The Impact of ICT on Health and Healthcare: Evidence from the development of a prototype Service-Based Information Broker

Submitted by Professors David Budgen & Pearl Brereton, School of Computing & Maths, Keele University

1. Introduction

This response to the study commissioned by the Royal Society is largely based upon our experiences from a recently completed research project. In this introduction we give the background to this and briefly summarise its main objectives and features. The following two sections provide fuller descriptions of the main technical issues involved, and we then draw upon our experiences to provide responses to the specific questions raised in the *call for evidence*.

The IBHIS (Integration Broker for Heterogeneous Information Sources) project was funded under EPSRC's Distributed Information Management (DIM) programme. Our aim was to address a challenge that is becoming increasingly commonplace as more organisations and public bodies store information about individuals in electronic form: namely, how to *integrate* such information when it is obtained from a set of autonomous and independent organisations, is stored in a multiplicity of formats, and is subject to both national and local rules about access. Our chosen domain was healthcare, where the problem this presents is widely recognised as creating a barrier to the provision of full and effective patient care. The project began in January 2002 and ended in December 2004 and involved close collaboration between four partners: software engineers from three universities (Durham, Keele and UMIST[1]), and also Keele's *Centre for Health Planning & Management* (CHPM). The *Meadows Centre* in Solihull also provided valuable support via healthcare practice 'use cases'.

To meet the challenge, we explored a solution that was radically different from the 'conventional' approach of creating ever larger integrated enterprise systems, with all of the questions that these raise about sustainability and evolution. Instead, we chose a relatively lightweight 'broker' approach that could exploit developments in distributed computing technologies. The development of the *service model* for software has been progressing for some time, and indeed, now underpins plans for the Grid. In IBHIS, we have successfully adapted, extended and employed service technologies to address the challenge and have brought them together to create a broker that provides a relatively large-scale demonstration of their use. As part of this, we have developed a new model for managing access control in a distributed environment, as well as mechanisms to enable semantic interoperability between data sources and the broker (Budgen *et al*., 2005).

In demonstrating our prototype broker to a mix of domain and technological audiences, we have not been able to identify any equivalent system in Europe, the USA or elsewhere. While some projects in healthcare (such as Nomad) and local government (such as LGOL-FAME) are drawing up *specifications* for such systems, none appear to have any form of implementation. This view has been reinforced by the selection of one of our papers as a track keynote at Medical Informatics Europe (Rigby *et al*., 2005), and also by the feedback received immediately after its presentation.

2. Software Service Architectures

The concept of a 'software service' extends the more constrained notion of 'web services' (Turner *et al*., 2003; Budgen *et al*., 2004). While the associated technologies are still emerging and evolving, they have proved to be stable enough for us to use as the basis for constructing a prototype demonstrator for our ideas (Kotsiopoulos *et al*., 2003; Turner *et al*., 2004). For our purposes, the key aspects of web services are that they provide platform and language-independence, largely through the provision of a 'document interface' style, together with the ability to perform *late binding*. All of these features have been exploited in the design of IBHIS.

3. The Broker Concept and Realisation

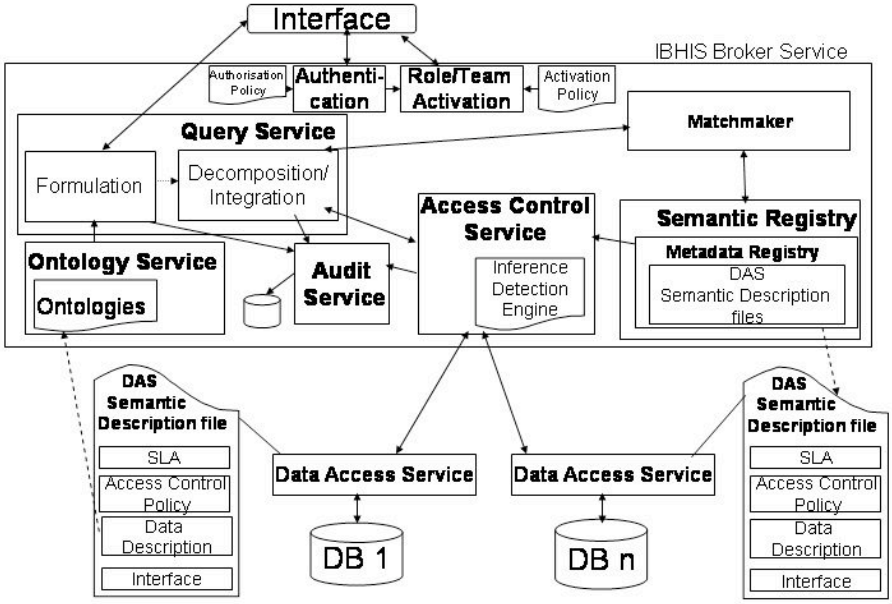
A useful definition of a broker is one that describes it as an entity that acts as a *trusted intermediary* during transactions. In the case of IBHIS, the broker system mediates between the end user (or team) and the set of

[1] Now the Informatics Division of the University of Manchester

relevant information sources (Bennett *et al*., 2003). It uses the query from the user, together with a registry system, to identify the set of relevant sources to consult; and its knowledge of the users status and current role to ensure that they only see the information that they are authorised to access (with the role being capable of dynamic modification to reflect changes of responsibility within a shift). The prototype broker exhibits a number of significant technological advances that are briefly summarised below.

