Institution: Newcastle University

Unit of Assessment: 11 Computer Science and Informatics

Title of case study: Expansion of the middleware software market

1. Summary of the impact

Research work on middleware for distributed computing at Newcastle has directly contributed to the growth of the worldwide middleware software market currently valued at $20bn. Specifically, the Web-service transaction standards used within the world's prominent middleware products, including the market leading WebSphere product from IBM and the JBoss middleware product from Red Hat Inc., the world's leading provider of open source solutions, owe their origins to this research work. The transaction software used within the JBoss middleware is also derived from this work.

The work in the past led to the creation of the spin-off company Arjuna Technologies, which continues to have an economic impact today, and to the establishment of the Red Hat R&D Centre in 2010 at Newcastle University, which has strengthened investment from international sources in research on leading-edge enterprise technologies.

2. Underpinning research

Research on distributed transaction processing middleware carried out by Prof. Shrivastava (*Lecturer*, *Professor from 1978-2011, emeritus from 2011*) and his research group that included Parrington (*RA from 1985-1996*), Caughey (*RA from 1990-99),* Little *(RA from 1990-2000*), Wheater *(RA from 1990-2000),* and Ingham *(RA from 1992-2000*), led in 1995 to the development of a toolkit for reliable distributed computing named *Arjuna* [P1].

A key design goal of Arjuna was to perform the integration of mechanisms – for locating and invoking operations upon local and remote objects, for concurrency control, for error detection and recovery from failures - in a manner that makes them not only easy to use but also permits application-specific enhancements. The innovative feature of Arjuna is the way this goal was accomplished by exploiting object-oriented structuring concepts present in widely used programming languages such as C++ and Java.

At the heart of the Arjuna system is an *AtomicAction* module (a protocol engine) that performs commit/abort of a transaction by processing instances of *AbstractRecord* objects registered by each of the objects taking part in the transaction. An object is free to provide its own implementation of A*bstractRecord* thereby enabling object specific commit/abort processing. This novel structuring concept is highly relevant in an open setting where a transaction manager should be able to control arbitrary types of objects (including legacy databases) within a transaction.

These features of Arjuna proved very effective in building reliable distributed applications resulting in impacts which shaped the industry as detailed in the section, *Route to Impact*. The research group won The British Computer Society's 'BCS IT Award' for the year 2000.

The group continued the research work on transaction services and middleware and in collaboration with IBM during 1999-2000 developed the concept of the *Activity Service* - a refinement of the AtomicAction module - for 'extended' transactions ([P2], co-authors Houston and Robinson are from IBM). This work was incorporated into a number of open industry standards in transaction processing and laid the foundation for the middleware products within Red Hat that contain Web-service transactions.

Subsequent research work, using the resources of several grants of which G1 and G2 are the main ones, focused on middleware for supporting inter-organisation services where issues of trust, security, fault tolerance and ensuring compliance to service contracts are of great importance ([P3], Little from Red Hat, Wheater from Arjuna Technologies).

The impact of the underpinning research is enabled through Arjuna Technologies, Red Hat's research centre and other industrial links.

3. References to the research

[P1] Parrington, G. D., Shrivastava, S. K., Wheater, S. M., & Little, M. C. (1995). "*The design and implementation of Arjuna*", USENIX Computing Systems Journal, 8(3) summer, pp. 255-308. *Google Scholar 155 citations* [*Key ref.]

[P2] Houston, I., Little, M. C., Robinson, I., Shrivastava, S. K. and Wheater, S. M. (2003), "*The CORBA Activity Service Framework for Supporting Extended Transactions*". Software: Practice and Experience, 33(4), pp 351–373. doi:10.1002/spe.512.

[P3] Little, M., Shrivastava, S., & Wheater, S. (2012)., "*Another look at the middleware for dependable distributed computing*", Journal of Internet Services and Applications, Special issue on the future of middleware, 3(1), pp 95-105

Key research grants:

[G1] EPSRC: *Trusted Coordination in Dynamic Virtual Organisations*, £360 000. PI: Shrivastava, period: 2004–2007. *[Was judged 'outstanding' by the reviewers].*

[G2] EPSRC platform grant: *Networked Computing in Inter-Organisation Settings*, £400,000. PI: Shrivastava, period: 2005 – 2010.

