

Manuscript: CL 2002-1133

Generating Realistic ISP-Level Network Topologies

Oliver Heckmann, Michael Piringer, Jens Schmitt, Ralf Steinmetz

{Heckmann, Piringer, Schmitt, Steinmetz}@kom.tu-darmstadt.de

Corresponding Author:

Oliver Heckmann (Heckmann@KOM.tu-darmstadt.de)

Multimedia Communications (KOM),

Department of Electronic Engineering & Information Technology,

Darmstadt University of Technology, Germany,

Merckstr. 25, 64283 Darmstadt, Germany

Tel.: +49-6151-166163

Fax: +49-6151-166152

EDICS Classification: CL 1.7.3

Original Submission Date: Dec. 20th, 2002

Associate Editor: Christos Douligeris

List of changes:

- clarification of parameter space search added, ref [6] added
- similarity measures clarified, more formally specified
- edge- and core nodes defined
- ref. [4] clarified and corrected
- spelling mistake found by reviewer 2 corrected
- several sentences shortened
- figure 1 made “nicer”
- table 2 split into two tables

Abstract — Simulations are an important tool in network research. As the selected topology often influences the outcome of the simulation, realistic topologies are needed to produce realistic simulation results. Using several similarity metrics to compare artificially generated topologies with real world topologies this letter gives hints how to use the wide-spread topology generators BRITE, TIERS and GT-ITM to create realistic topologies.

I. INTRODUCTION

The wide-spread topology generators BRITE [1], TIERS [2] and GT-ITM [3] offer a big range of configuration parameters, GT-ITM for example has 16 different configuration parameters (for the transit-stub model). How realistic a generated topology is depends on the combination of these parameters. Usually the generated topologies are judged realistic or not by pure visual inspection. In this letter, we define objective criteria (similarity metrics). Based on those we search for parameter combinations of the generators mentioned above to generate topologies that are similar with respect to the metrics to two real world ISP topologies. Those real world topologies are first the rather large US AT&T continental IP backbone and second the smaller DFN G-Win (german research network), see Fig. 1. With these results we can compare how realistic artificially created topologies are and derive parameter combinations for the generators. They can act as a starting point for anyone who wants to do ISP level simulations using topology generators. Similar work was done in [4] on AS level graphs with at least 1000 nodes in order to evaluate topology generators for AS level graphs.

The paper is structured as follows: In the next section we present our similarity metrics. After that we present as results the best combinations for the two example topologies and three generators. We conclude with a short summary and an outlook.

II. SIMILARITY METRICS

To measure the similarity of two network topologies we define the following metrics that capture the basic connectivity

properties of the topology graph. We are interested in graphs with the same connectivity properties but not in equivalent graphs. In the graphs we distinguish between edge nodes (which are connected to end-users and other networks) and core/backbone nodes (which are only connected to nodes of the same network). We define the following metrics

1. The first metric uses the hop-plot of all nodes. For each graph g we look at all n nodes and calculate how many other nodes can be reached within $h=1,2,3,\dots$ hops. From this we derive the relative frequency distribution F_h^g . We compare the frequency distributions of both graphs.
2. The second metric F_h^{ge} is similar to the first but only looks at edge-nodes.
3. Next from the outdegree d_i of each node i we derive the relative frequency distribution of all nodes for both graphs and use the significance level of a Wald-Wolfowitz test for the similarity of the two distributions.
4. We also compare the rank exponent \mathfrak{R}
5. And the outdegree exponent O of the first and second powerlaw as defined in [5].
6. We also used the relative difference $\left| \frac{n_{generated} - n_{reference}}{n_{reference}} \right|$ in the number of nodes
7. And the relative difference in the number of links as additional metrics.

To express the difference in two distributions we sum up the accumulated absolute difference over all classes. Every metric is normalized to return a value between 0 and 1 with 1 resembling the highest similarity. All metrics are added to a combined metric and the result is normalized again.

We used a heuristic similar to Hook & Jeeves [6] to search for the parameter combination that yields the maximum combined similarity metric. If multiple topologies are created with the same parameter combination the resulting combined similarity metric varies less than 2% for all tested topology generators.

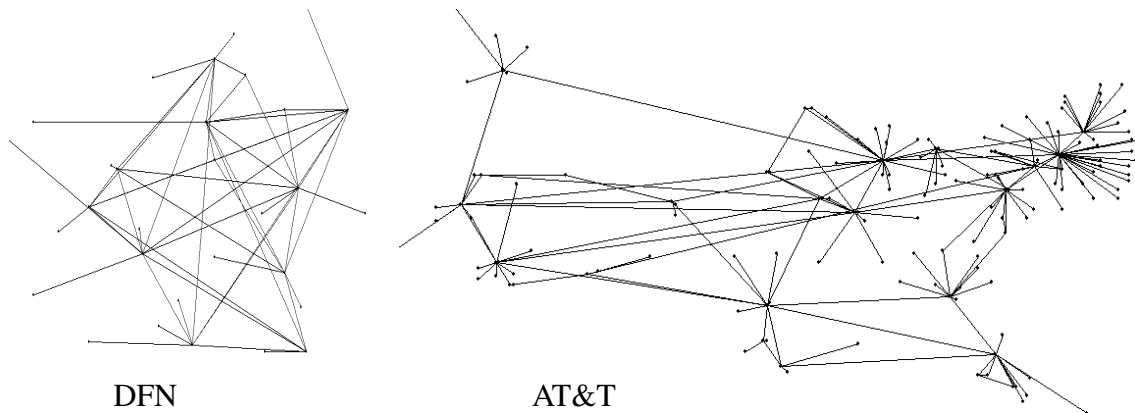


Figure 1: The DFN and AT&T Topologies

III. RESULTS

The parameters of Table 1 were found for Brite and the DFN and AT&T topologies with a high and satisfying combined and normalized similarity of 0.972 resp. 0.951. Please note that the values α and β do not seem to significantly influence the outcome of the measurements when the parameter links/node is

set to 2.

