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A Novel Routing Strategy on Space Communication Network

Yujian LI[1], **Xu-Liang WANG**[1], **Zhen-dong XI**[1] and **Bing-hong WANG**[2]

[1]JLOMAC, China Satellite Maritime Tracking and Control Department, Jiangyin, China
[2]Department of Modern physics, University of Science and Technology of China, Hefei, China

E-mail: jinzhili@mail.ustc.edu.cn

Abstract. In this paper, we propose an effective routing strategy on the basis of the so-called nearest neighbor search strategy by introducing a preferential time delay exponent β. Traffic dynamics both near and far away from the critical generating rate R_c are discussed. Simulation results demonstrate that the optimal performance of the system corresponds to β=-0.5. Due to the low cost of acquiring nearest-neighbor information and the strongly improved network capacity, our strategy may be useful and reasonable for the protocol designing of modern communication networks and space communication networks.

1. Introduction

A variety of systems in nature can be described by complex networks and the most important statistical features of complex networks are the small-world effect and scale-free property.[1,2,3] It may serve as a very useful tool for understanding nature and our society. Since the discovery of some common interesting features of many real networks such as small-world phenomena by Strogatz and Watts[1] and Scale-free phenomena by Albert and Barabási, [2] processes of dynamics conducting on the network structure such as traffic congestion of information now have drew more and more attention from engineering and physical field, due to the importance of large communication networks such as **WWW**[4] and **Internet**[5] in modern society. Evolution of networks structure and interplay of traffic dynamics also play an important role in the research of the traffic system including Internet, highway network and so on , they want to understand and explain the process of dynamics on the underlying structure.

Many previous excellent works focus on the evolution of structure driven by the increment of traffic[6,7,8] and some explore how different topologies impact the traffic dynamics[12,13]. Some works[10,11] gave several models to mimic the traffic routing on complex networks by introducing randomly selected source as well as particles (packets) generating rate and destination of each particles[18-22]. Those models define the capacity of networks described by critical generating rate, too. At this critical rate, a continuous phase transition from free flow state to congested state occurs. In the free state, the numbers of created and delivered particles are balanced, leading to a steady state. While on the jammed state, the number of accumulated particles increases with time is due to the limited delivering capacity or finite queue length of each vertex.

We believe that the study on the network search is very important for traffic systems, for the existence of particles routing from origin to destination and communication cost is very meaningful. A few previous studies incorporate the search strategies and the traffic processes on networks[9]. In this paper, we present a traffic model in which particles are routed only based on local topological information with a single tunable parameter β. In order to maximize the nodes handling and delivering capacity of the networks which can be measured by an introduced order parameter η, the optimal β is found out. We also check the dynamic properties in the steady state for different α including average number of particles versus vertex′s degree, particles distribution and particles traveling time distribution. The dynamics right after the critical generating rate Rc exhibits some interesting properties independent of β, which indicates that although the system enters the jammed state, it possesses partial capacity for forwarding particles. Our model can be considered as a preferential walk among neighbor vertexes. We arrange the paper as follows: in the following section we describe the model in detail, then simulation results of traffic dynamics are provided in both the steady and congested states, A conclusion and discussion are given in the last section.

2. Traffic model

The first paragraph after a heading is not indented (Bodytext style). Our traffic model is described as follows: at each time step, there are R particles generated in the system, with randomly chosen sources and destinations, and all vertexes can deliver at most C particles toward their destinations, which is one of the most interesting properties of the whole traffic network. The capacity of each vertex is set to be C. As a remark, there is difference between the capacity of network and vertexes. The capacity of the whole network is measured by the critical generating rate R_c at which a continuous phase transition will occur from free state to congestion. The free state refers to the balance between created particles and removed particles at the same time. When the system enters the jam state, it means particles continuously accumulate in the system and at last few particles can reach their destinations. In order to describe the critical point accurately, we use the order parameter:

$$\eta(R) = \lim_{t\to\infty} \frac{C}{R} \frac{< \Delta N_p >}{\Delta t} \tag{1}$$

