Why organizational networks in reality do not show scale-free distributions

Peng-Xiang Li · Meng-Wu Zhang · You-Min Xi · Wen-Tian Cui

Published online: 13 August 2008
© Springer Science+Business Media, LLC 2008

Abstract This paper discusses chain of command networks that are most likely to exhibit the scale-free (SF) property in organizational networks, explaining why organizational networks do not show SF distributions. We propose an evolving hierarchical tree network model without explicit preferential attachment. The model simulates several kinds of chain of command networks with the span of control ranging from extreme homogeneity to extreme heterogeneity. In addition to traditional degree distribution, a new kind of cumulative-outdegree distribution \( p(K_{\text{cum}} = k_{\text{cum}}) \) is introduced and discussed that gives a probability that a randomly selected node has exactly \( k_{\text{cum}} \) children nodes. Theoretical analysis and simulation results show that even if the network size is large enough to meet the demand of large-scale networks, the SF property can emerge only when a hierarchical tree lies in two extreme situations: (1) the exact same span of control exists at all levels of an organization; (2) the node outdegree (i.e. span of control) distribution obeys a power-law distribution. The empirical investigations show that real organization networks are between the two

This research work was supported partially by the Excellent Innovative Research Group Funds under grant No. 70121001 from the National Science Foundation in China, and partially by the Chinese National Science Foundation grant Nos. 70571062 and 70673077. We acknowledge the financial support of “985 engineering” project No. NS-005 of Xi’an Jiaotong University.

P.-X. Li (✉) · Y.-M. Xi · W.-T. Cui
Department of Organizational and Management, Management School, Xi’an Jiaotong University, Xi’an 710049, China
e-mail: lipengx@mail.xjtu.edu.cn

Y.-M. Xi
e-mail: ymxi@mail.xjtu.edu.cn

W.-T. Cui
e-mail: cuiwt@mail.xjtu.edu.cn

M.-W. Zhang
Faculty of Humanities and Social Sciences, Xi’an University of Technology, Xi’an 710048, China
e-mail: zhangmw_99@163.com
extreme situations. This is why organizational networks in reality do not show an SF
degree distribution or SF cumulative-outdegree distribution. This finding shows that
the SF property is the consequence of extreme situations, even though it is very com-
mon in nature and in society. In fact, the SF property is of no value in the study of
problems in organizations.

**Keywords** Complex networks · Cumulative-outdegree distribution · Degree
distribution · Hierarchical organization · Scale-free networks

1 Introduction

Recent research in management science indicates that a complex system across dis-
ciplines is a special issue and it is suggested that management researchers could reap
the benefits of varied advances in the study of large scale, dynamic network behavior
with particular relevance to problems in organizations and business. Complex sys-
tems should be used as a new paradigm for the integrative study of management,
physical, and technological systems (Amaral and Uzzi 2007). Scientists making ad-
vances in complex networks offer a unique opportunity for organization researchers
to utilize their research results in examining problems in management, organizations,
and business. The major organizing principles of large scale networks are the scale-
free (SF) property and the small-world (SW) property. The SF property is character-
ized by the power-law degree distribution, \( p(K = k) = Ak^{-\gamma} (\gamma > 0) \), where the
degree variable \( K \) measures the number of links of nodes in the network and \( k \) is a spe-
cific realization of random variable \( K \), with \( \gamma \) being the algebraic scaling exponent
and \( A \) being a proportional coefficient. It shows that the SF networks are heteroge-
neous: a few nodes have a very large number of links, but the majority of nodes have
only a few links. Barabási and Albert proposed growth and preferential attachment as
the two basic mechanisms responsible for the SF property (Barabási and Albert 1999;
Barabási et al. 1999). A SW network is characterized by a short network distance
and a high clustering coefficient. Watts and Strogatz demonstrated that the two SW
characteristics can be obtained from a regular network by rewiring or adding a few
long-range links (Watts and Strogatz 1998).

Organizations have various kinds of networks that play an important role at all
levels, both within and between organizations (White et al. 2004). The PCANS
model, as a structural model in organization simulation (Krackhardt and Carley 1998;
Carley and Krackhardt 1997), viewed organization structure as compound networks
consisting of three entities (individuals, tasks and resources) and five kinds of rela-
tionships among them. Xi and Tang (2004) described the network organization with
SW features by using the Multiplex Multi-Core Model. Metaphorically speaking, the
chain of command network in an organization chart is just like an artery or vein in
a human body, through which orders flow from the top down and all kinds of infor-
mation streams from the bottom to the top. Various kinds of informal networks link
people in an organization to each other, just like a capillary vessel in our body and,
through these networks, organization culture, creative ideas, and some gossip can be
diffused. All kinds of functional activities in organization management are based on