End-to-End Network Topology Generation

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ABSTRACT

Motivated by the desire to generate topologies which take into account the dynamic failure and growth of the Internet nodes and links, we identify the need for high quality, multi-scale, end-to-end network topology generators. After examining a number of commonly used generators and comparing their output with data sources available at wide area (AS level), ISP (IP routing level) and enterprise networks, we are developing a mechanism for synthetically generating topologies which are able to represent networks across multiple scales. We are extending this work to include the dynamic evolution of networks.

1. INTRODUCTION

The spatial analysis of the Internet is necessary for research on network planning, optimal routing techniques and failure detection measures. An important step towards in-depth analysis of the Internet performance is the availability of network topologies at different levels of granularity. In the topology generation literature, currently the focus of research is on use of distribution-driven methods, which rule out the randomly generated graphs and aim on attaching meta-data type informations (metrics) to the links and routers generated in a graph. The lack of a set of metrics to correctly compare topologies can be noted, as today the comparisons between two topologies are often based on two graphs fitting a known distribution or having similar power law exponents for node degree distribution.

An area which is of importance for future work is focus on tools that produce a complete view of the Internet, form the Autonomous System (AS) level and their relationships, down to the Point of Presence (PoP) level and eventually the links and router level topology. An example of such a situation would be enterprise networks spanning across the globe, with nodes and routers being part of multiple AS sets. Such a tool would provide researchers with a testbed for looking at problems such as wide area failure detection, propagation of network epidemics, fault isolation or resilience routing. The main goal of our work is to present a tool which is a representative, end-to-end network topology generator, with the ability to incorporate multiple scales and dynamic evolution of the networks.

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2. INTERNET TOPOLOGY GENERATION

In the topology generation research, there is need for a generator that provides a complete network from transit AS level to router level topology, so if we are given BGP peering relationships plus node degree distributions from traceroute as input, it can produce several ASes based on the distributions and metrics and relationships in the BGP data, and for each AS produce PoP and router level networks based on the connectivity degree (obtainable from traceroutes) and actual physical connectivity metrics (available from IS-IS data). This is the goal of our research.

Generation of the topology of the Internet calls for a model that achieves a good balance between keeping the structural characteristics and node degree-related properties. At the routing layer and within an AS, IS-IS weights can also be used to annotate links based on the link-state routing protocol. Figure 1 displays the end result of a small portion of the Internet that will be produced with a multi-layer topology generator.

3. COMPARISON OF TOPOLOGY GENERATORS

We carried out an extensive comparative study of different topology generators and their underlying mathematical models. Thorough comparison of available topology generators, we identified their similarities and differences in generating a topology (AS or router level) from the same datasets. This is a step towards being able to generate a hierarchical topology, that keeps the requirements such as AS connectivity distribution and

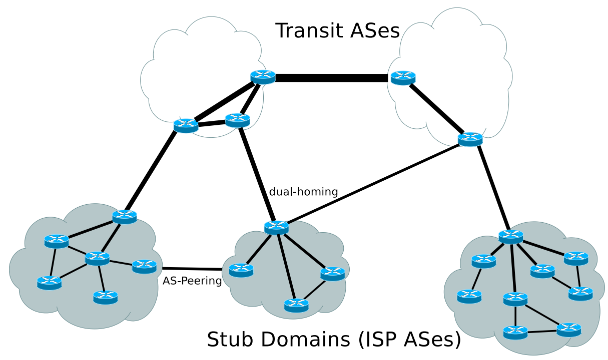

Figure 1: An abstract part of the Internet, link widths represent relative bandwidth.

router distribution intact.

This comparison is done by using the topology generators which are available for router and AS level models of the Internet, e.g., Inet [8], BRITE [5], Igen, GT-ITM [3]. Given a known input, such as certain number of nodes, the output from these generators and the underlying models can be directly compared. The results of this work sets an indicator for the relevance of models that are proposed by the research community for inclusion in the topology generator.

4. MULTI-SCALE TOPOLOGIES

The accuracy of a model for the Internet topology is improved by annotating the nodes and edges of the router and AS graphs with information that will bring the models closer to the reality of the networks. The numerous metrics studied in the literature are all tools available as a way of benchmarking a model against a real instance of a given topology, even though the collected data to date is far from being ideal for representing an ISP or the set of ASes within the Internet.

Real instances of router and AS-level topologies are needed in order to generate a topology that mimics that of a proportion of the Internet or an enterprise network. For this purpose, we use these datasets as a basis for getting our node degree distributions and connectivity statistics. At Router level, CAIDA Skitter [1] and RocketFuel [7] data are used. At Router-PoP level, RocketFuel data (important as it focuses on a single ISP) is used and at AS-level, GEANT [2] (NetFlow, BGP and IS-IS) data is be used. The availability of such data enables the correct inference of some of the underlying node degree and connectivity distributions of parts of the Internet. Such distributions will then be used as an input parameter for the topology generator.

Based on the above, we are developing of a tool that takes pre-defined models and metrics as input, and generates topologies at various scales, while keeping in mind the relationship and attachments of the nodes. The tool will make sure that the correct relationships are in place between ASes and routers at the appropriate level. An important novelty of the tool is the inclusion of the geographical information such as PoP level and AS membership information to the routers.

5. DYNAMIC NETWORK MODELS

There has been little work done in the topology research in order to incorporate discrete events such as addition of nodes and links or link failures into a topology generator. Such research is increasingly becoming of importance for enterprise network operators who try to achieve security and resilience by segmentation of networks into various operational domains using VLANs, private AS numbers, global routers and firewalls. As an important stage towards identifying dynamics of topologies, building up on previous efforts in the community in analysis of link failures in IP networks [4] and the evolution of AS level topologies [6], we are developing a methodology for embedding the evolution of the Internet in our generated topologies.

Acknowledgment

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