⊿Np = N(t+⊿t)-N(t) with <⋯> indicates average over time windows of width ⊿t and Np(t) represents the number of data particles within the networks at time t, here. For R < R_c, <⊿N>= 0 and η = 0, indicating that the system is in the free state with no traffic congestion. Otherwise for R >R_c, η -> r, where r is a constant larger than zero, the system will collapse at last. To navigate particles, each vertex performs a local search among its neighbors. If a particle's destination is found in the searched area, it will be delivered directly to its target, otherwise, it will be forwarded to a neighbor j of vertex i according to the probability:

$$\Pi_{i\to j} = \frac{\exp \beta * l_j / C}{\sum_i \exp \beta * l_j / C} \tag{2}$$

Here, l_i is the queue length in vertex *i*, so $\beta * l_j / C$ represents the waiting (delay) time of one new arrival particle. The sum runs over the neighbors of vertex *i* on the searched area and β related to waiting time is an adjustable parameter studied by us in the next context. Once a particle reaches its destination, it will be canceled from the system.

Here, we choose m = 5 and network size N = 1000 fixed for simulations. We should also note that the queue length of each vertex is assumed to be unlimited and the **FIFO** (First in First out) discipline is applied at each queue[9]. Another important rule called path iteration avoidance (PIA) is that a link between any pair of vertexes is not allowed to be visited more than twice by the same particle.[9] Without this rule, the capacity of the network is quite low due to many times' unnecessary visiting to the same links by the same particles, which does not exist in the real traffic systems. We note that this PIA routing algorithm does not damage the advantage of local routing strategy. If each particle records the links it has visited, the PIA can be easily performed. One can find that this rule does not need the global topological information. Therefore, we think this rule is rational and can considerably improve the network capacity.

3. Results and discussion

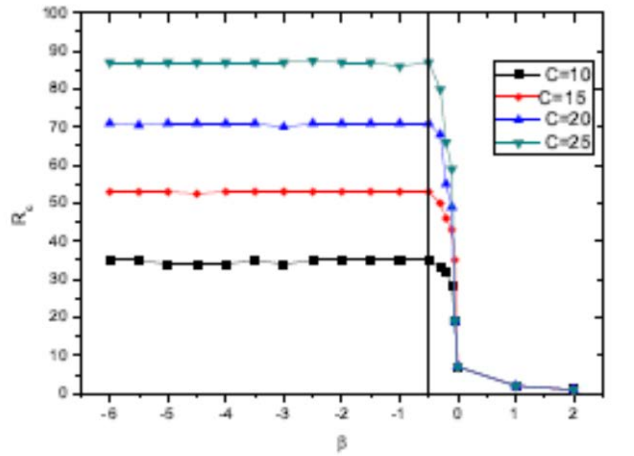

Figure 1 The critical R_c versus beta with network size N=1000, m=4. The critical beta =-0.5 marked by a black solid line.

As shown in Figure 1, It is easy to find that the capacity of the system is not the same for different beta. We can preliminarily determine that it is the critical situation. when the beta increases , the capacity of BA network measured by R_c considerably finishes the optimal performance at β =-0.5. we study every situations under different vertex capacity, and found that the critical system β is -0.5.

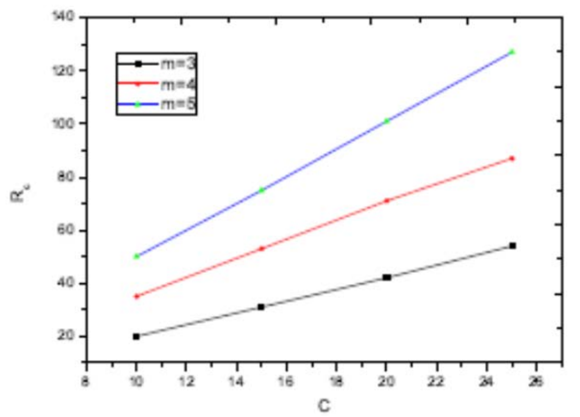

Figure 2(color online). The variance of R_c versus vertex capacity C with the increasing of m with network size N = 1000 and different vertex capacity.