4. Details of the impact

Research work at Newcastle University has contributed to major international standards and to the development of the worldwide middleware software market currently valued at $20bn [E1]. The impact of this research work dates back to the late 90's and it has continued to have substantial impact into the 2008-13 period. Hence the next section provides relevant background.

Route to impact

Arjuna Technologies Ltd, whose origin dates back to 1998, is a spin-off company founded by the researchers (Shrivastava, Caughey, Wheater, Little and Ingham) to commercialise the ground-breaking results of the research into middleware technologies (Arjuna system).

The structure of *Arjuna* [P1] and *Activity Service* [P2] directly led to the development of two transaction standards released by the international computer industry standards consortium, OMG [E2]; *Object Transaction Service (OTS)* and its enhancement, *Additional Structuring Mechanisms for the OTS* also known as the *CORBA Activity service*. The company built on this success by creating a standards compliant transaction system product of the Arjuna system ready for the upcoming Java middleware market.

In 2005, the major Java middleware company, JBoss, bought the Arjuna transaction system software to enhance its product line (JBoss application server), and "gain advantage over its main competitor", BEA Inc. [E3] (now part of Oracle). JBoss was later acquired by Red Hat Inc., the impact of which was market advantage and leadership for Red Hat in the international open-source enterprise application server market. Red Hat subsequently opened the *JBoss Middleware Development Unit* at Newcastle in 2006.

A study [E4] conducted by the ACM Impact project in 2008 "*to seek, on a technology-by-technology basis, the sources of the ideas, designs, and working prototypes of widely used software technologies*" clearly identified the distributed systems research work at Newcastle as having played an influential part in the development of the multi-billion dollar middleware industry, specifically mentioning the Arjuna transaction system.

These developments have continued to affect the international middleware market throughout the impact period and have paved a path for further impact.

Contribution to open standards

The success of the middleware software industry is dependent on conformance to open standards for software components and services that "*stimulate innovation, grow global markets, and protect the right of free choice of technology*" (https://www.oasis-open.org/org). OASIS is a global standards consortium with members including Google, Microsoft, IBM and BAE Systems.

The CORBA *Activity service* (see section *Route to Impact*), itself an industry standard, formed the basis of the OASIS WS-TX family of Web-service transaction standards which include *WS-AtomicTransaction (WS-AT), WS-BusinessActivity (WS-BA)* and *WS-Coordination (WS-C)* approved by OASIS in 2009 [E5]. Dr Ian Robinson, Distinguished Engineer at IBM and the Chair of OASIS WS-TX Standards Committee, confirms that the origins of WS-C are in the *CORBA Activity service* [E6].

OASIS Web-service transaction standards are the *de facto* standards so all major vendor's products implement them; in addition to IBM (WebSphere) and Red Hat (JBoss), these include Oracle (WebLogic) and Microsoft (.NET on Windows). It is conformance to open standards that has allowed the successful growth of the middleware industry.

Creating new business, improving the performance of existing businesses

Within Red Hat, the original Arjuna transaction system software (ATSS) continues to be of use in enhancing their middleware products with customised transactional services to meet new application requirements. ATSS was instrumental in the design of WS-TX conformant Web-service transaction protocols within JBoss that enabled Red Hat to produce, in 2008, the world's first implementation [E7]. Two additional cases, both spurred on by the increasing popularity of cloud computing deserve specific mention.

(i) 'RESTful' Web-services - a new way of application structuring - has gained prominence lately but unfortunately these services are unable to make use of WS-TX transaction protocols. Red Hat were the first to produce a customised transaction solution, in 2010, and theirs is the only open source product offering RESTful transactions [E7].

(ii) Cloud based applications are increasingly making use of new types of database systems, often referred to as NOSQL databases, for gaining high scalability; unfortunately most of these databases have little transactional support. Red Hat JBoss Data Grid is a notable exception, offering transactions.

