# Trends in Network Robustness Research

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March 25, 2012

**Abstract**

Due to the growing pervasiveness of civilian and military networks for the transmission of safety-critical and real-time data, it is critically important that they are resistant to selective and random network node deletions. Network robustness is a measure of the performance and throughput responsiveness of a network in response to such deletions. The nature of this metrics lends itself to the application of percolation theory, which can be used to describe the behavior of connected clusters in a random graph. This theory can be utilized to design and construct optimally robust networks in order to yield the best performance in the event of node deletions.

This paper presents some background information on network robustness and its importance in modern communication systems, presents some recent advances made in the topic, and concludes with avenues of future work that can be explored by researchers in the field.

## 1 Introduction

Military and civilian communications have seen two common trends in rencent years: an increase in network-oriented operations and an increase in high-risk threats to such networks [1]. These operational efforts place high reliance on the underlying network infrastructure for communication, so it is vital that this communication medium is protected against emerging attacks that focus on specific nodes in the network or communication lines that join nodes together. In this context the type of network attacks are irrelevant; the focus is more aligned with the optimal topology of networks and technological aids that can be utilized to help handle any changes in this topology.

This focus can be seen by a significant increase in research oriented around robust network design that provides high throughput and connectivitiy among all nodes in the network, especially when specific nodes are intentionally or unintentionally deleted from the network. Subsequently, the robustness of such networks can be viewed as a qualitative or quantitative measure of the network's resilience to such topology changes.

The problem of designing such networks has lent itself as a useful application of both graph theory and percolation theory. Graph theory has been applied to mathematically analyze the robustness of networks represented as undirected graphs based on their levels of vertex and edge connectivity. Similarly, percolation theory has been applied to study the behavior of connected clusters in undirected network graphs.

This paper will focus on recent research efforts centered around both of these branches of mathematical theory and their application to network design. It will also present practical methods of network engineering that have been employed to help networks deal with topology changes dynamically. Lastly, it will discuss avenues for future research and open problems that have been posed by researchers in the field.

## 2 Network Connectivity

It is natural to model any communication network as an undirected graph $G$, which has a fixed set of vertices $V(G)$ and edges $E(G)$ that connect such vertices. The topology of a network can thus be visualized graphically using elements from these two sets. For the remainder of this paper, we use the term vertex as a synonom for node and edge as a synonom for link. As an example of a graph representing a network, consider a completely connected network with $n$ nodes in which every node can directly communicate with every other node can be seen as $K_n$, the complete graph on $n$ vertices. In such a network, every node $v$ can communicate with exactly $n-1$ other nodes, which means that its degree $deg(v) = n - 1$.

In order to discuss the connectivity of networks, it is necessary to define the connectivity of such graphs in terms of both the vertices and edges.

## References

[1] Anthony Dekker Bernard. Network robustness and graph topology.