Brief Announcement: Efficient Flooding in Power-Law Networks *

Farnoush Banaei-Kashani
University of Southern California
Los Angeles, California 90089
banaeika@usc.edu

Cyrus Shahabi
University of Southern California
Los Angeles, California 90089
shahabi@usc.edu

ABSTRACT

Flooding is an effective mechanism for both broadcast and unicast modes of communication (in unstructured networks), providing broad coverage and guaranteeing minimum delay. However, flooding is not a scalable communication mechanism, mainly because of the communication overhead it imposes to the network. We use the percolation theory to formalize the main problem with flooding in the context of power-law networks, propose a remedial approach with our *probabilistic flooding* technique, and find the optimal operating point for probabilistic flooding rigorously, such that it improves scalability of the normal flooding by 99%.

1. INTRODUCTION

Power-law network is the signature of the omnipresent "complex systems". Complex systems are large-scale and dynamic interconnections of nodes (connected via physical links or logical relations) that *emergently* self-configure into random networks with power-law connectivity-degree distribution[1]. Power-law signature has been observed in natural complex systems, such as social networks and ecological networks, as well as man-made complex systems such as the Internet and World Wide Web.

Flooding is the typical mechanism used in all networks (including power-law networks) to broadcast (i.e., a one-to-many communication) a piece of information (e.g., an alert, or a query) from a source node to other nodes of the network. Besides, with *unstructured* networks (such as Gnutella peer-to-peer file-sharing network), where there is no hints about the right direction for routing the information from the source to a destination node, flooding can be used as an alternative to unicast communication (i.e., a one-to-one communication). In this case, flooding is used to communicate the information to as many nodes as required until the destination node receives the information. Power-law networks are generally unstructured.

In spite of many beneficial features, such as providing broad coverage and guaranteeing minimum delay, flooding is not a scalable communication mechanism, mainly because of the communication overhead it imposes to the system. It is important to note that with both broadcast and unicast modes of communications, it is desirable that the information is communicated to as many nodes as possible within the available time. Thus, the first time a node receives the information, the communication is not considered an overhead. Communication overhead is due to duplicate reception of the information, which stems from redundant connectivity of the network such that each node receives duplicates of the flooded information through multiple paths[2].

In [1], we introduce *probabilistic flooding* to eliminate the scalability problem with normal flooding. With probabilistic flooding, unlike normal flooding where each node always forwards the received information to all its neighbors (i.e., directly connected nodes), a node forwards the information to its neighbor probabilistically, with probability p. By changing the probability value p, we can control the *effective* connectivity of the network while information is forwarded. The idea is to tune the probability value p to a critical operation point (termed the *phase transition* point) such that statistically the network remains connected (to preserve full reachability) while redundant paths are eliminated. We apply percolation theory [2] to formalize this problem in the context of power-law networks and find the critical (optimal) operating point rigorously. Our formal analysis shows that the critical value of p can be as low as 1%, which translates to 99% reduction in communication overhead of flooding, hence, scalable flooding.

2. REFERENCES

[1] F. Banaei-Kashani and C. Shahabi. Criticality-based analysis and design of unstructured peer-to-peer networks as complex systems. In *Third International Workshop on Global and Peer-to-Peer Computing (GP2PC) in conjunction with CCGrid'03*, May 2003.

[2] D. Stauffer and A. Aharony. *Introduction to Percolation Theory*. Taylor and Francis, second edition, 1992.

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[1] $P(k) \propto k^{-\tau}$, where k is the connectivity-degree and τ is the constant skew factor of the power-law distribution.

[2] Mechanisms for detecting and dropping the *looping* information do not tackle the main source of the overhead, i.e., duplication due to existence of multiple forwarding paths.

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