

## Efficiency and Performance of Fragmentation of Networks

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Optimization of procedures for efficiently breaking complex networks is attracting much attention from two practical points of view: attacking and preventing attacks or failures. I present a novel procedure to break complex networks guided by the identification of modular structures. The module-based method<sup>a</sup> first identifies communities in which the network can be represented, then it deletes the nodes or edges that connect different modules by decreasing order in the betweenness centrality ranking list. I illustrate the method by applying it to various well known examples of social, infrastructure, and biological networks, showing that the proposed method always outperforms vertex attacks which are based on the ranking of node degree or centrality, with a huge gain in efficiency for some examples. Remarkably, for the US power grid, the module-based method breaks the original network of 4941 nodes in many fragments smaller than 210 nodes with less than 3% of nodes removed. Performance is addressed too by considering the processing time<sup>b</sup> to find the list of nodes, so the module based method is tested against the high adaptive methods which are based in sequential updates of the node list. Finally, the method is applied to two real examples of criminal networks.

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<sup>a</sup>Fast Fragmentation of Networks using Module-Based Attacks, Bruno Requião da Cunha, Juan Carlos Gonzalez Avella, and Sebastián Gonçalves. PLoS ONE 10(11): e0142824 (2015).

<sup>b</sup>Performance of attack strategies on modular networks, Bruno Requião da Cunha and Sebastián Gonçalves (arXiv:1608.02619).