1/10 Scale Simulation of the Inter-AS Network Formation by a Dynamic Network Formation Game Model

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Abstract

Authors have proposed dynamic network formation game model for modeling the inter-AS network formation and shown that networks made by this model have power-law degree distributions in common with that of the real network by 100 node computer simulations. In this paper, authors try to evaluate the validity of this model by 2,000 node simulations which are over 1/10 scale size of the real network.

Keyword: Network formation game, Complex network, Graph simulation

1 Introduction

In present, two types of routing protocols are used for formation of the Internet topology. The first is the IGP (Interior Gateway Protocol) which is the protocol for transport *in* the local network(NW), the second is the EGP (Exterior Gateway Protocol) which is the protocol for transport *inter*-local NWs. The subsets of the NW treated as the unit of inter-local NWs routing are called Autonomous Systems (ASs). Thus there are two kinds of topologies for the Internet topology, the router-level topology and AS-level topology (inter-AS NW topology). Generally an AS consists of two or more routers and is coincident with a NW which is owned and managed by Internet Service Providers(ISPs) or large companies or universities, etc. The inter-AS NW topology is the graph obtained by treating each AS as a node and by treating each interconnection between two ASs as a link. In this paper, a target NW for which authors modeling is the inter-AS NWtopology.

The inter-AS NW topology is formed by exchanging a number of EGP routing messages. Since some of major EGPs enable AS administrators to reflect their policy to routing control, these route informations represent intentions of AS administrators. Exchanging route informations with another AS means exchanging data traffic to that AS. AS administrators have high ability to make decisions. They autonomously, distributedly and selfishly make decisions about adding and removing their links. Thus one node represents one decision maker at the inter-AS NW formation and emerged topology can be modeled as the results derived by their many decisions.

Mahadevan *et al.* [2] investigated statistical properties of the real inter-AS NW topology of year 2004 by three observation methods. According to their work, the number of nodes and links are 9204–17446 and 28959–56949 respectively. The degree distributions obtained by 2 of 3 methods almost obey power-law with power index in the range of 2.16–2.25.

2 Game theoretical model for the inter-AS NW formation

Authors have proposed dynamic NW formation game model (dynamic NWFG model) for modeling the inter-AS NW formation. This model is based on the NW formation game which is known in the field of game theory and this represents NW formation process derived by many distributed decision making by self-interest agents. Authors have already shown that NWs made by this model have power-law degree distributions in common with that of the real inter-AS NW by small scale computer simulations, which are done by 100 nodes and random link costs [1]. On the other hand, these simulations are about 1/100 scale size of the real inter-AS NW in the sense of the number of nodes. Most of statistic features of NWs are difficult to compare between NWs of greatly different scale. Thus investigation of statistic features of NWs made by this model through more large scale simulation is needed for more detail evaluation of the validity of this model as the model of inter-AS NW formation. In the case that this model is played by many agents, it needs a huge computing power because each agent decides her strategy selfishly under her own information at each time steps. Effective graph analysis algorithms and parallelization technologies are both valid to reduce this problem of computing power. Authors' simulate 2,000 nodes simulation of this model by adopting the C++ template library "LEMON" [3] for effective graph analysis and computational resources of SR16000/M1 for large scale parallel computing. The scale size of these simulations is over 1/10 scale size of the real inter-AS NW, and twentyfold size compared to previous work in the sense of the number of nodes. On the presentation, authors will report the result of evaluation of the validity of this model as the model of inter-AS NW formation by compareing various statistic features of NW topologies made by 2,000 nodes simulation of this model and these of the real inter-AS NW topologies. Authors believe that representing NW formation process derived by many distributed decision making by self-interest agents based on game theory is very important because it may be able to lead to development of method for appropriate incentive design for socially effective NW topology.

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[2] P. Mahadevan *et al.*, "The Internet AS-Level Topology: Three Data Sources and One Definitive Metric," Computer Communication Review, vol. 36, pp. 17–26, ACM, 2006.

[3] *LEMON :* `http://lemon.cs.elte.hu/trac/lemon`