RIPS Project 2008
Microsoft Research Asia (MSRA)

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Project title: Study on network formation games

Consider peer-to-peer networks in which peers voluntarily connect to each other to share some resources. Every peer in the network is selfish, in the sense that it wants to maximize its own utility (based on some metric definitions). Therefore, the network formation game is such a game in which peers may individually change its connections to other peers in order to maximize its own benefit.

Different games may have different optimization objectives. For example, peers may want to minimize its average distance to all other peers, or it may want to maximize the fraction of traffic passing through it (so it can get paid the most). The former metric is call closeness centrality while the latter metric is called betweenness centrality [1, 2]. There are certainly other objective functions. There are several papers studying the games related to closeness centrality [3, 4, 5], but there is no study yet on optimizing for betweenness centrality.

For this project, the students are expected to study network formation games in which each vertex is a player and each player wants to maximize its betweenness in the network. There are two main versions of the game the project will focus on. In the first version, each player is allowed to add at most k outgoing *directed* edges to k different selected vertices, and edges have no weights. The second version differs from the first version in that edges are undirected (but each edge has an owner --- a simple way to think about it is that when building the network, edges are directed and each vertex owns the k outgoing edges, but when computing the betweenness, edges are treated as undirected).

For these two versions of the games, we would like to study the following problems:

(a) Is it true that for any number n of vertices and any number $k < n$, the game always has a pure Nash equilibrium? If so (and we conjecture so), can we find one or several general classes of structures that are stable?

(b) What are the properties of any Nash equilibrium? For example, is it always strongly connected? Does it have a short diameter (O(log n) diameter)? How fair is it in a Nash equilibrium (i.e. how large is the betweenness difference between a vertex with the largest betweenness and a vertex with the smallest betweenness)?

(c) If finding exact equilibria is difficult, can we find approximate Nash equilibrium? An approximate Nash equilibrium is one in which each player will not change its strategy if its gain is only a small additive (or multiplicative) factor of the current utility.

There are many other questions one could ask concerning such games, but for this project we will focus on the above questions. Our research group at MSRA has started working on this type of network formation games recently. We obtained some initial results about betweenness formation games, but many are still unknown. These questions may not be easy to solve in a short two-month period, but some partial results could be obtained. The students are expected to try both solving the problem analytically and by conducting extensive computer simulations. The simulations for many cases could be a more practical and effective approach to tackle these problems.

This study will be very helpful in understanding the formation of peer-to-peer networks, and in general many social networks in which individuals have their own selfish objectives. One may also apply the results obtained into the study of economic aspects of these networks, such as how to design charging schemes for the connections to form large-scale and efficient networks. This is an active area related to Internet economics.

References

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