Web-Based Management of IP Networks and Systems

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To Béatrice

To the memory of Louise and Henri

Γηράσκω δ'ἀιεὶ διδασκόμενος

The older I get, the more I learn

Solon

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FOREWORD

Management is about monitoring the current state of network and system components, receiving event reports and controlling the components in order to provide the required service expected by users. Network management has concentrated on management of comparatively simple hardware devices such as routers and hubs. Telecommunications management has been concerned with managing more complex switches and intelligent network services. Systems management is concerned with managing resources such a disk store or memory and setting scheduling or security policies. However there is now a trend towards management of end-to-end services and applications rather than individual network and system components. These services may make use of many different network and system components, so a common standards based approach to management is essential.

Standards for management of networks and systems have been an elusive goal pursued by many in the Management Community over the past 10 years. In the early '90s we saw the war of words between protagonists for the Simple Network Management Protocol (SNMP), being developed for the Internet, and the various International Organization for Standardization (ISO) management standards being pushed by Telecommunications organisations. In spite of the so-called convergence between networking and telecommunications, SNMP was not widely used in telecommunications and the ISO standards were not used by the Internet community. Systems management was all vendor specific. The Distributed Management Environment (DME) from the Open Software Foundation was going to the be the saviour of all the world's management problems in the mid '90s but it quickly disappeared without trace. SNMP-based management is currently the dominant approach for network management and is being proposed as being suitable for systems and service management as well.

In this book, Jean-Philippe Martin-Flatin gives some interesting insights into the problems of SNMP-based management and evaluates many of the alternatives such as Java, mobile code and Web-based approaches. He proposes a Web-based Integrated Management Architecture (WIMA) which has the advantage that it makes use of widely used web

standards such as the HTTP protocol and XML for data representation, rather than inventing something specific for management. The prototype implementations described in the book indicate the practicality of the work and that it can make use of distributed processing concepts which will be essential for management of large-scale systems. Although it is very difficult for an individual to influence the many large organisations developing management solutions, I hope that the simplicity of the approach described in this book does make some impact.

Professor Morris Sloman

Imperial College, London, UK

PREFACE

The management of most IP networks is currently based on an open management architecture named after its communication protocol: the Simple Network Management Protocol (SNMP). We analyze a number of problems with this approach. Some are related to the efficiency, scalability, latency, and expressiveness of SNMP; others are due to the way the management-platform market evolved in the 1990s.

Although IP systems can also be managed with SNMP, in practice, their management usually relies on proprietary mechanisms. This defeats the purpose of open management and does not facilitate the integration of network management with systems management.

After reviewing the numerous alternatives that are currently investigated by the management community (e.g., mobile code and intelligent agents), we propose to base the next generation of management applications on a new management architecture: WIMA, the Web-based Integrated Management Architecture. WIMA is based on standard Web technologies. It relies on a push-based organizational model for regular management (i.e., data collection for offline processing, and monitoring over a long period of time) and notification/event delivery, and a pull-based organizational model for *ad hoc* management (data retrieval over a very short time period).

Its communication model is characterized by (i) the use of a standard communication protocol (HTTP) instead of a domain-specific protocol (SNMP); (ii) the use of persistent connections between agents and managers (and between mid- and top-level managers in distributed hierarchical management); (iii) the independence of the information model (SNMP MIB, CIM schema, etc.) and the communication model; and (iv) a reversed client-server architecture that facilitates crossing firewalls.

In WIMA, the preferred method for representing management data in transit is XML. It is well suited to distributed hierarchical management, and unifies the communication model across the range of disciplines covered by enterprise management (i.e., network, systems, application, service, and policy-based management). This facilitates the integration of management and offers high-level semantics to management-application designers.

All the major problems that we identified in SNMP are solved in WIMA. Our architecture is validated by a research prototype, JAMAP, which is described in Chapter 10.

Audience of this book

This book presents rather advanced material. It is not a primer. We assume that the reader already knows the basics of network management and object-oriented analysis & design, and introductory textbooks are referenced. Great care was taken to make this material readable to a vast audience, from practitioners in industry to students, from programmers to designers, and from administrators to managers.

The terminology defined in Chapter 2 clarifies frequent misunderstandings and should be valuable to all. Chapters 3, 4, and 6 can be used by academics for teaching B.S. and M.S. courses in distributed network and systems management, or by consultants for training administrators. They can also be instructive to MIS directors who wish to update their knowledge of enterprise management. Chapter 3 should benefit engineers in charge of designing and developing SNMP-based management applications. In Chapter 5, our analysis of the solution space should be interesting to managers and administrators investigating the current market. It explains why Web-based management is not only trendy, but also makes technical sense. Chapters 7, 8, and 10 should be very useful to start-ups and corporate organizations developing management applications, and to M.S. and Ph.D. students embarking on a Web-based management project. They contain a wealth of technical hints and tips that could save software designers and developers months of work. Finally, by explaining the advantages of using XML for representing management data, Chapter 9 should enlighten those professionals and students who still believe that Web-based management is only about adding a Web browser to an existing management application.

