ABSTRACT

Complex systems modeled as networks, has emerged as an exciting field of study in the last decade. This is primarily due to the fact that our day to day lives are deeply intertwined with "hopelessly" complex systems. Modern communication infrastructure, which connects any two people in seconds materializes due to co-operation of billions of devices such as routers, cell phones and computers. Social media exists due to interaction of billions of entities such as people, organisations etc. which leads to spectacular phenomenon such as information cascade. Even our inherent capability to comprehend society around us requires seamless interactions between billions of neurons in our brain. Since networks lie at the center of social, technological and biological systems, it is important to come up with mathematical description of the structure, which may lead to optimal control of the underlying processes.

Resilience of a complex network relates to how well some of its properties are retained under attacks. Robustness has been historically studied from the perspective of node property of degree. This translates to how essential connectivity in the network can be disrupted by random and targeted node failures. Understanding robustness is crucial in tackling scenarios such as the catastrophic 2003 blackout in America, Canada as well as 2008 global financial meltdown. However existing works do not shed light on how other key properties are affected such as **centrality** due to random failures.

Centrality resilience is more difficult to detect than connectivity resilience. When one part of a network cannot communicate with the rest of the system, it is easy to infer that the cause is due to disconnectivity. Attack on centrality, however, may not disconnect the network, but result in longer distances when traversing the network.

The increased length of the distances, is due to the change in the ranking of the high centrality vertices which may not be immediately apparent until the centralities of the system are recomputed. This may potentially lead to delays in transport network or high latency in communication resulting in economic losses.

In this thesis we show that path-based centralities form dense clusters or “rich clubs“ in certain networks, which manifest in the **inner cores** of a network. We demonstrate that stability of high central nodes in the network is related to these substructures. We empirically and theoretically show that “rich clubs“ exists, if the **core-periphery structure** of the network is such that each shell is an expander graph, and their density decreases from inner to outer shells. We extend the concept of a single rich club to that of “scattered rich clubs“ and explain how they connect to centrality resilience. We subsequently extend our analysis to time-varying networks and develop approaches to predict high central nodes based on the stability of the **core-periphery structures**. We finally show that **k-core structures** can be useful is developing novel network representation learning algorithms which is effective in various downstream prediction tasks.

Keywords: core periphery structure, centrality resilience, centrality rich club, scattered rich club, network representation learning.