



Final Project Documentation D1.2.1

Contract no. 511085
Acronym: PROVENANCE
Full Title: *Enabling and Supporting Provenance in Grids
for Complex Problems*

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The PROVENANCE project receives research funding from the European Community's Sixth Framework Programme

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1 Introduction

In this document we provide a roadmap to the EU Provenance project’s document output. This output is categorised according to the project’s deliverables. By providing this document for reviewers of the project we aim to facilitate navigation through the output of the project and to help provide an appreciation of the project’s overall contributions. The documents described below are split into eight categories as shown in [Figure 1](#).

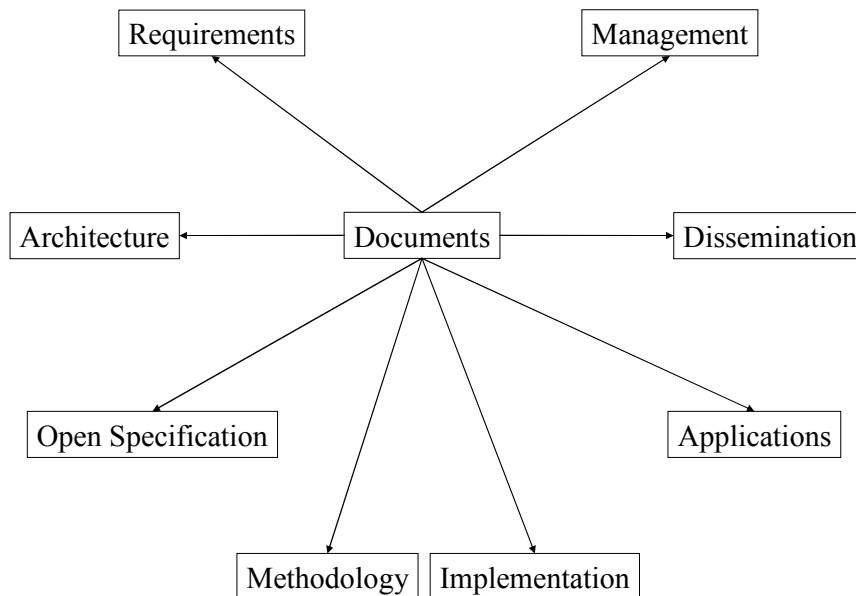


Figure 1: Documentation Roadmap

These categories describe the documents produced by the project as follows:

1. *Requirements* describes the set of documents produced as input to the other workpackages
2. *Architecture* describes the set of documents that relate to the project’s architecture for provenance systems
3. *Open Specification* describes the set of documents that set out the open specification model of the provenance architecture
4. *Methodology* describes the project’s best practice methodology for designing provenance aware applications
5. *Implementation* describes the documents leading to a scalable, secure implementation of the architecture
6. *Applications* describes the documents produced by the demonstration application partners

7. *Dissemination* describes the project's published papers in a variety of workshops, conferences and journals that contribute to the dissemination of the project's findings
8. *Management* describes the documents generated as part of the management of the project.

Following the sections covering these categories, we provide a section that contains an overview of all the contractual deliverable together with a complete bibliography of all the project publications.

2 The Provenance Requirements

Requirements were gathered by SZTAKI for the Provenance Architecture and subsequent implementation. These were gathered via an online questionnaire and were analysed to produce first a User Requirements document [14] from which was generated a Software Requirements document [15]. These then provided the input requirements to Southampton's Provenance Architecture activities. Documents produced later in the project justified design decisions based on these requirements.

3 The Provenance Architecture

A key deliverable of the EU Provenance project was the design of an architecture for provenance systems. Such an architecture was to be designed in a technology independent manner and would provide the framework for the design of a provenance store implementation (undertaken by IBM). In pursuit of this aim, Southampton researched and designed an architecture, whose development was captured by three key documents. First, the document entitled *A Proof of Concept Design for Provenance* [32] described a pre-prototype architecture that raised a number of important issues. Second, a document entitled *A Logical Architecture Strawman for Provenance Systems* [73] was delivered that described in much more detail a provenance architecture. Work on this architecture continued, resulting in many interim releases of the document describing the final architecture for the project (ten in total). This final document, entitled *An Architecture for Provenance Systems* [16] became the key reference in the development of the Provenance Store – a concrete architecture designed by IBM for the EU Provenance Project, of the Client Side Library developed at Southampton [36], and of the Provenance Tools developed by Cardiff University.

