Statistical Properties of Community Dynamics in Large Social Networks

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ABSTRACT

The authors’ focus is on the general statistical features of the time evolution of communities (also called as modules, clusters or cohesive groups) in large social networks. These structural sub-units can correspond to highly connected circles of friends, families, or professional cliques, which are subject to constant change due to the intense fluctuations in the activity and communication patterns of people. The communities can grow by recruiting new members, or contract by loosing members; two (or more) groups may merge into a single community, while a large enough social group can split into several smaller ones; new communities are born and old ones may disappear. According to our results, the time evolution of social groups containing only a few members and larger communities, e.g., institutions show significant differences.

Keywords: Community Dynamics, Percolation, Social Networks

INTRODUCTION

Until the recent past, social network research was based on questionnaire data, reaching typically a few dozen individuals (Granovetter, 1992; Wasserman, 1994; White, 1976). The main advantage of this approach is that it can provide very detailed information concerning the ties between people: what sort of acquaintance is it based on, how intense is the relation, whether it is mutual or not, what is the emotional background behind the connection, etc. However, a major drawback is that the size of the sample that can be generated this way is very limited, and as long as it is based solely on the opinion of the surveyed people, the strength of the ties remains subjective.

A major shift in paradigm begun to take place in this field around the millennium, when large datasets describing various social relations between people have become available for
research (Barabási, 2003; Mendes & Dorogovtsev, 2003; Watts & Strogatz, 1998). Due to the rapid development in informatics, the handling of social networks constructed from e-mail or phone-call records with more than a million nodes can be easily solved with present day computers. When compared to the questionnaire date, the information about the individual links is limited in these systems. However, the strength of the ties can be measured in more objective way, by e.g., aggregating the number of e-mails or phone-calls between the people. One of the most important new results obtained from the study of large scale social networks based on automated data collection was given by J.-P. Onnela et al. (Onella et al., 2007), providing empirical evidence for the famous Granovetter hypothesis (Granovetter, 1973).

In this chapter our focus is on the communities (modules, clusters, or cohesive groups) of large social networks, associated with more densely linked parts. These structural sub-units can correspond to families, friendship circles, or a tightly connected group of colleagues (Scott, 2000; Watts, Dodds, & Newman, 2002), and have no widely accepted unique definition (Everitt, 1993; Fortunato & Castellano, 2009; Girvan & Newman, 2002; Newman, 2004; Palla, Derényi, Farkas, & Vicsek, 2005; Radicchi, Castellano, Cecconi, Loreto, & Parisi, 2004; Shiffrin & Börner, 2004). Community finding turned out to be an important issue in other types of network systems as well (Knudsen, 2004), e.g., the location of multi-protein function al units in molecular biology (Ravasz, Somera, Mongru, Oltvai, & Barabási, 2002; Spirin & Mirny, 2003) or finding sets of tightly coupled stocks in economy (Heimo, Saramäki, Onnela, & Kaski, 2007; Onnela, Chakraborti, Kaski, Kertész, & Kanto, 2003) can be crucial to the understanding of the structural and functional properties of the systems under investigation. Due to the importance of communities in complex network theory, the set of available community finding methods is vast (Fortunato & Castellano, 2009). Here we shall use the Clique Percolation Method (CPM, Palla et al., 2005), which (due to its local nature) is especially suitable for studying evolving communities.

The frequent changes in the activity and communication patterns of individuals result in a constantly changing social network (Barabási et al., 2002; Ebel, Davidsen, & Bornholdt, 2002; Holme, Edling, & Liljeros, 2004; Liljeros, Edling, Amaral, Stanley, & Aberg, 2001), consisting of dynamically evolving communities. Our knowledge of the mechanisms governing this underlying community dynamics is limited, but is essential for a deeper understanding of the development and self-optimization of the society as a whole (Hopcroft, Khan, Kulis, & Selman, 2004; Kossinets & Watts, 2006; Noh, Jeong, Ahn, & Jeong, 2005; Pollner, Palla, & Vicsek, 2006). In this chapter we investigate in detail the time dependence of communities on a large scale and uncover the basic relationships of the statistical features of community evolution (Palla, Vicsek, & Barabási, 2007). We examine two networks of major interest, capturing the collaboration between scientists and the calls between mobile phone users. The observed communities show a number of elementary evolutionary steps in time, which range from community formation to breakup and merging. We find that large groups persist longer if they are capable of dynamically altering their membership, suggesting that an ability to change the composition results in better adaptability and a longer lifetime for social groups. Remarkably, the behavior of small groups displays the opposite tendency, the condition for stability being that their composition remains unchanged. We also show that the knowledge of the time commitment of the members to a given community can be used for predicting the community’s lifetime. These findings offer a new view on the fundamental differences between the dynamics of small groups and large institutions.
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