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Manju Ahuja
Florida State University

Vivek Choudhury
Florida State University

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Evolution of Virtual Organizations over Time: An Empirical Examination

Manju Ahuja, Florida State University, mahuja@garnet.acns.fsu.edu
Vivek Choudhury, Florida State University, vchoudhu@garnet.acns.fsu.edu

Abstract

This paper addresses the evolution of the network structure of a virtual organization over time. Data has been collected on the E-mail messages exchanged by the members of a virtual organization at two points in time, 4 years apart. Social network analysis will be used to compute, and compare across time, two measures of emergent network structure – degree of hierarchy and centralization. Structure will be assessed both at the level of the overall organization as well as for each of principal 3 task categories – design (the core task of the organization), group maintenance, and resource management.

Introduction

Of all the terms that have been used to describe the emerging organizational forms, perhaps one of the most common is ‘virtual’. Lipnack and Stamps (1997) define a virtual team as “a group of people who interact through interdependent tasks guided by common purpose” that “works across space, time, and organizational boundaries with links strengthened by webs of communication technologies” (p. 7).

These new organizational forms are constructed out of emergent and ephemeral communication linkages that are formed, broken, and reformed with considerable ease (Palmer, Friedland, and Singh, 1986). Fluid and unimpeded by preordained formal structures (Krackhardt, 1994), they are characterized by a high degree of informal communication (Monge and Contractor, in press). Researchers have found that if the interactions of informal groups are tracked over a period of time, they exhibit a pattern of communication and reveal what has been referred to as network structure. Network structure is “the arrangement of the differentiated elements that can be recognized as the patterned flows of information in a communication network” (Rogers and Kincaid 1981, p. 82). These informal network structures often explain organizational behavior better than formal structures (Monge and Contractor, in press).

One aspect that has received little attention is the evolution of the structure of virtual organizations. For instance, Monge and Eisenberg (1987, p. 331) have stated that “with rare exceptions (Rice, 1982), network researchers have yet to design and conduct longitudinal network research that would inform us about the

dimensions of stability and change.” In this research, we examine communication among the members of a virtual organization at two points in time to provide empirical evidence of the evolution over time of its emergent structure.

A Virtual Organization – The SOARGroup

The virtual organization studied in this research – the Soar group – is engaged in research and design of a general purpose artificial intelligence architecture (Soar). Soar (originally defined as “State Operator And Result”) learns about possible solutions to problems as it solves them and continuously improves its capability to solve similar problems. Soar has also become a tool for studying the theoretical construct of cognition (Newell, 1990).

The Soar group has no single shared physical setting. Since its inception in 1982, the Soar group has spread to several universities and corporations nationally and internationally. The key participants are academic researchers and developers at Carnegie Mellon University, University of Michigan, and University of Southern California. Researchers from several corporations such as Xerox and Digital Equipment Corporation are also involved.

The Soar group communicates extensively by email to share information and coordinate tasks. For example, a member can inform the group through email when he or she finds a bug or discovers new requirements. Or members may post problems on a bulletin board, or solutions to problems posted by other members. The Soar group holds workshops twice a year, where the members have an opportunity to interact face-to-face.

The main task of the Soar group is *design*, including research and development, of the Soar architecture. The second task is *group maintenance*, that is, tasks concerning day-to-day operations of the group, such as organizing meetings and workshops, and maintaining distribution lists. Finally, members of the group need to make decisions regarding the *management and allocation of resources* including money, personnel, machines, disk space, and computer time.

Research Questions and Hypotheses

In this research, we will examine the evolution in the structure of the Soar group between 1989 and 1993. Two measures of network structure will be used -- degree of hierarchy and centralization -- because they apply to directed graphs depicting communication taking place among different points in a graph.

Degree of Hierarchy: Degree of hierarchy indicates the extent to which relations among the individuals in the organization are “ordered,” and there is little, if any reciprocity (Krackhardt, 1994). Krackhardt measures degree of hierarchy as follows:

$$D_H = 1 - \left[\frac{V}{MaxV} \right]$$

where V is the number of unordered or reciprocated links in the organization (A is linked to B and B is linked to A), and $Max V$ is the number of unordered pairs of points (A is linked to B or B is linked to A). A graph that is completely hierarchical will have no “reciprocated” or symmetrical links. Degree of hierarchy in a completely hierarchical network graph will be 1, whereas a completely non-hierarchical graph will be indicated by a score of 0.

Centralization: Centralization refers to overall integration or cohesion of a network graph. It indicates the extent to which a graph is organized around its most central point (Freeman, 1979). We use the measure degree centralization. The degree of a point is shown by the number of arrows coming in or going out of the point in a graph (Freeman, 1979). Conceptually, the degree of a point in the graph is the size of its neighborhood. This is measured by the aggregate difference between the centrality scores of the most central point and those of all other points. It is the ratio of the actual sum of differences to the maximum possible sum of differences. Degree centrality scores can range from 0 to 1, 0 being the score for a completely decentralized network.

We will examine changes (or lack thereof) in structure, both at the overall level as well as in the structure associated with each of the three tasks outlined above. While the research is partly exploratory, in light of our very limited knowledge of how virtual structures evolve over time, we have developed some preliminary propositions, based largely on our understanding of the evolution of more traditional organizations. The primary drivers behind these propositions are twofold: specialization and routinization.

We expect that during the early years of a group, there are a few experts, and much of the communication

flows through these individuals. Typically, the founders of the group will act as centralized repositories of knowledge about the core tasks of the group, in this case, design. Over time, however, there should be increasing specialization of roles and knowledge among members of the group. As a result, collaborative tasks, such as design, that require the joint input of different specialists, will exhibit a more decentralized communication structure.

Proposition 1: The structure associated with the design task will become more decentralized over time.

For tasks such as group management and resource management, the initial structure will be decentralized as the group jointly tries to determine how different processes will be managed and how different resources will be allocated. As these processes become routinized, however, and responsibilities for specific tasks are assigned to one or two individuals (specialization), the communication structure for these tasks will become more centralized.

Proposition 2: The structure associated with group management and resource management tasks will become increasingly centralized over time.

Combining the above two propositions, since the core task of the Soar group is design, we expect that:

Proposition 3: In general, the overall structure of the organization will become more decentralized over time.

Finally, as suggested above, we expect that over time, an increasing portion of the organization’s tasks will become routinized, that is, even virtual organizations will develop “organizational routines” (Nelson and Winter, 1982) to mirror the organizational routines that are present in most traditional organizations. In addition, a common language will develop among the members of the organization. As a result, a greater portion of the communication will be in the form of one-way broadcast messages, rather than interactive exchanges with frequent clarification and feedback, thereby leading to a more hierarchical structure.

Proposition 4: In general, the structure of the virtual organization will become more hierarchical over time.

Method and Data Collection

Data has been collected on E-mails exchanged among the members of the group at two different time periods – in the summers of 1989 and 1993. The Soar group had 63 members in 1989 and 66 members in 1993. These E-mails have been categorized with respect to the nature of the task associated with the communication.

A binary matrix has been constructed for each task using these email messages, with rows representing message senders, and columns representing message receivers. A value of "1" in the intersection of row A and column B indicates a communication link between A and B, whereas a "0" indicates lack of such a link. These matrices will be utilized as input to the Social Network Analysis software package UCINET (Borgatti et al. 1992) to compute Centralization values. The matrices will also be used to analyze Degree of Hierarchy using the software package Krackplot (Krackhardt et al. 1994).

The measures of network structure at these two time periods will be compared to draw some conclusions about the evolution of the structure during this time period. We expect to have completed the analyses, and have results to report, by the time of the conference.

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