JBoss has allowed Red Hat to compete in the middleware market with other major vendors with products like WebSphere (from IBM) and WebLogic (from Oracle). In fact, the Web-service transaction module (WS-BA) within IBM's WebSphere application server, the world's dominant commercial application server, is also implemented as an *Activity service* (result of Newcastle research) [E6].

In summary, ATSS has helped Red Hat to produce enhanced products. In 2011, Red Hat released their new product *OpenShift,* a *PaaS (Platform-as-a-service)* solution for the cloud which integrates closely with JBoss (which uses Java Enterprise Edition), indicating that "*With this new integration, OpenShift becomes the first PaaS in the industry to deliver Java Enterprise Edition (EE) 6, simplifying how application developers build and deploy Java in the cloud*". In 2012, Red Hat announced its cloud computing strategy, with "*plans to deliver the OpenShift cloud application platform available as a PaaS for enterprises in an open and hybrid cloud…….we expect the enterprise PaaS market to be worth more than $3 billion by 2015*" (press archives [E9]).

Besides the benefit to Red Hat, follow-on beneficiaries include those that use this software to enhance their operations, e.g. Autotrader UK, Brazil's Ministry of Health and Frost Bank USA who have all reported benefits like improved business performance, better security, reliability and efficiency (case studies available at [E8]).

Arjuna Technologies, economic benefits & transfer of knowledge to industry

The impact presented above is on the growing international middleware market of Web technologies and cloud computing. The research has also had an impact by bringing part of the economic benefit of this growth to the UK. It is estimated that Arjuna Technologies has contributed over $19M gross value-added (GVA) to the region in shareholder return, salaries and infrastructure spend (all from US-based software companies), and provided over 150 person-years of high technology employment [E10].

The purchase of the Arjuna transaction system software and proximity to research expertise in the areas of middleware and cloud computing played a large part in Red Hat deciding to create an R&D centre outside of the USA in 2010 [E11]. The centre is estimated to have contributed $15M GVA and 75 person-years of high-tech employment.

The presence of Arjuna and Red Hat has strengthened the UK's links with & investment from major global businesses in the field [E10]. A number of highly skilled people have taken up specialist roles in industry that draw on their research at Newcastle University: the researchers, Caughey and Wheater are respectively, CEO and CTO at Arjuna Technologies. Ingham is a Program Manager at Microsoft, Redmond, and Little is Vice President of Engineering and Fellow at Red Hat.

5. Sources to corroborate the impact

[E1] "Market Share Analysis: Application Infrastructure and Middleware Software, Worldwide, 2011", Gartner, April 2012, www.gartner.com/id=1992415

[E2] Transaction service release pages (2002) http://www.omg.org/spec/TRANS/1.3/ & http://www.omg.org/spec/OTS/1.0/

[E3] Press report: "JBoss goes upscale with Arjuna deal", (2005) www.theregister.co.uk/2005/12/05/jboss_arjuna_acqusition/, The register, 5th December.

[E4] Emmerich, W., Aoyama, M. & Sventek, J., "*The Impact of Research on the Development of Middleware Technology*", ACM Transactions on Software Engineering and Methodology, Vol. 17, No. 4, Article 19, 2008, 1-48.

[E5] Approval of the three WS-TX 1.2 OASIS Standards. https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=ws-tx

[E6] Corroboration from IBM;
see also http://ianrobinson.blogspot.co.uk/2007/01/roots-of-ws-coordination.html

[E7] Corroboration from Red Hat.

[E8] Case studies http://www.redhat.com/resourcelibrary/case-studies/

[E9] Red Hat press release archive http://gb.redhat.com/about/news/press-archive/

March 2012: http://www.redhat.com/about/news/press-archive/2012/3/red-hat-reports-fourth-quarter-and-fiscal-year-2012-results

August 2011: http://www.redhat.com/about/news/press-archive/2011/8/red-hat-is-first-to-deliver-java-ee6-via-platform-as-a-service-with-openshift

[E10] Corroboration from Arjuna Technologies Limited.

[E11] Red Hat press release (2010) "*Red Hat Research Centre Opens At Newcastle University….*", https://www.redhat.com/about/news/press-archive/2010/3/2963.