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Survey

Catastrophic event phenomena in communication networks: A survey

*Christopher Dabrowski**

Mailstop 8920, National Institute of Standards and Technology, Gaithersburg, MD 20899, United States

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ABSTRACT

With the rise of the Internet, there has been increased interest in the use of computer models to study the dynamics of communication networks. An important aspect of this trend has been the study of dramatic, but relatively infrequent, events that result in abrupt and often catastrophic changes in network state. In the research literature, such catastrophic events have been commonly referred to as *phase transitions*. As interest in phase transitions in communication networks has grown, different approaches to the study of such phenomena have arisen. These approaches are based on differing goals of the researchers, differing investigative methods, and selection of different causal agents to study. While researchers using various approaches have made progress in understanding phase transition phenomena in communication networks, today there is only an incomplete understanding of the overall state of knowledge on this topic and no agreement on a common explanation of how such events occur in communication networks. To provide better understanding of the work done so far, this paper surveys research on phase transitions in communication networks and summarizes what has been learned. The paper identifies four different approaches taken by researchers studying this topic, describes the scope of the work done, identifies the contributions that have thus far been made, and characterizes differences in views on the nature of phase transitions in communication networks. An assessment is also made of weaknesses in the work that has been done, most notably the lack of realism in network models used to date. This survey discusses characteristics of real-world communication networks that need to be included in such models to improve their realism.

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* Tel.: +1 301 975 3249.
E-mail address: christopher.dabrowski@nist.gov.

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1. Introduction

With the rise of the Internet,[1] there has been increased interest in the use of computer models to study the dynamics of communication networks. An important aspect of this trend has been the study of catastrophic events that result in an abrupt change in the macroscopic state of an entire network or in a distinguishable sub-network of significant scope. Of most impact are changes in which the network goes from a state in which it is operating normally and communications flow freely to a state where the network is severely degraded or effectively ceases to operate. Such catastrophic events have been commonly referred to in the literature as *phase transitions* from a global operational state to a failed state [1–5]. Events of this kind often can occur suddenly, providing no apparent warning before the rapid onset of a change that quickly permeates an entire network and alters its global state. In other cases, the events occur more gradually, suggesting the possibility that they can be predicted. These, and similar, events have been linked to different causes, including excessive load [1,6,7,2,8,3,4,9,10], propagation of computer viruses [11–14], and cascades caused by targeted attacks or failures [15–19]. Despite the potential of such unexpected events to cause widespread economic disruption, the occurrence of phase transitions in real-world communication networks is at best incompletely understood and methods for their prediction are unknown. By communication networks (real-world communication networks), this study refers to the Internet and the world-wide web (WWW), and significant subsets of these. The study excludes other types of networks (biological, social, voting, etc.) although references by some researchers may occasionally be made to these.

[1] Certain commercial products or company names are identified in this report to describe our study adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the products or names identified are necessarily the best available for the purpose.