Research Summary[1]

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My research interests lie in three broad areas of Networks: (i) Modeling real-world complex networks (ii) Random structures and algorithms, and (iii) Designs of large-scale dynamic networks. These areas act as the three vertices of a triangle with mutual inspiration between them. For example, while creating modeling tools for (i), I have been developing my best technical skills and expertise in (ii) for small-world random structures. Also, new theoretical results inspired new approaches and useful techniques to solve practical problems in (iii). I outline my contributions and future work below. More details can be found online in [7].

There has been extensive research characterizing and modeling real-world random networks, where the small-world phenomenon and the power-law degree distribution have been widely recognized as common properties. The small-world effect has been modeled as a simple local-contact graph augmented by a distribution of random links, by Watts & Strogatz [8], Kleinberg [1], and many others. While these local contacts are likely the source for high clustering, the random links (uniform in early models) create long-range contacts which shrink the graph diameter. Kleinberg uses a special *non-uniform, distance-bias* distribution of random links where links favor closer nodes over more distant ones, and produces a nice model for another aspect of small-worlds: short routes not only exist but can be found using limited local information only.

I envision a new direction of research on this type of random structures, which are formed by adding a non-uniform distribution of random links to a simple local-contact graph. I study general rules and characteristics for making small-world (and related) properties. Particularly, I consider the abstract properties of the random link distributions which can introduce short paths (typically, with length poly-logarithmic in the size of the graph) between the sites of the local-contact graph. Thus, I develop a general small-world construction framework, featuring a hierarchical family of random structures where *short paths can be found using decentralized routing in more refined classes*[3, 6]. This results in a thorough analysis of Kleinberg's small-world models and many other settings [2, 3, 6], and a number of analysis techniques that can be generally useful (in settings with non-uniform random links).

On modeling real-wold random network, I focus more on the Internet topology and related networks and observe that geographical factors are not only important in modeling these, but also crucial in designing new virtual networks or backbone infrastructures. In [4], I propose *a new general model for small-world properties which also considers geographical factors, yet can feature power-law degrees.* Especially, I analyze a structure where a growth-bounded base graph is augmented with a distance-bias distribution of random links, which helps to see why the Internet graph is a small-world with low diameter, but is locally growth bounded. I next intend to develop models which *combine distance-bias distributions of random links with power-law degrees* Our approach would be the first to analyze the role of geographical factors behind small-world properties and power-law degrees.

I provide a general framework for designing routing networks where the geographical distance has an important role: links tend to appear less often for farther distances. I propose a novel decentralized routing strategy (to best exploit this distance-bias tendency) and *network constructions which can optimize several measures simultaneously*: low graph weight (total edge weight), small routing diameter, bounded degrees and low congestion [5, 4]. This can be useful for classical areas of network designs with applications in hybrid wireless networks and optical wavelength division multiplexing (WDM) networks [5, 4]. I have also started working on concrete designs for a more general setting, where nodes can be distributed non-uniformly and node-to-node communication demands are not uniform.

My work significantly extends previous study of small-world random structures and contributes to the classical study of random graphs, in both theory and application aspects. Unlike most recent work in power-law research, our approach aims at routing strategies which avoid relying too much on high-degree nodes. This improves network load-balancing, robustness and resilience (to accidental collapses of high-degree nodes). This line of research blossomed from a desire to understand the striking aspects of the small-world effect.

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[1] More details can be found on-line at: http://wwwcsif.cs.ucdavis.edu/~nguyenvk/.

References

[1] J. Kleinberg, "The small-world phenomenon: An algorithmic perspective," in *Proc. of ACM Symp. on Theory of Computing (STOC)*, 2000, pp. 163–170.

[2] C. Martel and V. Nguyen, "Analyzing kleinberg's (and other) smallworld models," in *Proc. of ACM Symp. on Princ. of Dist. Comp. (PODC)*, 2004, pp. 179–188.

[3] V. Nguyen and C. Martel, "Analyzing and characterizing small-world graphs," in *Proc. of ACM Symp. on Discrete Algorithms (SODA)*, 2005, pp. 311–320.

[4] ——, "Localities plus (distance-bias) random links: Small-world models and applications," Submitted to STOC'06.

[5] ——, "Designing low cost networks with short routes and low congestion," To apprear in INFOCOM'06.

[6] ——, "Non-uniform random links in small-world graphs: Models, analysis and applications in network designs," To be submitted to SIAM J. on Computing.

[7] V. Nguyen. (Dec 2005, Full version) Statement of research. [Online]. Available: http://wwwcsif.cs.ucdavis.edu/ nguyenvk/VanNguyen-Research.pdf

[8] D. Watts and S. Strogatz, "Collective dynamics of small-world networks," *Nature*, vol. 393, pp. 440–32, 1998.