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FG Algorithm Engineering
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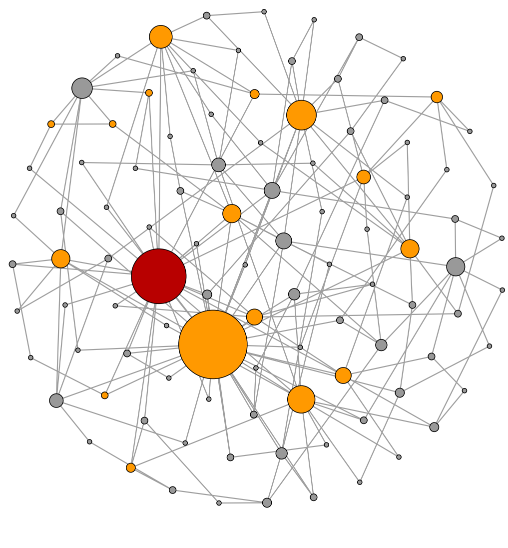
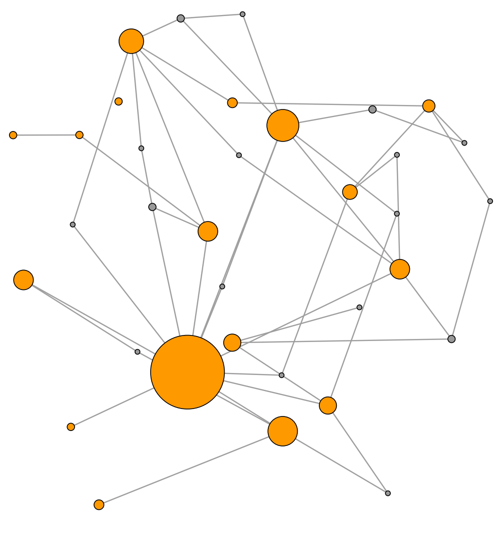
Strategic Network Formation under Attack

Master Project Proposal – Summer Semester 2016
https://hpi.de/friedrich/

Networks are everywhere. We crucially depend on reliable networks in nearly every aspect of our lives and thus there is a rich theory of how networks should be build and how they can be optimized. But despite this huge body of knowledge, we do not fully understand many of the complex networks we interact with everyday. Some prominent examples are the Internet or any form of social networks like our friendship network, co-author networks or the Facebook or Twitter networks.
These networks are hard to understand since they have not been designed from scratch and there is no central authority to monitor and optimize them. Instead, networks like the Internet emerged by the repeated interaction of independent selfish agents. These agents decide with whom to share information or with whom to connect based on their individual situation and their egoistic preferences.
The need for analyzing such complex networks has sparked the young research direction called *Algorithmic Game Theory* which models the formation of networks as a strategic game played by rational and selfish players.



The network before the red node is attacked. Orange nodes have chosen to install firewalls.



The network after the attack. Only firewalled nodes and nodes behind firewalls survive.

Purpose of the Project In this Master Project we set out to investigate such a game-theoretic model both theoretically and experimentally. In our strategic network formation game there are players which can create costly links to other players. The combination of the individual decisions of all players then induces a network. The goal of each player is to obtain a reliable

network, which ensures good connectivity to all other players. However, players are greedy and thus weigh their individually obtained network quality against the cost spent for creating links. But if everyone tries to free-ride the network, what happens to the overall network quality?
We are especially interested in networks, which are reliable even under attack from a malicious third party. Even worse, we assume that an attacked node of the network completely fails and the attack spreads virus-like to its neighbors. However, there is hope for our players: they can selfishly decide to buy a firewall and thus protect themselves. This can easily be translated into a so-called utility-function for every player, which determines the individual utility of the current network for a specific player: Let T be the set of network nodes which may be attacked and let G_t be the network G after the attack on node $t \in T$ and the subsequent viral spread of the attack from t to neighboring nodes and their neighbors and so on. Let $CC_{G_t}(v)$ denote the number of nodes in the connected component of node v in the network G_t. Moreover, let c_e denote the cost for creating links and let c_f be the cost for installing a firewall. Then the utility of a surviving player v in network G is

$$u_v(G) = \frac{1}{|T|}\left(\sum_{t \in T} CC_{G_t}(v)\right) - k_v \cdot c_e - \ell_v \cdot c_f,$$

where k_v is the number of links in G bought by player v and $\ell_v \in \{0, 1\}$ denotes whether player v chose to install a firewall. Thus, the utility of player v is the expected number of nodes to which v is still connected post attack minus v's cost spent for creating edges and installing a firewall.
The goal of this project is to understand the network formation process and its outcomes for several variants of the model sketched above. We investigate properties of so-called equilibrium networks, which are outcomes of the game where no agent can improve by a strategy-change. These theoretical analyses should be complemented with experimental evidence gained by extensive simulations.

What we expect from you We expect basic proficiency in working with graph-theoretic concepts and the curiosity and willingness to delve into an interesting research topic within Theoretical Computer Science. Our main goal is a rigorous understanding of the model and the resulting networks and we expect you to contribute theoretical as well as empirical results towards this end.

What you can expect from us We will gently introduce you to the field and accompany you all along the interesting journey. This will be a team effort and we aim at publishing our results at a renowned international conference.

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You're also welcome to visit us on floor A-1.