Computer Networks 52 (2008) 2097–2128

Contents lists available at ScienceDirect

Computer Networks

journal homepage: www.elsevier.com/locate/comnet

A survey on resource discovery mechanisms, peer-to-peer and service discovery frameworks

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ARTICLE INFO

Article history:
Available online 25 March 2008

Keywords:
Service and resource discovery
Survey
Search
Overlay networks
Types of clustering
Peer-to-peer networks
DHT
Kademlia
Pastry
Napster
Chord
Gnutella
Viceroy
CAN
KaZaA
FastTrack
eDonkey
Freenet
BitTorrent
Bootstrapping
Resource constrained networks
Wireless networks
Ad hoc networks
Heterogeneous networks
Ubiquitous computing
Wireless sensor networks
UPnP
SLP
Salutation
Bonjour
Jini

ABSTRACT

Service and resource discovery has become an integral part of modern networked systems. In this survey we give an overview of the existing solutions for service and resource discovery for a wide variety of network types. We cover techniques used in existing systems, as well as recent developments from the research front. We also provide taxonomy for discovery systems and architectures, and review the various algorithms and search methods applicable for such systems. Peer-to-peer overlays are discussed in detail and solutions for non-IP-based networks are also included in the review. We also specifically comment on issues related to wireless networks, and give an overview of the various issues and complications that should be considered in future work in this domain.

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doi:10.1016/j.comnet.2008.03.006

1. Introduction

Service and resource discovery is becoming more and more important with the growth in the size and the diversity of computer networks. Furthermore, the ubiquity of the mobile and wireless networks is making different discovery services critically important in the future. Considerable amount of work has been done in this field, but mostly the resource and service discovery solutions have been approached as an implementation task to develop new protocols or frameworks, not trying to classify, categorize and to seek out generalities.

This survey paper covers resource and service discovery (SD) mechanisms in general, provides a taxonomy to differentiate between various systems and describes several popular service discovery and peer-to-peer frameworks. This survey paper covers resource and service discovery mechanisms in general, and we also provide a taxonomy to differentiate between considered systems. There have been several recent review type of articles, among them the ones by Edwards [1], Zhu et al. [2], Vanthournout et al. [3] and Lua et al. [4]. The scope of our review has a wider scope than the ones in [1] or [2]. The work of Lua et al. [4] covers P2P networks, but the traditional service discovery systems are out of scope of the paper. The article [3] is, in part, closer to our approach, but is limited to IP-based resource discovery mechanisms, and focuses mostly on taxonomy development. We will consider also non-IP systems, and we are technology agnostic between P2P, wireless and large-scale Internet based frameworks. We will also present some popular search algorithms and shortly comment on issues related to wireless and embedded networks in the resource discovery context.

The paper is organized as follows. In the rest of the introduction we provide the basic terminology and main characterization of the service discovery frameworks. In Section 2 the possible system architectures are described and classified with more details. We discuss different network related issues like packet propagation and dynamic query termination techniques in Section 3. In Section 4 the distributed search algorithms and protocols that utilize these methods are introduced. The discussed search protocols are mostly applicable to unstructured decentralized system. Different clustering approaches, that are used in hybrid frameworks, are addressed in Section 5. In Section 6 we discuss decentralized structured architectures are analyzed on the example of DHT-based system. The most famous and well-spread peer-to-peer systems are discussed in Section 7. In Section 8 we describe classical service discovery frameworks. The issues specific to service discovery in non-fixed and heterogeneous networks are discussed in Section 9. Additionally, in Section 10 we describe some complications to be considered when designing a service discovery system. Finally, in Section 11 we provide some general discussions and conclusions.

1.1. Terminology and main characteristics

The terms *service discovery* and *resource discovery* are often used interchangeably. Although, some subtle differences could be defined on this, we do not to take a firm stand on the issue. Oxford English Dictionary [5] gives the following definition:

> *Resource (n.):* A means of supplying some want or deficiency; a stock or reserve upon which one can draw when necessary; an action or procedure to which one may have recourse in a difficulty or emergency; an expedient device, shift.

In general, we follow Vanthournout et al. [3] by defining that a resource is any source of supply, and specifically can consist of files, file-system, memory, CPU-capability, communication capability (e.g., radio modem), etc. *Resource discovery* is any mechanism that is providing capability to locate resources. We, furthermore, loosely define *service discovery* as a subset of resource discovery, in such a way that service discovery should be mostly seen as a capability to find specific services such as applications or well-defined networked services that are not pure abstractions. However, the difference between service and resource discovery is not particularly important, or interesting, for this survey.

The specific terminologies used to describe resource and service discovery frameworks[1] are often highly different, in part because this gives the possibility to emphasize different and unique aspects in their designs. A taxonomy of service discovery systems featuring the commonly used terminology is given in Fig. 1.

An important issue is the *naming* of resources. With naming we denote any mechanism that supports a logical way to give and maintain resource names in service discovery systems. General naming systems or schemes are out of the scope of this article. An integral part of the resource discovery process is to search matching resources for client requests. Both naming and *search* are, of course, generic problems that are encountered in many computer science and networking applications. A number of different resource naming approaches have been proposed. The selection can strongly affect and limit the discovery mechanisms. The basic approaches can be roughly divided to *hash table*, *attribute/string*, and *directory* based naming. The alternative taxonomy is based on *template-based*, *predefined template* and *free-form* approaches.

1.2. Main characteristics of the system

Each service discovery (SD) system has either structured or unstructured *architecture*. Structured architectures are further subdivided into centralized (client–server) or decentralized ones. Hybrid architectures try to combine the advantages offered by different architecture types to boost the overall system performance. The original Gnutella [6] follows the unstructured approach while SLP [7] and Napster [8] are examples of structured centralized systems. DHT-based systems, for example Kadmelia [9] based eDonkey networks called Overnet and Kad, are the examples of decentralized structured systems. Gnutella2

[1] We use here specifically term *framework* to emphasize that we do not limit us to resource discovery *protocols*, but consider also system level proposals.