3.1 Papers describing the Provenance Architecture

Several papers have been authored that examine different aspects of the architecture. Of historical interest, the paper, *A proof of concept: Provenance in a Service Oriented Architecture* [54] presented a first look at the Provenance Architecture. In *Security Issues in a SOA-based Provenance System* [86] the security considerations pertaining to a Service Oriented Architecture based provenance system are discussed and approaches to address them are presented.

Two investigations were carried out over the summer of 2006 that resulted in two

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technical reports being released. The first examined the visualisation of provenance information and is entitled *An Investigation into Provenance Visualisation (Summer Project Report)* [52], and the second, entitled *An Investigation on the Performance of Storing the Process Documentation in a Relational Database -Summer Project Report-*, examined the performance of a provenance store based on the architecture when tied to a relational database [62].

In addition to the above documents, Southampton has also released other documentation for partners to facilitate their use of the architecture. In *Linking 101* [80], a tutorial on aspects of the architecture is given that enables distributed process documentation to be systematically stored. Finally, a document was written that provides answers to frequently asked questions about the architecture. The document can be accessed from the following link [61].

At the International Provenance and Annotation Workshop held in Chicago, May 2006, the Southampton team presented a paper entitled, *Principles of High Quality Documentation for Provenance: A Philosophical Discussion* [58] in which several principles for documenting the past, grounded in work from philosophy and history are derived, which allow for provenance questions to be answered within a computational context. The paper provides a rationale for the adoption of certain key assumptions during the development of the Provenance Architecture. The publication entitled *Provenance and Annotation of Data—The International Provenance and Annotation Workshop (IPAW)* [74], presents all the papers presented at IPAW.

In the Provenance Challenge (see below for a description of this Southampton organised event), Southampton presented a paper entitled, *Extracting Causal Graphs from an Open Provenance Data Model* [69]. This paper describes Southampton's open provenance architecture (OPA), which is based on the Open Specification also developed by Southampton. A noticeable feature is that distinctions are made between the data recorded about what has occurred, *process documentation*, and the *provenance* of a data item, which is all that caused the data item to be as it is, and is obtained as the result of a query over process documentation. This distinction enables the tailoring of the system to separately address the requirements of recording and querying documentation.

4 Open Specification Documents

These documents introduce a framework for computational provenance; a set of nine technical specifications that define the normative description of the provenance framework in terms of a SOA model and related XML definitions. These technical specifications, summarised in [Figure 2](#), define the means by which: a computational representation of process documentation can be realised, how process documentation can be recorded and queried, how the recording and querying of process documentation can be made secure, and how process documentation can be recorded in distributed systems.

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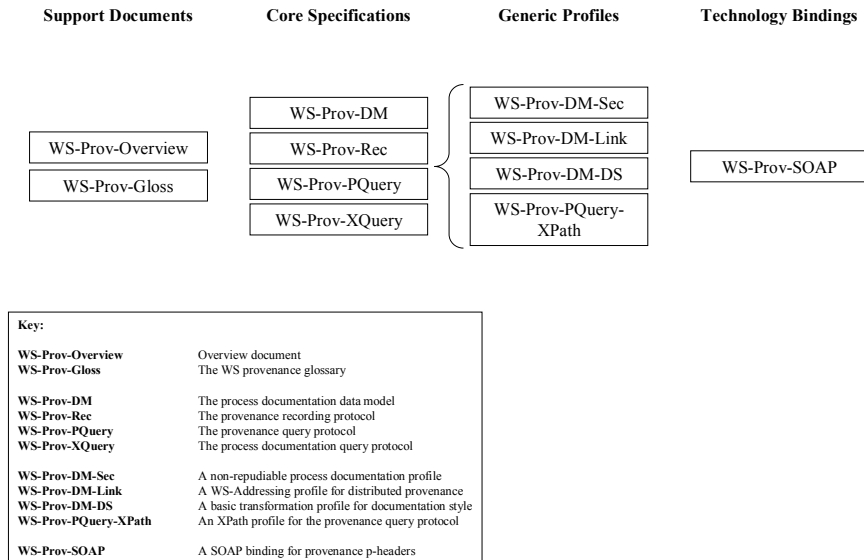


Figure 2: The Open Specification Documents

The family of documents comprise a set of two support documents [40, 50], four documents that introduce and specify the core framework [41, 42, 43, 44], four generic profiles that extend the basic framework [45, 46, 47, 48] and one example of a technology specific binding [49].

In support of the Open Specification the paper entitled, *Standardisation of Provenance Systems in Service Oriented Architectures—White Paper* [76] presents provenance in computer systems as a mechanism by which business and e-science can undertake compliance validation and analysis of their past processes. It describes how an open approach can bring benefits to application owners, IT providers, auditors and reviewers, and specific recommendations to move forward a standardisation activity in this domain are made.

