

Preface

The main goal of this book is to cover important issues in optimization of present large-scale P2P systems as well as help in designing future systems. The book contains a comprehensive survey and summary of research results complemented by authors' own contributions to the field in the recent years. The book is extensively illustrated by examples to help the understanding as well as includes an extensive list of references on P2P articles and resources.

Evolution of P2P Systems

The field of structured P2P systems has seen a fast growth and evolution upon introduction of first distributed hash tables (DHTs) in the early 2000s. The first proposals including Chord, CAN, Pastry, and Tapestry were gradually improved to cope with scalability, locality, and security issues. Deployable as an overlay on the application layer without the need to change the network infrastructure, the P2P approach had opened great opportunities for innovation for developers. By utilizing the processing and bandwidth resources of end users, P2P approach enables high performance of data distribution which is hard to achieve with traditional client-server architectures. That enables commercial use of P2P systems such as distributing updates to the World-of-Warcraft virtual world, where patches over 100 MBytes are applied simultaneously to all users using P2P technology. Many popular social networks, such as Facebook, utilize the DHT internally to store tremendous numbers of key-value pairs.

Now P2P computing is a vast research field with multiple conferences and research groups in the area. The P2P computing is being actively utilized in the Internet for software updates, P2PSIP VoIP, video-on-demand, and distributed backups. Recent introduction of identifier-locator split proposal for Future Internet architectures poses another important application for DHTs, namely mapping between host permanent identity and changing IP address. The growing complexity and scale of modern P2P systems requires introduction of hierarchy and intelligence

is routing of requests. Additionally, researchers proposed several anti-cheating mechanisms to ensure fair resource distribution and avoiding the “tragedy of commons.” Popular P2P systems have been a subject of various attacks thus bringing security and resilience issues to the front.

Perspective on P2P evolution by Prof. Jon Crowcroft

Peer-to-peer systems have been around for a long time. Back in the 1970s, IBM developed the logical unit 6 of the systems network architecture, which incorporated peer-to-peer application communication support. Then things went quiet for a while, until the 1990s. Two different communities emerged. The nascent file sharing world developed largely unstructured peer-to-peer systems which allowed decentralised symmetric communication between uploaders and downloaders. Meanwhile in the academic world, two seminar projects, the Tapestry work in Berkeley and the Consistent hashing and Chord work at MIT, were based on a more structured approach with a view to more scalable operation in the longer term. At first, it seemed that unstructured systems were the way to go, but gradually the manageability of structured systems started to win out, particularly within the emerging large-scale cloud services.

In this book we see that at the very end where examples of commercial applications from Amazon’s Dynamo and S3, Facebook’s Cassandra system, LinkedIn’s Voldermort and even now, the trackerless versions of Bittorrent, all make use of DHTs for scalable key-value stores for a wide variety of uses and reasons. The book addresses the underlying tools and techniques of structured peer-to-peer systems ranging from the wide variety of routing approaches that can be taken through neighbour maintenance, localisation and optimisation of the system. The material is descriptive and analytical, affording the reader an understanding of the design principles and performance characteristics of the different approaches. The maturity of structured peer-to-peer is evident, and this book provides a clear guide to the trade-offs in selecting a system for a purpose.

Structure of the Book

The book starts with introductory part providing terminology, main problems in design of P2P systems, and mathematical notation. The description of classic DHTs is rather compact as it can be readily found in the existing books. Nevertheless, it should refresh the reader’s knowledge of basic DHT topologies necessary for understanding material in other book parts.

The second part of the book considers P2P systems built on the principle of local knowledge, i.e., interactions with direct neighbors of a node in the system.

It introduces hierarchical structure to classic DHTs, clustering approaches, and ranking of node's neighbors according to their contribution to the system.

The third part of the book looks at the algorithms going beyond the local neighborhood of a node, such as “pure” hierarchical DHTs and their analytic modeling. We also consider the look-ahead routing where the node can utilize information on its neighbor's neighbors and a more general cyclic routing approach. This part also covers advanced techniques for ensuring fairness in resource distribution among the peers. Security aspects of P2P architectures, detection, and exclusion of malicious nodes are discussed as well.