The parameters for Tiers result in a similarity of 0.998 and 0.995, the highest similarities found in our experiments, they are depicted Table 2.

The results for GT-ITM are displayed in Table 3 and Table 4 and have a similarity of 0.966 resp. 0.879.

topology	type	method	AS	nodes	router model	α	β	links/node
DFN	Bottom up	random pick	17	30	GLP	0.42-0.46	0.62-0.68	3
AT&T	Bottom up	random pick	31	154	GLP or BA	irrelevant	irrelevant	2

TABLE 1: PARAMETERS OF BRITE FOR DFN / AT&T-LIKE TOPOLOGIES

DFN	WAN	MAN	LAN	nodes/WAN	nodes/MAN	nodes/LAN
	1 [*]	1	1	9	4	17
	redundancy for WAN	redundancy for MAN	redundancy for LAN	redundancy for MAN to WAN	redundancy for LAN to MAN	
	6	4	1 ^a	7	2	
AT&T	WAN	MAN	LAN	nodes/WAN	nodes/MAN	nodes/LAN
	1 ^a	1	3	25	6	41
	redundancy for WAN	redundancy for MAN	redundancy for LAN	redundancy for MAN to WAN	redundancy for LAN to MAN	
	3	4	1 ^a	3 - 4	4	

TABLE 2: PARAMETERS OF TIERS FOR DFN / AT&T-LIKE TOPOLOGIES

* Parameter cannot be changed in TIERS 1.2

method	avg stubs/transit	extra t-s links	extra s-s links
transit-stub	1	10	6
top nodes	edge method	alpha	beta
1	3	0.99	-
transit nodes	edge method	alpha	beta
5	4	0.35	100
stub nodes	edge method	alpha	beta
5	2	0.5	100

TABLE 3: PARAMETERS OF GT-ITM FOR DFN-LIKE TOPOLOGIES

method	avg stubs/transit	extra t-s links	extra s-s links
transit-stub	3	12	12
top nodes	edge method	alpha	beta
3	3	0.3	-
transit nodes	edge method	alpha	beta
4	3	0.5	-
stub nodes	edge method	alpha	beta
4	3	0.2	-

TABLE 4: PARAMETERS OF GT-ITM FOR AT&T-LIKE TOPOLOGIES

To conclude Tiers was able in both cases to produce topologies that had the highest similarity to the real world ISP topologies, GT-ITM produced the least similarities. The level of similarity that could be reached is quite high and indicates that hierarchical topology generators are able to produce realistic router level topologies. This is contrary to the findings of [5] for AS level topologies.

Further experiments showed that the similarity with regard to most metrics (except of course the number of links and nodes metrics) remains roughly equal if the number of nodes and links

are increased proportionally for all topology generators. The found parameters can thus be easily scaled.

IV. SUMMARY AND OUTLOOK

In this work we have presented similarity metrics for network topologies and based on these we derived the combination of input parameters for 3 topology generators that lead to the highest similarity with 2 real world ISP-level topologies. The results show ranges of parameter combinations that generate realistic topologies and can act as a starting point for anybody

who wants to do realistic ISP level simulations.

We are aware that our results are only estimations for a limited number of topologies and metrics and plan to continue it using more topologies as well as more and different combinations of similarity metrics. We created a website <http://www.kom.e-technik.tu-darmstadt.de/~heckmann/topologies/> where we give access to our software and collect information about realistic ISP level topologies.

V. ACKNOWLEDGMENTS

This work is partly sponsored by the german research network provider DFN (<http://www.dfn.de>) as part of the LETSQoS project (<http://www.letsqos.de/>).

VI. REFERENCES

- [1] BRITE. Boston university representative internet topology generator, <http://www.cs.bu.edu/brite/>.
- [2] TIERS. Tiers topology generator, <http://www.isi.edu/nsnam/ns/ns-topogen.html#tiers>.
- [3] GT-ITM. Georgia tech internetwork topology models, <http://www.cc.gatech.edu/projects/gtitm/>.
- [4] H. Tangmunarunkit, R. Govindan, S.Jamin, S. Shenker, and W. Wollinger. Network topologies, power laws, and hierarchy. Technical Report Technical Report USC-CS-01-746, University of Michigan, USA, http://www.isi.edu/~hongsuda/publication/USCTech01_746.ps, 6 2001.
- [5] M. Faloutsos, P. Faloutsos, and C. Faloutsos. On power-law relationships of the internet topology.
- [6] R. Hooke and T. A. Jeeves. Direct search solution of numerical and statistical problems. pages 212–229, 8 1961.