

Institution: Newcastle University

Unit of Assessment: 11

Title of case study: Expansion of the middleware software market

Period when the underpinning research was undertaken: 2000-2011

Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Santosh Shrivastava Barry Hodgson	Senior Research Investigator Director of Strategy NICD	1986- present 1998- present

Period when the claimed impact occurred: 2013-2020

Is this case study continued from a case study submitted in 2014? ${\sf Y}$

1. Summary of the impact (indicative maximum 100 words)

Newcastle's Arjuna transaction system software (ATSS) has contributed to international transaction processing standards and to the middleware products market through Red Hat, the world's leading provider of open source software products. Since REF 2014, ATSS (also known by its new name *Narayana*) has not only increased the scale of its impact but also increased the breadth by integration into a number of additional Red Hat middleware products. After IBM's acquisition of Red Hat in 2019, a number of Red Hat products (with Narayana) are shipped in IBM's Cloud Pak for Applications product, increasing the customer base. The impact presented above is on the growing global market for Application Infrastructure and Middleware (AIM) Software, estimated at US\$30.6bn in 2020 and projected to reach US\$45.7bn by 2027. [*redacted*]

The underpinning research also continues to have an impact through economic benefit to the UK. Red Hat has continued to invest in its European Middleware HQ based in Newcastle. [redacted]

2. Underpinning research (indicative maximum 500 words)

Research on distributed transaction processing middleware carried out by Prof. Shrivastava (Lecturer, Professor from 1978-2011, emeritus from 2011) and his research group led to the development of a toolkit for reliable distributed computing named *Arjuna*. 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. Arjuna supports a computation model in which applications manipulate objects under the control of *atomic transactions* (also referred to as *atomic actions*). A transaction is characterised by *ACID* (Atomicity, Consistency, Isolation and Durability) properties. In an ACID transaction, either all of the work conducted within its scope is performed (no failure case: transaction is said to be *committed*) or no work is performed, meaning the effects of any partial work are undone (failure case: transaction is *aborted*). Typical failures causing a transaction to abort include computer crashes and network related failures causing continued loss of messages.

At the heart of the Arjuna system is an *AtomicAction* module (a transaction manager) that performs commit/abort of a transaction in a novel application specific manner. 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. The group continued the research work on transaction services and middleware, and in collaboration with IBM



developed the concept of the *Activity Service* - a refinement of the AtomicAction module - for *extended transactions* ([P1], co-authors Houston and Robinson are from IBM).

It has long been realised that ACID transactions by themselves are not adequate for composing business activities (that are long running applications), as aborting a constituent transaction might not be practical or even possible. What is required is non-ACID transaction model where constituent transactions can be selectively *committed, aborted* or *compensated*. Such a model is frequently referred to as an extended transaction or LRA (long running activity). The Activity Service is a framework for supporting any transaction model, whether ACID or non-ACID.

Results from the above work were incorporated into a number of open industry standards in transaction processing [P2] and laid the foundation for transaction processing middleware products from Red Hat, the world's leading provider of open source software products. [P2]. Red Hat middleware with enhanced transaction support provided by Arjuna software proved a key enabler for its widespread adoption in the emerging world of cloud computing.

3. References to the research (indicative maximum of six references)

[P1] 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. DOI: <u>10.1002/spe.512</u>

[P2] Little, M. C., & Shrivastava, S.K. (2011), "The evolution of the Arjuna Transaction Processing System". In: C.B. Jones, J.L. Lloyd (eds.) Dependable and Historic Computing, LNCS 6875, pp. 323–343, Springer. DOI: <u>10.1007/978-3-642-24541-1_25</u>

[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 (indicative maximum 750 words)

The Arjuna transaction system software, ATSS (also known by its new name *Narayana* [E1]) plays a central role in enhancing Red Hat middleware products with transactional services [E1, E2].

The Activity Service [P1], itself an Object Management Group (OMG) industry standard (known as the Additional Structuring Mechanisms for the Object Transaction Service) formed the basis of a number of ACID and non-ACID extended transaction standards for Web services produced by OASIS, a global standards consortium [P2]. The structure of the AtomicAction module of ATSS/Narayana made it relatively straightforward to incorporate the features required by the Activity Service so that both ACID as well as non-ACID extended transactions (LRAs) can be supported with equal ease [P2]. Thus, the ATSS/Narayana software was instrumental in the design of standards conformant Web-service transaction protocols that are within Red Hat's Java middleware platform product JBoss EAP (Enterprise Application Platform).

Since its inception, ATSS/Narayana has continued to be a central part of Red Hat's Middleware offering, providing the transactions engine for the hugely successful Java middleware platform product EAP. ATSS/Narayana has increased the scale of its impact, as EAP sales have continued to grow at around [*redacted*] and increased the breadth of its impact by integration into a number



of additional Red Hat middleware products, including Quarkus, Vert.x, Fuse, AMQ, BPM Suite, Thorntail and DataGrid [E1, E2].

