevens, 2002) Stevens M. 'Service Oriented Architecture Introduction'. April, 2002. Available at: <http://www.developer.com/services/article.php/1010451>

(Tarczy-Hornoch et al, 1997) Tarczy-Hornoch P, Kwan-Gett T. S, Fouche L, Hoath J, Fuller S, Ibrahim K. N, Ketchell D. S, LoGerfo J. P. 'Meeting Clinician Information Needs by Integrating Access to the Medical Record and Knowledge Resources via the Web'. Proceedings of the AMIA Annual Fall Symposium, 1997.

(UK DoH, 2002) Department of Health, UK. 'What is Protocol-Based Care?'. Available at: <http://www.modernnhs.nhs.uk/protocolbasedcare>

(Van Bommel and Musen, 1997) Van Bommel J. H, Musen M. A. *Handbook of Medical Informatics*, Houten/Diegem: Springer 1997.

(Wald et al, 2001) Wald J. S, Pedraza L. A, Reilly C. A, Murphy M. E, Kuperman G. J. 'Requirements Development for a Patient Computing System'. Proceedings of the AMIA Symposium 2001.

(Warfield, Coady and Hutchinson, 2001) Warfield A, Coady Y, Hutchinson N. 'Identifying Open Problems in Distributed Systems'. Proceedings of the European Research Seminar on Advances in Distributed Systems (ERSADS) 2001.

(Webster, 2001) Webster C. 'A Methodology for Web-Enabling a Computer-based Patient Record with Contributions from Cognitive Science'. IMIA, Medinfo 2001

(Weibull, 2003) 'Reliability Basics – Relationship between Availability and Reliability'. Reliability Hotwire eMagazine. 26; April 2003.
Available at: <http://www.weibull.com/hotwire/issue26/relbasics26.htm>

(Westphall and da Silva Fraga, 1999) Westphall C. M, da Silva Fraga J. 'Authorization Schemes for Large-Scale Systems based on Java, CORBA and Web Security Models'. Proceedings of the 7th IEEE International Conference on Networks, 1999.

(Win and Cooper, 2004) Win K. T, Cooper J. 'Information Age, Electronic Health Record and Australia Healthcare'. International Journal of the Computer, the Internet and Management. 12; 3, September - December 2004.

(Winter, 1999) Winter R. 'Lexicology of Scale'. Winter Corporation Articles, Intelligent Enterprise, February 1999. Available at:
http://www.wintercorp.com/rwintercolumns/ie_9902.html

(Zaini, Khir and Pheng, 1999) Zaini A, Khir A, Pheng C. S. 'An Introduction to Diabetes Mellitus: A Chronic Disease'. University of Malaya Medical Centre: 10-15, 1999.

(Zhu et al, 2004) Zhu F, Turner M, Kotsiopoulos I, Bennett K, Russell M, Budgen D, Brereton P, Keane J, Layzell P, Rigby M. 'Dynamic Data Integration using Web Services'. Proceedings of the IEEE International Conference on Web Services (ICWS) 2004.

Figure 1. Taken from Microsoft 'What is a portal?'. Available at:
<http://www.microsoft.com/uk/windowsserversystem/portals/what-is/default.mspx>

Figure 2. Taken from EPR Ltd. 'Health Information Repository – Electronic Health Record'. Available at: http://ehr.co.za/epr_flow_diag.php

Figure 3 Taken from Egenera – Oracle. Available at:
http://www.egenera.com/images/p_oracle_mig.gif

Figures 4, 6, 8, 9. Taken from Schaeck (2001). See above.

Figure 5. Taken from Kosińska and Słowikowski (2004). See above.

Figure 10. Taken from EMR Systems – Presentation. Available at:
<http://www.emrsystems.net/emrsystemsincpowerpointshow.pps>

Figure 11. Taken from Darlington K: 'Expert Systems in Nursing'. Journal of the British Computer Society Nursing Specialist Group (ITIN), April 1997.

Figure 12. Taken from Vidgen R, Goodwin S, Barnes S. 'e-Everything: e-Commerce, e-Government, e-Household, e-Democracy: Web Content Management'. Proceedings of the 14th Bled Electronic Commerce Conference, 2001.

Figure 13. Adapted from R&D Metis – CNET.
Available at: <http://www.cnet.se/metiseng.vns>