4.1 Papers describing the Open Specification

In the *Report on the International Provenance and Annotation Workshop (IPAW'06)* [53] a descriptive account of the discussions that arose between participants during IPAW is given. These discussions centered on the differing uses of the term 'provenance' by the participants. These differences are captured in the paper entitled *Usage of 'provenance': A Tower of Babel. Towards a concept map* [72], in which a concept map that summarises key associated concepts and their relationships to provenance is described; importantly, such a concept map helps avoid ambiguities of current usages, which is key if the community is to be able to move towards a common standard.

In the *Special Issue on the First Provenance Challenge* [77] the provenance

challenge is described: a special event organised by Southampton to further the development of an open standard for provenance systems. In particular, the challenge examines the following points:

1. The representations that systems use to document details of processes that have occurred.
2. The capabilities of each system in answering provenance-related queries.
3. What each system considers to be within scope of the topic of provenance (regardless of whether the system can yet achieve all problems in that scope).

In *The Provenance of Electronic Data* [75], a description of the provenance lifecycle is given as well as an argument for the need for an open approach to provenance. The paper also describes how a provenance system can be used in a medical domain application.

5 The Provenance Methodology

In addition to the development of the Provenance Architecture, Southampton developed a methodology to allow application developers to design provenance-aware applications. This methodology went through two major iterations resulting in *PrIME: A Methodology for Developing Provenance-Aware Applications* [18], which greatly extended the original methodology.

5.1 Papers describing the Provenance Methodology

As well as developing the provenance methodology and authoring two documents that can be used by application developers to make their applications provenance aware, Southampton has also authored a paper entitled *PrIME: A Software Engineering Methodology for Developing Provenance-Aware Applications* [79], that presents PrIME from a software engineering methodology perspective. This paper was presented at the International Workshop on Software Engineering and Middleware in November, 2006.

In *Provenance in Agent-mediated Healthcare Systems* [66], three aspects of provenance in agent-mediated healthcare systems are examined, first provenance is defined and shown how it can be applied to agent-mediated healthcare applications; second, a method for independent and autonomous healthcare agents to document the processes they are involved in without directly interacting with each other is described; and third, it is shown how this method solves the privacy issues of provenance in agent-mediated healthcare systems. The paper provides insight how the Provenance Architecture can be applied to a domain using the provenance methodology.

6 The Provenance Implementation

The Provenance Implementation is a reference implementation of the Provenance Architecture including features to support the security and scalability requirements. The requirements were extracted from the software requirements document and

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addressed in two versions for each of the security [19 and 20] and scalability [21 and 22] requirements. Instead of a separate implementation for security and scalability, their final deliverables were included in the final implementation workpackage deliverable.

Three tools deliverables have resulted from the project. The first deliverable [23] described the overall Provenance Tool Suite – outlining interaction between the tools, and the criteria for selecting between different technologies to implement the tools. The two key selection criteria here involved choosing a suitable Portal technology, and choosing a suitable rule engine. The types of users most likely to utilize the tools was also outlined in this deliverable, along with assessment of requirements from the work undertaken in work packages 2 and 3. This assessment was subsequently discussed with colleagues from the application workpackages. Deliverable [24] describes the overall setup process, and various components that need to be configured during the setup process. A protocol is described in this document, along with particular states that need to be handled during this setup process. The setup involved in the Portal and the Analysis tool is also described – with suitable examples. Deliverable [25] describes the overall configuration process – outlining the types of configurations that would be needed within a provenance system in its entirety, and subsequently in the configuration of the tool suite. The deliverable also describes how the rule engine needs to be configured – with examples to demonstrate the process. The configuration of the Navigation and visualisation Tool is then described – again examples are provided to demonstrate the process. Performance results for uploading rules into the analysis engine, and for supporting provenance visualisation are also provided.

The implementation and integration workpackage first produced a proof of concept prototype based on existing technology [32]. It then produced a set of document deliverables to match the release of the reference implementation internally to the project [33] and later to the external community [34, 35 and 36]. The final deliverable includes details of the implemented security and scalability features.

6.1 Papers describing the Provenance Implementation

Cardiff has produced a number of publications and given demonstrations of the tool suite. All of the publications have been reviewed by international programme committees, and appear in the proceedings of the associated event. Cardiff have also given talks at various conferences to emphasise the importance of provenance in distributed systems.

Cardiff also participated at the IPAW event organised by the University of Southampton, and presented work on recording actor state – as reported in paper [89]. Three views on actor state are reported here:

1. when the actor records process documentation
2. when the actor uses the Client Side Library
3. when actor state needs to be inferred from the platform on which it is hosted.

