Towards a Threat Model for Provenance in e-Science

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Abstract. Scientists increasingly rely on workflow management systems to perform large-scale computational scientific experiments. These systems often collect provenance information that is useful in the analysis and reproduction of such experiments. On the other hand, this provenance data may be exposed to security threats which can result, for instance, in compromising the analysis of these experiments, or in illegitimate claims of attribution. In this work, we describe our ongoing work to trace security requirements for provenance systems in the context of e-Science, and propose some security controls to fulfill them.

1 Introduction

As an important paradigm of scientific research, computer simulations are increasingly being used to perform computational scientific experiments. As the scale of these experiments increase, scientific workflow management systems become a relevant tool to specify, execute, and analyze them. These systems can collect provenance information, often distributed in grids or remote clusters, that is useful in the analysis and reproduction of such experiments. If the appropriate security controls are not in place, provenance systems may be exposed to threats that may compromise the integrity, confidentiality, or availability of provenance data. In this work, we describe our ongoing work to trace security requirements for provenance systems in the context of e-Science, and propose some security controls to fulfill them. The study of security issues in provenance systems is relatively recent. However, some important security requirements, described in section 2, were not yet identified in related academic works, to our knowledge. In section 3, we conclude describing subsequent steps in our provenance security research.

2 Security Requirements for Provenance Systems

The typical execution of a workflow involves specifying its flow using some mechanism, such as a parallel scripting language or a GUI-based workflow specification tool. Later on, it can be executed by a workflow management system, this involves selecting appropriate computational resources, submitting tasks to these resources, and transferring data. After the experiment is executed, scientists typically face the challenge of analyzing a large number of output data files to understand the outcome of the

experiment, provenance systems are useful in this context since they can help to determine, for instance, which tasks were executed to generate a particular data object, and which parameters were used for these tasks. This provenance data is usually collected and stored during workflow execution, to describe causal relationships between tasks and data (retrospective provenance); or during workflow specification, to describe the planned tasks, and data flow (prospective provenance). In general, provenance data is accessed and analyzed by scientists using a query language, such as SQL. In our ongoing threat modeling effort, we are enumerating threats to each of these components of a provenance system. Many of these are already taken into account by security frameworks for underlying technologies used by provenance systems, such as databases and grids. Provenance security is a relatively recent research issue [12] [7] [14], found in different areas such as scientific workflows, databases, and storage systems. Provenance data is useful in security audits [1], and there are cases in which the subject of provenance data may lead to privacy concerns [3]. Braun et al. [2] analyze the problem of providing adequate access control techniques to provenance data, observing that it describes causal relationships, that are not adequately protected by commonly used access control techniques. Hasan et al. [9] [8] propose a security solution with the goal of protecting confidentiality and integrity of provenance data. They use asymmetric cryptography for achieving confidentiality and signature-based checksums for achieving integrity. Nagappan et al. [10] present a model for sharing provenance data that uses role-based access control techniques where the user dynamically select its confidentiality level. A common approach for protecting provenance information [2] [10] [11] is to use access control mechanisms to prevent unauthorized access to this information. None of these approaches allow for non-restricted dissemination of provenance information with maintenance of correct attribution, a requirement in the context of e-Science. Scientists, specially in the life sciences, often avoid sharing details of experiments prior to publishing their results in some academic journal or event, to assure correct attribution of scientific results. During this interval, scientific collaboration is prevented. Therefore, security controls that prevent illegitimate claims of attribution are an important security requirement for provenance systems. These controls must allow the verification of not only who executed an experiment but also when it was executed. A combination of digital signatures and cryptographic timestamps [6] were used in the Kairos [5] security architecture for provenance systems to provide these properties. Another desirable security property is fine-grained access control, where scientists can delegate to their collaborators access to provenance data, so it can be read or modified.

3 Concluding Remarks

This work describes our progress in defining a threat model and proposing security controls for provenance systems in the context of e-Science. We identify the assurance of correct attribution of scientific results as an important security requirement for these systems. For this purpose, we proposed Kairos [5], a security architecture for provenance that uses cryptographic timestamps [6] and digital signatures. We are working with the Swift [13] parallel scripting system to extend its provenance system [4] with appropriate security controls. As future work, we will investigate fine-grained access control techniques, and a data model to store and query security properties.

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