

Chapter VIII

Peer-to-Peer Systems

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ABSTRACT

Peer-to-peer systems have become extremely popular on the Internet in recent years. However, peer-to-peer systems are not limited to Internet applications, but are also of significant interest to ubiquitous computing. This is because both peer-to-peer systems and ubiquitous computing are based on collaboration between independent, autonomous entities. Peer-to-peer systems are built around resource sharing and in this chapter, we will look at the different aspects of this resource sharing, from the types of resources to be shared to how the peers are connected to each other and on to how the resources can be located in these different kinds of networks. This chapter is organized as follows. First we provide a definition of what peer-to-peer is and discuss its relevance to ubiquitous computing in more detail. The section “Current Systems” gives an overview of currently deployed and used peer-to-peer systems. Then, we will present a classification of peer-to-peer systems according to how resources are located. In the section “Resource Location in Peer-to-Peer Networks” we will present algorithms for locating resources in peer-to-peer networks. Finally, the chapter discusses the future of peer-to-peer systems.

INTRODUCTION

Peer-to-peer technologies (or P2P for short) have broken through in recent years as an attractive alternative to the traditional client-server-based architectures and systems. A lot of the attention paid to peer-to-peer systems has been caused by the widespread use of P2P file sharing networks, where (often illegal) media content is being distributed. Recently deployed peer-to-peer systems

however demonstrate that the peer-to-peer concept extends to other applications as well and can also be used in commercial scenarios.

In this chapter, we will present a definition of what peer-to-peer is and what it means as a communication paradigm. In many ways, peer-to-peer is the opposite of the traditional client-server communication paradigm, since in peer-to-peer networks all nodes are more or less equal in terms of their duties and privileges. We will give

an overview of currently deployed peer-to-peer systems and analyze how they exhibit the peer-to-peer properties.

Later, we will present a classification of peer-to-peer systems, based on how resources in the networks are located. Although this classification is only one of many possibilities, it is also one of the most commonly used classifications of peer-to-peer systems. Based on this classification, we will take a closer look at search algorithms in peer-to-peer networks. In a large network, where the resources are distributed over a large number of peers, being able to locate the required resources efficiently is of great importance. We will therefore dedicate the bulk of this chapter to discussing search algorithms in peer-to-peer networks.

DEFINITION OF PEER-TO-PEER

There exist many different definitions of what peer-to-peer is in the community (Oram, 2001; Steinmetz & Wehrle, 2005, Subramanian & Goodman, 2005). However, many of the current definitions have several points in common, which we have distilled and combined below.

In our definition, peer-to-peer systems exhibit the following characteristics:

- **Autonomy from central servers:** Peer-to-peer systems typically have no central, controlling components in them. However, as we will see in Section “Unstructured Peer-to-Peer Systems”, some peer-to-peer networks (most notably Napster (Napster, 2001) and BitTorrent (BitTorrent, 2007) to a lesser extent) are based on a central coordinator, but the actual work of the system *always* happens directly between the peers, without any need to involve the coordinator.
- **Sharing resources at the edge of the network:** Peers in a peer-to-peer network offer their resources for others to use and they

use resources provided by other peers. We will discuss the types of resources in more detail below. An open question in peer-to-peer networks is whether all peers should be forced to contribute to the system (e.g., BitTorrent and Skype (Skype, 2007)), or whether the system should tolerate peers which are not contributing. Such non-contributing peers are also called free-riders (Adar & Huberman, 2000), since they only consume resources on other peers without providing any.

- **Individual nodes have intermittent connectivity:** Individual peers in a peer-to-peer network are typically fully independent, since they are under the control of the individual users. A peer joins the network when it wants and can leave at any time. Typically, there are no guarantees about when peers are online; instead, the system relies on a large number of participants, so that it does not matter what individual peers do.

The above characteristics already point out some of the advantages and disadvantages of peer-to-peer systems. The main advantages of peer-to-peer systems, compared to traditional client-server systems are that peer-to-peer systems typically scale well to a large number of participants, up to several millions of simultaneous users. Furthermore, thanks to the large number of participants, peer-to-peer systems are robust against failures, and practice has shown them to also be very efficient in performing the task they were designed to do. Peer-to-peer systems can also have the advantage of not requiring dedicated and expensive servers, since the individual peers can offer the same resources at a much lower (monetary) cost. The costs of using a peer-to-peer solution are independent of the number of users, whereas the costs of a centralized client-server system scale up with the number of users.

However, replacing a client-server system, for example, a file server, with a peer-to-peer

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