1. ***Data Access Service (DAS).*** This is a key element in the IBHIS architecture, and is used to provide the mechanism through which the broker can access information from an autonomous source, as well as being responsible for ensuring that any requests conform to local access rules (Zhu *et al*., 2004; 2005). A DAS incorporates four key elements: the *DAS Description File* that provides a semantic description of the elements of the DAS; the *Metadatabase* that stores the mappings between the domain ontology and the local record structures (so simplifying evolution and change); the *DAS Engine* that analyses and authenticates queries and then uses the Metadatabase to translate these into the appropriate local form; and the *Data Sources* that provide local data storage.
2. ***Distributed Access Control.*** For IBHIS we have developed a new hybrid access control model that we term *Service-enabled Data Access Control* or S-DAC, that extends the role-based access control (RBAC)concepts, by adding features appropriate to the domain (dynamic team-based permissions, different levels of emergency over-ride etc.) and the ability to transfer authority (Turner *et al*., 2005). The process of access control in IBHIS is therefore a three-stage process involving: *Authentication* both of the individual and also their role and team membership elements (which may be time-dependent); *Data Access Control*, performed in terms of *attributes* after formulation of a query and before this is issued to the relevant DASs, and then in terms of *content* upon the returned values; and *Inference Checking* upon the returned data items to remove any information that would allow the user to infer knowledge that they would otherwise not be authorised to access.
3. ***Semantic Interoperability.*** The purpose of this is to enable a user to formulate a query using terms from the domain ontology, making IBHIS a second generation mediator system using the *local-as-view* form of schema. Semantic interoperability in IBHIS is addressed through three key elements: *Data Description* through extending the concepts that can be described by using XML, achieved through the use of OWL; a *Semantic Registry* that stores the domain ontology and the data description files—consulted by the broker when decomposing a query; and the *Query Engine* itself that is used to map between local data description and the global ontology.

The Figure below illustrates the relationships between these elements. (The broker is itself made up of statically bound services that perform the main functions, and this accesses data services that are dynamically bound—being redefined for each query, and with new providers being able to offer a service by registering with the Semantic Registry). Fuller details of the architecture are described in (Budgen *et al*., 2005).



4. Responses to Specific Questions

1. *What relevant technology trends are likely to impact on health and healthcare in the next ten to fifteen years?* We envisage continuing development of software service architectures and the migration of the Grid middleware systems to make greater use of these. This will in turn make decentralised information management both feasible and tractable—and in the process will remove the need to create new, complex (and potentially vulnerable) centralised record repositories.
2. *What areas in the provision of health and healthcare could be positively or negatively affected by these developments?* We see the provision of facilities such as the IBHIS broker as affecting both healthcare practice (the ability to draw information together across boundaries) and also research (making epidemiological studies more tractable and practical).
3. *What actions should be undertaken now to maximise positive impacts, or to prevent or minimise adverse effects?* The systematic collection and documentation of case studies for both practice and research is essential support for benchmarking. Also, our experiences show the potential benefits of working as an interdisciplinary team—and we would strongly advise that the research councils seek to find ways of encouraging such close working.
4. *Do you have any concerns with the generation, release and subsequent use of personal data?* We believe that the fine-grained access control mechanisms incorporated in IBHIS are robust enough to protect personal data—and again, removing the need to centralise the storage of such data will be an added degree of protection against unauthorised access.
5. *What medico-legal and ethical issues merit consideration when introducing new technologies, such as the responsibilities, processes and liabilities for decision making?* We have no comments on this.
6. *What regulations or other mechanisms (including standards) would facilitate the responsible development of relevant technologies?* We have no specific comments on this issue.
7. *What infrastructure would be required to allow any new technologies to be used effectively?* Apart from the obvious one of Grid support, we see the two challenges that emerge from the experience of demonstrating our system to a wide range of audiences from the healthcare domain as being: the need for a stronger ontological framework (we have used a subset of SNOMED-CT); and the development of an interface framework so that users see an interface that is familiar (used in the various tools that support their work) yet also tailored to their specific needs.
8. *What are the most likely promoters and barriers to the take up of new ICT devices and systems?* The barriers are both organisational and technological. A major example of the former, which we return to at the end of this response, is bridging the gap between a research prototype (such as IBHIS) and implementation. Technologically, we observe that the provision of an appropriate user interface is a major challenge for tools such as our broker. While researchers may be prepared to work with a 'generalised' form of interface (indeed, may want the flexibility it provides), those working in practices will need a minimal overhead. User interface technologies for engineering ergonomically satisfactory forms of interaction seem to be far from well-developed. On the output end, satisfactory visualisation/filtering of potentially large volumes of data will be an increasing issue.
9. *What education and training would need to accompany the introduction of any new technologies, and who would need to be involved?* We have no specific response to this question.
10. *How are professional roles and responsibilities likely to be affected by the increasing use of ICT?* The distributed virtual team will be one challenge that such technologies create, both in terms of how they interact, and how they deploy the greater access to information that arises. One of the questions that IBHIS raises is how the access permissions of a healthcare team can be aggregated?
11. *How can the development of technologies that meet patients' and informal carers' needs and are practically usable be best facilitated?* Our own experience suggests that interdisciplinary research and development teams are an essential element, and should be given high priority. Also, that such teams need to interact continuously throughout a project.
12. *What are the potential impacts of the costs of any of these new technologies?* A significant benefit should be the improvement in the ease of change—with present software technologies, evolution is still largely through major upgrades and new packages—service technologies offer scope for making incremental changes, as well as better scope to adapt to organisational change.

