

## A Centrality Ranking Strategy in Modular Complex Networks

Centrality measures rank nodes using the classical descending order ranking scheme, with the top being the most influential. However, this ranking scheme has a major drawback. It is agnostic of the mesoscopic organization of most real-world networks. To tackle this issue, we propose a community-aware ranking scheme identifying influential nodes across all the network communities [1]. Given a centrality measure, the proposed strategy selects the top central nodes in each community and ranks them in decreasing order of their community size. Then it moves to the next most central node in each community and proceeds with the same ordering strategy. One iterates this process until reaching the given budget of nodes. This strategy allows the selection of influential nodes in all the communities without saturating their zone of influence. We investigate the proposed approach with the Susceptible-Infected-Recovered (SIR) diffusion model on a set of synthetic and real-world networks using two local centrality measures (Degree and Maximum Neighborhood Component), two path-based measures (Betweenness and Closeness), and two iterative refinement measures (Katz and PageRank). We compare it with the classical descending order ranking scheme based on the final outbreak size (i.e., the nodes in the recovered state). Figure 1 (A) illustrates the relative difference in the outbreak size ( $\Delta R$ ) between the ranking schemes for the Degree and Closeness centrality in the EU Airlines and AstroPh networks. A positive value of ( $\Delta R$ ) indicates that the proposed ranking scheme is more effective in igniting a larger diffusion. One can notice that the community-aware ranking scheme consistently outperforms its alternative. Figure 1 (B) represents the EU Airlines and AstroPh networks. The big nodes are the top 15% extracted by Degree centrality in the two ordering strategies. The nodes selected by the proposed ranking scheme are spread across the network. In contrast, with the classical descending order ranking scheme, they concentrate on the core of the networks. Consequently, the diffusion dies out internally, leaving the remaining communities intact. We observe similar behavior in the other networks and centrality measures under investigation. One can use this generic community-aware ranking scheme with various centrality measures in all network types (undirected/directed and unweighted/weighted). Its main advantage is to naturally selects distant nodes to expand any diffusion phenomena based on any given budget. It is suitable for use cases such as viral marketing, awareness campaigns, hindering misinformation on networks, and vaccination strategies in networks with community structure.

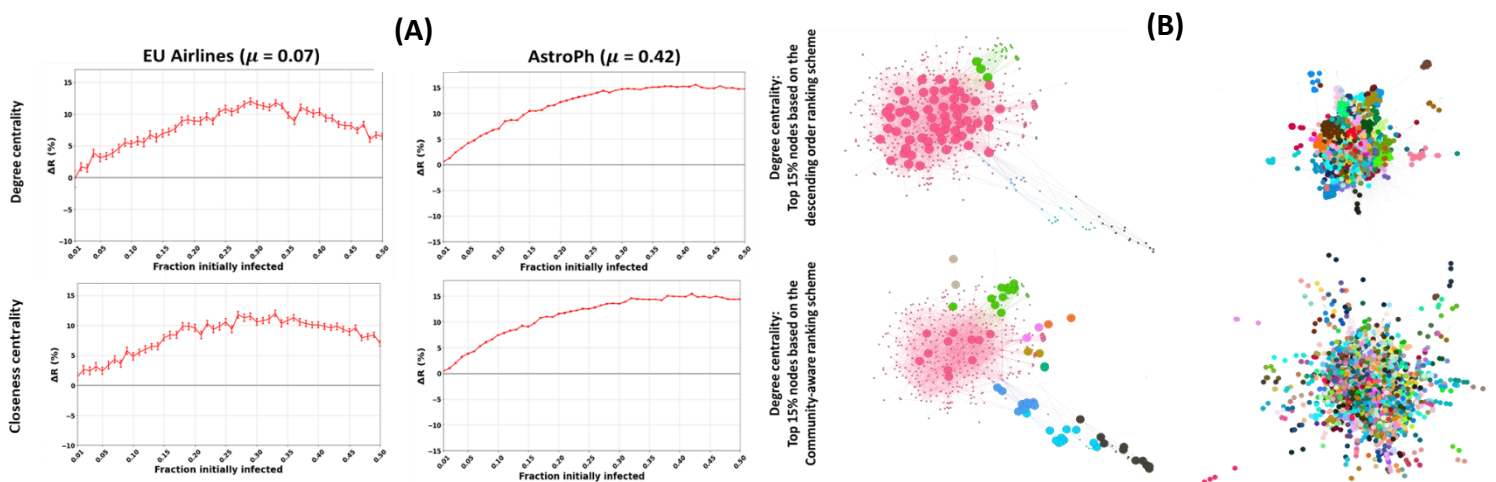


Figure 1 – (A) The relative outbreak size ( $\Delta R$ ) as a function of the fraction of initially infected nodes. The red curve indicates the relative performance difference of the community-aware ranking scheme compared to the descending order ranking scheme for Degree and Closeness centrality. (B) The top 15% of nodes selected based on the Degree using the classical descending order and community-aware ranking schemes in the EU Airlines and AstroPh networks.

[1] Rajeh, Stephany, and Hocine Cherifi. "Ranking influential nodes in complex networks with community structure." Plos one 17.8 (2022): e0273610, <https://doi.org/10.1371/journal.pone.0273610>