The forth part of the book focuses on P2P applications. We describe CR-Chord, and extension of Chord utilizing Cyclic Routing for routing around malicious or overloaded nodes. Indirection infrastructures are another application which extends *i3* for use as control plane for host identity protocol (HIP). We conclude this part by a chapter that describes commercial distributed systems used by companies such as Google and Amazon to run their services. Although such systems are not P2P in the traditional sense, many of them have evolved from P2P designs and still use DHT-style algorithms internally.

Throughout this book we use the following conceptual terms: *principle*, *property*, and *theorem*. A principle defines rules or guidelines to be applied in the network design; a solution that follows the principle achieves good properties. A property is a fact, typically empirical and intuitive about the subject; it either clarifies model requirements and assumptions or is very simply derived from them. A theorem is a profound fact derived for the given model; it formally characterizes the efficiency of the model. For majority of theorems we provide either a complete proof or, if the technical details are not very important for the discussion, a sketch with references to appropriate sources.

Intended Audience

The book is meant for advanced students and researchers interested in evolution of P2P systems. The undergraduate students can find an introduction to the basic P2P system and popular DHTs useful, while master and PhD students can find latest information on hierarchy in DHTs, resource ranking, and request routing. The book will be of great value to researchers working on DHTs as it contains novel results and analysis of existing DHT mechanisms, as well as for engineers and programmers implementing DHTs to their software, such as BitTorrent. A course or seminar on advanced P2P systems can be taught to postgraduate students based on this book.

While there are multiple books covering P2P networking and application, there is no good reference book for hierarchical P2P systems that would also cover fair resource allocation and efficient routing of requests. As the scale and complexity of P2P systems is growing, hierarchy becomes a critical factor to efficient operation.

The book is to a large extent based on authors' own scientific contributions as well as diligent survey of existing work in this area. The book fills the missing gap in the current P2P literature for students, researchers, and engineers.

About the Authors

Dmitry Korzun received his B.Sc. (1997) and M.Sc (1999) degrees in applied mathematics and computer science from the Petrozavodsk State University (Russia). He received a Ph.D. degree in physics and mathematics from the St.-Petersburg State University (Russia) in 2002. He is an associate professor at the Department of Computer Science of Petrozavodsk State University PetrSU, Russia (since 2003) and a part-time research scientist at the Helsinki Institute for Information Technology HIIT, Aalto University, Finland (since 2005). His research interests include analysis and evaluation of distributed systems, discrete modeling, ubiquitous computing in smart spaces, Internet of Things, software engineering, algorithm design and complexity, linear Diophantine analysis and its applications, theory of formal languages and parsing. His educational activity started in 1997 at the Faculty of Mathematics of PetrSU. Since that time he has taught more than 20 study courses on hot topics in computer science, applied mathematics, and information and communication technology. He is an author of more than 100 research and educational publications.

Andrei Gurtov received his M.Sc (2000) and Ph.D. (2004) degrees in computer science from the University of Helsinki, Finland. He was appointed a professor at University of Oulu in the area of Wireless Internet in December 2009. He is also a principal scientist (on leave currently) leading the Networking Research group at the Helsinki Institute for Information Technology focusing on the host identity protocol and next generation Internet architecture. He is co-chairing the IRTF research group on HIP and teaches as an adjunct professor at the Aalto University and University of Helsinki. Previously, his research focused on the performance of transport protocols in heterogeneous wireless networks. In 2000–2004, he served as a senior researcher at Sonera Finland contributing to performance optimization of GPRS/UMTS networks, intersystem mobility, and IETF standardization. In 2003, he spent six months as a visiting researcher in the International Computer Science Institute at Berkeley working with Dr. Sally Floyd on simulation models of transport protocols in wireless networks. In 2004, he was a consultant at the Ericsson NomadicLab. Dr. Gurtov is a coauthor of over 100 publications including a book (Host Identity Protocol (HIP): Towards the Secure Mobile Internet, ISBN 978-0-470-99790-1, Wiley & Sons, June 2008. Hardcover, 332 pp.), book chapters, research papers, patents, and IETF RFCs. His publications received more than 1,000 citations according to Google Scholar. He is a senior member of IEEE.

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