13. *What are the implications of the international use of future technological developments, such as global use of health data, variability of ICT-enabled support, and interoperability?* We have been considering some of these issues in a forthcoming bid to the EU. While a broker such as IBHIS can potentially operate across frontiers (and languages) there are some obvious potential issues such as the translation of ontologies and frameworks that need to be addressed.

The major issue that we would wish to raise, over and above these, is the need for better mechanisms for supporting the transition between a research prototype and application to practice. In other words, taking it from the laboratory and demonstrating it in the field, in order to assess how well the ideas scale up, and to provide evidence of its robustness to potential commercial developers.

During the final months of the project, and for some time afterwards, we provided talks and demonstrations to a range of audiences, from clinicians to researchers to GPs and patients, including a Nuffield Trust Symposium. Without exception, our ideas and illustrations were positively received. In addition, the final review of the project through EPSRC included comments such as "*this project has the potential to make a major impact in the Healthcare domain*" and "*the results of this project should be exploitable in the Healthcare domain within a three to five year time frame*". We have contact with at least two organisations that would be interested in collaborating in larger-scale trials of the broker concept in such areas as child protection and cancer research. Such a step would involve such activities as taking our demonstration prototype and providing it with the necessary interface, as well as developing tools to enable us to engineer DASs for different types of data store—activities that are a mix of research and initial development. However, we have not been able to identify any organisation that has a responsibility for funding such a *field trial* of the ideas involved in the broker.

References

Bennett KH, Gold NE, Layzell PJ, Zhu F, Brereton OP, Budgen D, Keane J, Kotsiopoulos I, Turner M, Xu J, Almilaji O, Chen JC and Owrak A (2003). A Broker Architecture for Integrating Data Using a Web Services Environment, in *Proceedings of First International Conference on Service-Oriented Computing (IC-SOC)*, Lecture Notes in Computer Science, 409-422, Springer-Verlag.

Budgen D., Brereton P. and Turner M. (2004). Codifying a Service Architectural Style, in *Proceedings of COMPSAC 2004*, IEEE Computer Society Press, 16-22.

Budgen D, Turner M, Kotsiopoulos I, Zhu F, Russell M, Rigby M, Bennett K, Brereton P, Keane J and Layzell P (2005). Managing healthcare information: the role of the broker, in *From Grid to HealthGrid: Proceedings of HealthGRID 2005*, Oxford, April 2005, IOS Press, 3-16.

I. Kotsiopoulos, J. Keane, M. Turner, P.J. Layzell and F. Zhu (2003). IBHIS: Integration Broker for Heterogeneous Information Sources, in *Proceedings of COMPSAC 2003*, IEEE Computer Society Press, 378-384.

Rigby MJ, Budgen D, Brereton OP, Bennett KH, Russell MJ, Turner M, Kotsiopoulos I, Layzell PJ, Keane J and Zhu F (2005b). The Data-Gathering Broker—A User-Based Approach to Viable EPR Systems. *Accepted as Track Keynote for Medical Informatics Europe (MIE 2005)*, August 2005.

Turner M., Budgen D. and Brereton O.P. (2003). Turning Software into a Service, IEEE Computer, 36(10), 38-44.

Turner, M, Zhu, F, Kotsiopoulos, I, Russell, M, Budgen, D, Bennett, K, Brereton, P, Keane, J, Layzell, P, and Rigby, M. (2004). Using Web Service Technologies to create an Information Broker: An Experience Report, in *Proceedings of ICSE 2004*, IEEE Computer Society Press, 552-561.

Turner M, Brereton OP and Budgen D (2005). A service enabled access control model for distributed data. *Accepted for publication in IEE Proceedings—Software*, Special Issue on Access Contrtol.

Zhu F., Turner M, Kotsiopoulos I., Bennett K. Russell M., Budgen D., Brereton P., Keane J., Layzell P., Rigby M. and Xu J. (2004). Dynamic Data Integration Using Web Services, in *Proceedings 2nd International Conference on Web Services* (ICWS 2004), IEEE Computer Society Press, 262-269.

Zhu F., Turner M, Kotsiopoulos I., Bennett K. Russell M., Budgen D., Brereton P., Keane J., Layzell P., Rigby M. and Xu J. (2005) Dynamic Data Integration: A service-based Broker Approach. *accepted for publication in* International Journal of Business Process Integration and Management (IJBPIM).