Self-Organizing Networks described by Evolutionary Algorithms *

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1. SELF-ORGANIZATION IN COMPLEX NETWORKS

The fitness of an evolving complex network is dependent on the question how well it can preserve the quality of service despite the dynamic processes of removed or added edges and nodes. This can be easily seen in any communication network used today: Whenever communication routers are removed from the system there needs to be some dynamic process that re-routes the information such that no other communication between participants is harmed. Since the quality of service is mainly depending on the network's structure, this rearranging requires that certain properties of the network are maintained, e.g., a short diameter of the network. If a network is not able to support such a dynamic, its fitness is unstable and depending on the environmental circumstances. After some bad experiences with such a network, users will avoid it and switch to another type of communication. In some communication networks this dynamic process is guided by a central designer. Much more interesting is the self-organization of such re-organizing processes in decentralized communication networks, such as the peer-to-peer-system Chord [2] or the Internet router system.

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We have shown in [1] that a part of these self-organizing evolutionary processes in networks can be easily described by a formal framework. In this framework, one vertex is chosen at random in every timestep, evaluates the network with respect to its own position in the network and then changes the network locally, guided by two changing rules. Some instances of this formal framework can also be viewed globally as a kind of an (1+1) evolutionary algorithm with a stochastic fitness function. Such, we have described the self-organization of a complex system as a special kind of evolutionary algorithm.

In our first examples, the changing rules themselves are not evolving. The next question will thus be: How could evolutionary processes have evolved that lead to a stable self-organizing dynamic in complex systems? Or: How did the system self-organize the evolution of these changing rules? A simple answer to this question might be that a complex system which is not able to self-organize its network structure is not as fit as one that does. I.e, we see a selection pressure on the level of the whole system. But there are networks that are not selected by their fitness as a whole because there is no alternative to them: An example is the set of airports and flights. Although this transport system may be sometimes inefficient, there is no real alternative to it. Thus, every single component of this system, e.g., an airline, has to decide how to alter the structure by announcing new flights and cancel others such that the functionality of the structure is improved for its own passengers. If the airline is successfull, this will attract passengers and thus improve the fitness of the single agent within the complex system. If not, the airline either has to evolve its changing rule or to give up.

If this is the way evolution in networks is accomplished, then evolutionary processes have evolved on the level of single agents. If other agents would then copy the behavior of the 'fit' airline, this would correspond to a vertical gene transfer in biology.

2. REFERENCES

[1] K.A. Lehmann and M. Kaufmann. Evolutionary algorithms for the self-organized evolution of networks. In *Proc. of GECCO 2005 (accepted)*, 2005.

[2] Ion Stoica, Robert Morris, David Karger, Frans Kasshoek, and Hari Balakrishnan. Chord: A scalable peer-to-peer lookup service for internet applications. In *Proceedings of the 2001 ACM SIGCOMM*, pages 149–160, 2001.