Paper [88] demonstrates how actor state may be captured using the Ganglia monitoring tool. This is one of the most widely used monitoring engines within the

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Grid community, and also supported within the National Grid Service in the UK and the US TeraGrid project. Paper [83] demonstrates how actor state and interaction p-assertions can be used in a model to evaluate trust in a workflow.

A number of talks and demonstrations were also given by the Cardiff team. These included a demonstration at the UK eScience All Hands Meeting and at the Open Grid Forum [90, 92]. The demonstration was attended by a number of UK and European project participants, and has led to good subsequent interaction with these individuals. Another talk was given to participants who were not from the computer science area. This was delivered via the “Global Studio” site at Cambridge University, with participation from Keio University, Japan, Korean Information Society, and Korean Information Strategy Development Institute. The focus of this event was on the impact of “social networking” and “peer-2-peer” technologies on creativity in the arts. provenance mechanisms in Grid systems vs. those in the arts were compared and discussed. When comparing the proliferation of content creation by the “masses” – as witnessed in recent take up of “Blogs” and sites such as “YouTube” and “MySpace” – this talk focused on how one could assess the “provenance” of content that is provided via such media. Talk [91] was given at the UK Portals conference in Portsmouth University, where the criteria for selecting the eXo Portal was outlined, along with discussion of features that were made available in the provenance portal. Talks [109, 110 and 111] were given in Asia – as part of GridAsia 2006 and a subsequent collaboration meeting in Thailand. Here, the importance of provenance themes were outlined – with reference to other work taking place in the South East Asian High Performance Computing community. Provenance Tools being developed in the project were also outlined.

7 The Provenance Applications

The Aerospace and Organ Transplant Management applications used the software developed in the project implementation workpackage. Each application builder prepared a specification which described how their application would make use of the provenance architecture and identified any domain specific issues that needed to be addressed [26 and 29]. Following the implementation and deployment of the application [27 and 30], they each produced a report [28 and 31] which evaluated the use of provenance and assessed their applications against the original requirements used to generate the Provenance Architecture.

7.1 Papers describing the Provenance Applications

DLR has produced one publication and given a number of talks covering provenance from the viewpoint of engineering applications. The paper [67], presented at the IPAW’06 conference, describes the implementation of provenance in a simulation environment for engineering applications.

Members of the DLR team have given a number of talks and presentations in a variety of internal and public meetings. Two presentations, given at a joint ESA-DLR workshop [95] and an internal DLR workshop on integration technology, focused on

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integration and simulation environments and covered the benefits of provenance information within this context. A seminar talk at DLR [94] covered provenance terminology and the EU Provenance project.

The paper [56] describes the use of the Navigation tool within the EHCR application. The paper first describes how electronic healthcare records may be fragmented across different hospitals that a particular patient visits, and subsequently describes how the Navigation tool and the Portal may be used to analyse p-assertions that have been submitted to rebuild the treatment history of a patient. This paper also demonstrates close collaboration between the tools and OTM application workpackages. Paper [81] describes how the Analysis Engine and Analysis Tool can be used to undertake trust assessment from a workflow. Essentially, the key idea here is to demonstrate the use of the analysis engine as a way to assess whether the result that has been produced from a workflow can be “trusted”. A decision tree mechanism is used to make this evaluation.

8 Provenance Project Management

This section shows how the deliverables produced by workpackages 1 (Management) and 10 (Collaboration) are related. For the management periodic reporting, a series of reports were delivered at months 3 [1], 6 [2], 12 [3 and 4], 18 [5] and 27 [6 and 7]. These reports highlighted technical and management progress made during the reporting period. Exploitation of the project outcomes is a high priority objective of the project so a working exploitation strategy document was produced by the project with versions delivered at months 6 [9], 12 [10 and 11] and 18 [12]. At the end of the project in month 27, a final exploitation report was produced which provided an overview of the project [13]. This final documentation deliverable was also produced [8].

Workpackage 10 identified the collaboration of the project with others in the FP6 Framework. Its activities were reported periodically at months 4 [37], 12 [38] and 27 [39].

8.1 External references to the Provenance project

Southampton University generated a number of press releases throughout the project [123, 124 and 125] to advertise important activities. IBM through its Analyst Relations department arranged briefings for a number of IT Analysts about the project. These briefings resulted in references [119 and 128]. A further briefing has been arranged for December 2006 to report on the outcomes at the end of the project.

The project has also been identified in other news sites [120, 121, 126, 127 and 128].

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This section includes a formal bibliography of all documents generated by the Provenance Project. It includes contracted deliverables together with other research publications, talks and external announcements.

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