Index Keys

IEEE Web Thesaurus
<http://www.ieee.org/web/developers/webthes/>

- Communication System Operations and Management
- Web and Internet Services
- Management Information Systems
- Computer Networks

Computing Research Repository (CoRR)
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Copyright Notices

This book is derived from the author's Ph.D. dissertation, which was published by the Swiss Federal Institute of Technology, Lausanne (EPFL) in October 2000 [163]. Some parts are copied *verbatim*, but many sections have been updated or rewritten.

A fraction of the material presented in Section 3.3.1 was published in March 1999 in *The Simple Times*, the online magazine of the SNMP community [243]. This article was co-authored by Ron Sprenkels, who contributed several ideas explained there. This section also benefited from discussions that took place during the first meeting of the IRTF Network Management Research Group.

Early versions of the material presented in Chapter 4 were presented by the author in two articles: one published by Plenum Press (now part of Kluwer Academic) in the *Journal of Network and Systems Management* [160], and another published jointly by the University of Technology, Sydney, Australia and the University of Western Sydney, Nepean, Australia in the proceedings of the DSOM'97 workshop [158].

In Chapter 4, Fig. 5 is adapted from Weinshall and Raveh [285, pp. 56–57], published by Wiley.

Early versions of the figures in Chapter 7 and Chapter 8 appeared in a paper by the author published by the IEEE in the proceedings of the IM'99 symposium [161].

An early version of the material presented in Chapter 10 appeared in an article by the author published by Springer Verlag in the proceedings of the DSOM'99 workshop [162].

In Appendix A, we give the IETF's definition of the Interfaces Group in RFC 1213 [173, pp. 16–23]. This material is reproduced with the permission of the Internet Society.

In Appendix C, we include an example of CIM-to-XML metamodel-level mapping given by the DMTF [73]. This material is reproduced with the permission of the DMTF.

In Appendix D, we include an example of remote method invocation of a CIM object given by the DMTF [77, Section A.10]. This material is reproduced with the permission of the DMTF.

Finally, JAMAP, the software described in Chapter 10, was released by the author under the GNU General Public License of the Free Software Foundation [97].

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prototype described in Chapter 10 and for allowing release 0.4 of this software to be freely available under the GNU General Public License.

I thank my former Ph.D. supervisor, Jean-Pierre Hubaux, for welcoming me on his team at EPFL, for offering me exceptional working conditions, and for giving me a lot of freedom and independence while conducting my research. Thanks also to the members of my Ph.D. committee (Roland Balter, Subrata Mazumdar, André Schiper, and Morris Sloman) for the time they spent reviewing my dissertation and their valuable feedback.

I gratefully acknowledge that most of the implementation of JAMAP, the research prototype described in Chapter 10, was performed by Laurent Bovet [31] and Claire Ledrich [147] in the course of their M.S. theses, under my supervision. Laurent's work was funded by EPFL, Claire's by AT&T Labs Research.

I had the chance to work or discuss with many great people over the years and cannot name them all. I would particularly like to thank Simon Znaty, who taught me how to do research; Andrea Westerinen, who thoroughly reviewed this book and suggested useful changes and corrections; Jürgen Schönwälder, who reviewed several chapters and with whom I love to argue about the future of network management; Werner Almesberger, who helped me quantify the memory footprint of TCP connections in the Linux kernel and reviewed Chapter 8; Luca Deri, George Pavlou, and Gian Pietro Picco, who sent me precious comments on early versions of the material presented herein; Ditlef Martens, Otto Pesonen, and Baudouin Raoult, who taught me so much about the Unix internals; Tony Bakker and Dick Dixon, who taught me the basics of networking; Walter Zwieflhofer and Claus Hilberg, who taught me rigor when "selling" a technical solution to management; Holly Cogliati, who patiently improved my English, taught me the differences between American and British English, and proofread this book; and Patrick Lachaize, who encouraged me to move into IP networking back in 1989.

I express my deepest gratitude to Gilles Maignaud, Alain Martinez, and François Martin for teaching me, when I was 16–18, that mathematics, physics, and science at large can be great fun. Even in difficult times, I have always strived to take some pleasure in doing my job. Their advice has served me throughout my career.

Finally, I am very grateful to my family and friends for their unwavering support and positive feedback over the years. Most of all, I am indebted to my wife, Béatrice, who put up with the long nights and weekends that I spent writing this book. I knew that I had married a rare pearl...

Jean-Philippe Martin-Flatin, Lausanne, Switzerland, July 7, 2002