ABSTRACT

Superpeer networks are formed and maintained as a result of several node and link dynamics like bootstrapping, peer churn, attack, link rewiring etc. Significant amount of work has been done by the p2p research community in the development of efficient bootstrapping protocols. However, it is not obvious why bootstrapping of nodes and different local dynamics lead to the emergence of bimodal superpeer networks. Stability of superpeer networks also suffers from high rate of peer churn and attacks. The movements of the peers often partition the network into smaller fragments which results in breakdown of communication among peers. Although several attacks and defence techniques are discussed in the literature, less attention has been paid to assess the impact of such attacks upon the overall topology of the superpeer network. Hence, apart from the simulation and experimental study, there is a need for understanding the emergence and resilience of superpeer networks from a theoretical perspective.

In this thesis, we propose theoretical frameworks to analyze the resilience and emergence of superpeer networks against several node and link dynamics. In resilience analysis, we model the network topology and peer dynamics with the help of probability distributions and derive a critical condition for the stability of superpeer networks. The results obtained from the theoretical analysis are validated through simulation. We simulate attacks and failures on real world commercial p2p networks namely Gnutella as well as on the super-

peer networks generated using theoretical degree distribution. The influence of network size as well as degree-degree correlation present in the real world networks (Gnutella) are also analyzed.

In order to understand the emergence of superpeer networks, we model bootstrapping protocol through a node attachment rule, where the probability of joining of an incoming peer to an online node is proportional to the node property (shared resource, processing power, bandwidth) and degree of the online node. We develop a formalism that calculates the degree distribution of emerging superpeer networks based upon such bootstrapping process and bandwidth constraint. We further refine the above growth framework and include dynamics like (a) peer churn and (b) link rewiring along with the bootstrapping process. The analytical framework calculates the threshold churn rate, required to break down the superpeer structure. It also discovers that in presence of proper rewiring, the QoS of p2p network shows graceful degradation in face of churn. Our theoretical model provides some empirical estimation of churn and rewiring rate of the Gnutella network which is consistent with the measurement studies.

In summary, the network resilience and other topological properties like diameter, amount of superpeers in the network, size of the largest connected component etc. play the key role on the performance of the evolving superpeer networks. We believe that proper analytical understanding will help network engineers in regulating these topological properties and subsequently improve the performance of various p2p services.

Keywords: Superpeer network, network resilience, peer dynamics, complex networks, degree distribution, giant component, generating function, network growth, bootstrapping protocols, preferential attachment.