In July 2019, IBM closed its landmark acquisition of Red Hat for \$34bn and Red Hat product sales are now growing faster, by leveraging the deep IBM customer base. Red Hat revenue increased 18% in the first quarter of 2020, sales increased by 50% over the previous year and Red Hat signed the largest deal in its history [E3]. Whilst Red Hat has never reported on individual products, it is internally recognised that the Red Hat Enterprise Linux product attracts around 50% of global revenue with Middleware sales accounting [redacted] Red Hat reported full fiscal year total scale of impact is visible. Integrated in EAP, ATSS/Narayana now supports global mission critical business applications attracting sales of [*redacted*].

The additional breadth of ATSS/Narayana impact can be seen through greater market share and a larger developer community for the Red Hat products in which it is integrated. Market share for EAP continues to soar. In 2017, Tomcat was the clear leader with 63.8% of the Application Server market with EAP/WildFly in second place at 13.8% [E5]. Red Hat leads the Tomcat project and ATSS/Narayana is also added to the Tomcat distribution. This has created a distribution channel for ATSS [redacted] The channel has widened further for ATSS/Narayana recently with Microsoft partnering with Red Hat to enable users to run JBoss EAP on the Azure App Service [E6].

The impact period 2013-2020 has seen enterprises moving their IT services to the cloud. Cloud platforms are increasingly building applications from loosely coupled modular components, termed *microservices*. This move to building applications from loosely coupled microservices has accelerated the interest in non-ACID extended transactions (LRAs) as the composition mechanism. The Microprofile project of the Eclipse Foundation (that hosts a global community of active open source projects) is one of the most prominent efforts aimed at optimizing Enterprise Java for the microservices architecture. The Eclipse MicroProfile LRA is based on WS-LRA extended transaction model developed by the OASIS Web Services Composite Application Framework Technical Committee [E7]. WS-LRA is part of a number of ACID and non-ACID extended transaction standards for Web services produced by OASIS that - as stated earlier-based on the Activity Service (see also [E8]).

Red Hat's MicroProfile LRA implementation is based on ATSS/Narayana. Red Hat's new Java platform Quarkus now incorporates MicroProfile. In less than a year since it was released, adoption of Red Hat's Quarkus has skyrocketed with 16% of enterprise java developers now using the framework [E1]. In September 2019, Red Hat recorded 55,000 new users and 250,000 page views for Quarkus in one month [E1]. In addition, customers of IBM's Cloud Pak for Applications product now have access to the full portfolio of Red Hat's Runtimes and associated components. EAP and Quarkus are part of Red Hat Runtimes, which since 2019 is shipped in IBMs Cloud Pak for Applications and pushed to new and existing customers as the suite of software they should use when either migrating from WebSphere or thinking about building new Cloud-based applications. In this way it is clear that EAP, Quarkus and therefore ATTS/Narayana are becoming the default for IBM customers building new applications [E9].

The impact presented above is on the growing global market for Application Infrastructure and Middleware (AIM) Software, estimated at US\$30.6bn in 2020 and projected to reach US\$45.7bn by 2027 [E10]. The research also continues to have an impact through economic benefit to the UK. Red Hat has continued to invest in its European Middleware HQ based in Newcastle, moving to Newcastle University's Catalyst building in 2019. [*redacted*]

5. Sources to corroborate the impact (indicative maximum of 10 references)

[E1] Corroboration from Red Hat (Letter of support from Dr. Mark Little, VP Red Hat)

[E2] Corroboration from Red Hat (Letter of support from Mike Piech VP, General Manager Middleware Business Unit, Red Hat)



[E3] https://www.zdnet.com/article/ibms-first-guarter-results-get-a-boost-from-red-hat/

[E4] <u>https://www.redhat.com/en/about/press-releases/red-hat-reports-fourth-quarter-and-fiscal-year-2019-results</u>

[E5] <u>https://dzone.com/articles/most-popular-java-application-servers-2017-</u> edition or <u>https://newsroom.eclipse.org/news/announcements/amid-growth-cloud-native-</u> enterprise-java-adoption-eclipse-foundationannounces or https://www.infog.com/news/2020/02/developer-surveys/

[E6] <u>https://techcommunity.microsoft.com/t5/apps-on-azure/public-preview-a-managed-jboss-eap-experience-on-azure/ba-p/1700210</u> and <u>https://twitter.com/ccompy/status/1308562306259795968</u>

[E7] Eclipse MicroProfile LRA: <u>https://github.com/eclipse/microprofile-</u> <u>lra/blob/master/spec/src/main/asciidoc/microprofile-lra-spec.adoc</u>

[E8] Remarks by Eric Newcomer, WS-CAF committee member: https://www.infoq.com/articles/newcomer-on-ws-standards/

[E9] <u>https://access.redhat.com/articles/4394291</u> and <u>https://www-01.ibm.com/common/ssi/cgi-bin/ssialias?infotype=AN&subtype=CA&htmlfid=899/ENUSLP19-0686</u>

[E10] <u>https://www.reportlinker.com/p05817914/Global-Application-Infrastructure-and-Middleware-AIM-Software-Industry.html?utm_source=GNW</u>.