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Multi-factors oriented study of P2P Churn

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SUMMARY

The dynamics of peers, namely Churn, is an inherent property of peer-to-peer (P2P) systems and is critical to their design and evaluation. Although every excellent P2P protocol has some solution to this issue, studies on Churn are still seldom. This paper studies various factors related to Churn, and uses them to analyze and evaluate P2P protocols. Prior researches on Churn are all based on the P2P network factors in Churn environment, and their difference is whether to use these factors as predecessor references to build Churn analytical models or as successor references to test the models. According to this difference, this paper first divides various factors into two categories: impacting Churn and affected by Churn. There is a causal relationship between these two categories. Factors impacting Churn are cause, and the factors affected by Churn are effect. In this paper, we use this causality to simulate and analyze P2P Churn. Cause is used as the input data and effect is used as the output result. Second, based on the classification of Churn factors, we present a performance evaluation framework and two comparing models. Based on the framework and models, we simulate and analyze three P2P protocols and get some useful results such as the performance of these protocols under Churn, the advantage of Chord over others, and the most important factors impacting Churn. Finally, we present a method to improve recent P2P Churn models by adding some influence factors. Copyright © 2009 John Wiley & Sons, Ltd.

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1. INTRODUCTION

Churn, the dynamics due to peer joining, leaving, and failure, can greatly increase costs or decrease search quality of peer-to-peer (P2P) system. Previous Churn-related studies can be mainly divided into three categories. The first is to directly acquire and analyze Churn correlative factors [1–4], such as the arrival and departure time of peers. The second category builds Churn models based on some simulation or analysis study of P2P system [5, 6]. The last one studies Churn using some other methods such as statistics and probability [7, 8].

Above researches focus primarily on Churn, but more Churn-related studies are brought about by some other issues. First, in order to increase P2P system's adaptability, every P2P protocol should consider Churn. So there are a lot of special Churn researches for some P2P protocol according to their own property [9, 10]. Second, currently proposed P2P networks are originally proposed for Internet-based wide-area applications and assume that the participating peers are stationary. However, a growing number of devices are now connected to the Internet through wireless links, and the problem is that peers may move and we will face the peer mobility problem. Churn in mobility is becoming a more serious problem [11]. Finally, as one of the most pervasive problems of P2P systems, many P2P studies are indeed Churn problems just with a different name. Lynch *et al.* sketched amendments to the Chord protocol to guarantee consistency by way of guaranteed atomicity [12]. Rapid adaptation to arriving and departing peers in P2P network is an alias of Churn [13]. Fault Tolerant Active Rings is a protocol for active joining and leaving, which is also a Churn problem [14] *defacto*. Since the generalized de Bruijn graphs possess very short average routing distances and high resilience to peer failure, optimal-diameter de Bruijn graphs are suitable for P2P system [15]. A good design of accurate and timely detection of peer failures can improve the resilience of P2P networks [16]. Routing geometries including hypercube, ring, tree-like structure, and buttery network can affect the resilience and proximity properties of P2P networks [17].

The above statements illustrate the diversity and complexity of Churn studies. But indeed both the studies focusing primarily on Churn and studies caused by other issues all depend on Churn factors. Some researches use Churn correlative factors directly; other models or methods should be tested by these factors. For example, Li *et al.* consider Churn factors of lookup performance and cost [1]. Rhea *et al.* identify and explore three factors affecting P2P performance under Churn: reactive versus periodic failure recovery, message timeout calculation, and proximity neighbor selection [2]. Stutzbach *et al.* mainly use session length to analyze Churn [5]. Krishnamurthy *et al.* decrease failed or incorrect lookups rate under Churn [8]. In short, every study above has considered one or more kinds of Churn factors.

Considering the importance of various factors for Churn study; on the other hand, there was no previous work to summarize and classify these factors. This paper researches P2P Churn based on different factors. Our main contributions are as follows:

- We summarize and analyze in detail various Churn factors, which include not only impacting Churn but also affected by Churn, such as number of peers, visitation periods of peers, joining frequency of peers, time to live of peers, retransmission times of the query failure, interval of the query failure, lookup latency, lookup accuracy rate, bandwidth consumption.
- We classify these factors and present a performance evaluation framework and two comparing models of P2P Churn. The Churn-related factors are divided into two categories: impacting Churn and affected by Churn. There is a causal relationship between these two categories.

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Factors impacting Churn are cause and factors affected by Churn are effect. We use this causality to simulate and analyze P2P Churn. Cause is used as simulation input and effect is used as simulation output.

- Using the evaluation framework and models, we simulate and analyze three P2P protocols, Chord, Kelips, Tapestry, and get some useful results, such as the performance of these protocols under Churn, the advantage of Chord than others, and the most important factor impacting Churn.
- Finally, we give a method to improve recent P2P Churn models by adding some important Churn factors, and we use this method to a Churn model [4].

The remainder of this paper is organized as follows. Section 2 summarizes Churn factors and gives the performance evaluation framework and two comparing models. We also briefly introduce the method to improve recent P2P Churn model. Subsequently, Section 3 simulates and analyzes three P2P protocols based on our evaluation framework and comparing models. Section 4 shows how to improve a Churn model [4] in detail. Finally, Section 5 concludes this paper.

2. CHURN FACTORS AND EVALUATION FRAMEWORK

2.1. Churn analysis

One of the most important problems that the P2P network faces is the Churn caused by the peers joining and leaving. Churn is not just a single problem of P2P network, but it relates to almost every aspect of P2P network including query efficiency, query accuracy, network convergence rate and so on. So there are a lot of factors relevant to Churn. The motivation of churn factors classification in this paper is to explore this kind of factors as many as possible, and more importantly research the relationship between these factors and Churn problem. This paper first divides various factors into two categories: impacting Churn and affected by Churn. The factors impacting Churn include the scale of the network (the number of the peers in the system), the busy degree of the network (visitation periods between peers), the stabilization of the network (the time to live, the frequency of peers joining the network, etc.), the retransmission times and the interval of the failure to inquire and so on. The factors affected by the Churn, include the lookup accuracy rate, the lookup latency, and bandwidth consumption in the P2P system, and so on.

2.2. Evaluation framework

The summary and classification of Churn factors is given in Table I. The factors impacting Churn can be further divided into environmental factors and characteristic factors, and the factors affected by the Churn can be further divided into the effect of performance and the cost caused by Churn.

Using environmental factors as the x-axis, characteristic factors as the y-axis, and the factors affected by the Churn as the z-axis, we get a Churn evaluation framework. The evaluation framework of P2P systems under Churn is intuitively given as a three-dimension model in Figure 1.

The simulations based on this evaluation framework can be used to illustrate the performance of different P2P systems in the same data set under Churn and to analyze the effect of different factors on the performance of the same P2P protocol. Furthermore, these results could give some useful suggestions to evaluate and design P2P system. In order to reflect the value of this evaluation framework, we will carry out some simulations and analysis using this model in the next section.

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