As shown in Figure 2, the increment of vertex capacity C and link density m considerably enhances the capacity of BA network measured by R_c due to the fact that with higher link density, particles can more easily find their target vertexes.

4. Conclusion

We have introduced a new routing strategy based on local information, trying to give a solution to the problem of traffic congestion in modern communication networks. The optimal parameter β =-0.5 is obtained with maximizing the whole system's capacity. In addition, the property that scale-free network with occurrence of congestion still possesses partial delivering ability suggests that only improving processing ability of the minority of heavily congested vertexes can obviously enhance the capacity of the system. The variance of critical value R_c with the increment of C is also discussed. Our study may be useful for designing communication protocols for large communication networks due to the local information the strategy only based on and the simplicity for application. The results of current work may also shed some light on alleviating the congestion of modern technological networks.

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References

[1] Watts D. J. and Strogatz S. H., 1998 *Nature* **393** 440.
[2] Barabási A.-L. and Albert R., 1999 *Science* **286** 509.
[3] Albert R. and Barabási A. -L., 2002 *Rev. Mod. Phys.***74** 47.
[4] Pastor-Satorras R., Vázquez A., and Vespignani A., 2001 *Phys. Rev. Lett.* **87** 258701.
[5] Albert R., Jeong H., and Barabási A.-L., 1999 *Nature* **401** 103.
[6] Barrat A., Barthélemy M., and Vespignani A., 2004 *Phys. Rev.Lett.* **92** 228701.
[7] Barrat A., Barthélemy M., and Vespignani A., 2004 *Proc. Natl. Acad. Sci. U.S.S.* **101** 3747.
[8] Wang W.-X., Wang B.-H., Hu B., Yan G., and Ou Q., 2005 *Phys. Rev. Lett.* **94** 188702.
[9] Wang W.-X., Wang B.-H., Yin C.-Y., Xie Y.-B., and Zhou T., 2006 *Phys. Rev.* E **74** 016101.
[10] Yin C.-Y., Wang B.-H., Wang W.-X., Yan G., and Yang H.-J., 2006 *Eur. Phys. Jour.* B **49** 205.
[11] Wang W.-X., Wang B.-H., Yin C.-Y., Zhou and T., 2006 *Physical Review* E **73** 026111.
[12] Singh B. K., and Gupte N., 2005 *Phys. Rev.* E **71** 055103.
[13] Ashton D. J., Jarrett T. C., and Johnson N. F., 2005 *Phys. Rev. Lett.* **94** 058701.
[14] Zhao L., Park K., and Lai Y. C., 2004 *Phys. Rev.* E **70** 035101.
[15] Lee E. J., Goh K.-I., Kahng B., and Kim D., 2005 *Phys. Rev.Lett.* **71** 056108.
[16] Petter Holme, and Beom Jun Kim, 2002 *Phys. Rev.* E **65** 066109.
[17] Goh K.-I., Lee D.S., Kahng B. and Kim D., 2003 *Phys. Rev. Lett.* **91** 148701.
[18] Kim B. J., Yoon C. N., Han S. K. and Jeong H., 2002 *Phys. Rev.* E **65** 027103.
[19] Zhao L., Lai,Y.-C. K. Park, and Ye N., 2005 *Phys. Rev. E* **71** 026125.
[20] Zhang Huan, Liu Zonghua, Tang Ming, and Hui P. M., 2007 *Phys. Lett.* A **364** 177.
[21] M. A. de Menezes, and Barabási A.-L., 2004 *Phys. Rev. Lett.***92** 028701.
[22] Liu Zonghua, Ma Weichuan, Zhang Huan, Sun Yin, and Hui P. M., 2006 *Physica* A **370** 843.