A Multi-local World Network Model

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Abstract. Although people have the characteristics of group movement in their daily life, they are not distributed in a single local-world. People from different regions are connected with each other for many reasons, such as work and study. Therefore, on the basis of a local-world evolving network model, we propose and study a network model with the concept of multi-local world connectivity, which simulates Human Daily multi-workspace and multi-residential areas. In addition, the statistical characteristics of its complex networks are analyzed by simulation experiments.

Keywords: Local-world · Multi-local · Complex networks

1 Introduction

Since the 1990s, the information technology represented by the Internet has developed rapidly. With the rapid development of continuous progress of human society, we have already stepped into the Internet era [1]. From Internet to WWW [2], power system to global transportation network, biological brain to metabolic network, scientific research cooperation network to various economic, political and social relations, people are living in a world full of complicated networks [3].

Network is like a "double-edged sword", which not only brings convenience to people's work and life, but also improves production efficiency and quality of life [4]. However, it leads to negative effects such as computer viruses. The increasing networked human society requires people to have a better under-standing of various artificial and natural complex network behaviors. To study the structural properties of various complex networks [5], a unified tool for describing networks is needed. This tool is a kind of network model or graph in mathematics [6]. All networks can be viewed as a system of nodes connected together in some way. When designing and evaluating the network system or protocol, it is very important to choose a model which is consistent with the real situation [7]. Although there are many kinds of models have been proposed, such as, the RWP model [8] and the GMM model [9]. They still can't simulate the real-life networks very well.

In this article, we construct a multi-local world network model which is better consistent with the law of human's daily behavior according to the local-world characteristics of networks [10]. It simulates the relationships among people which have multiple work and living areas [11] and analyses the connectivity, scale-free characteristics and network degree distribution of the models.

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2 The BA Scale-Free Network Model

Barabási and Albert proposed a scale-free network model in order to explain the mechanism of a power-law degree distribution [12, 13]. According to the equation

$$\Pi_i = \frac{k_i}{\sum_j k_j} \tag{1}$$

The preferential attachment probability of each node is calculated. *P(k)* is the probability that the degree of node *i* is exactly *k*. The degree distribution function of BA network is obtained that $P(k) \sim 2\ m^2/k^3$. All indicate that the probability *P(k)* satisfies a power law with an exponent 3. All indicate that the probability *P(k)* satisfies a power law with an exponent 3. The scaling exponent is independent of m, the only parameter in the model, as shown by Fig. 1(a).

3 The Multi-local World Network Model

The BA scale-free network model calculates all nodes' preferential attachment probability by using Eq. (1), and then, generating the holistic network's average degree value. Because of the local-world was proposed, we have known that each node has its local connections in the real-life networks [14]. But just like people who work in different places. Wherever we go, we always return to our residences. As a result, most of human's movements are concentrated in typical areas like dwellings or work location [15]. Therefore we proposed a multi-local world network model. The generation algorithm of the multi-local world network model is as follows:

1. Randomly set up M regions and each region has m_0 nodes.
2. When choosing the regions to which the new node connects, assume that the probability Π_{local} that a new node is connected to region M_i depends on the node number of M_i at every time step t, in such a way that

$$\Pi_{local} = \frac{t + m_0}{t + M * m_0} \tag{2}$$

3. The new node was connected to m nodes with m edges when the region has been selected. We assume the probability $\Pi_i (i \in \text{multi-local})$ that the new node is connected to node i depends on the degree k_i.
4. According to step2 and step3, using a double preferential attachment $\Pi_{local}(i)$ defined at every time step t by

$$\Pi_{local}(i) = \Pi_{local} * \Pi_i = \frac{t + m_0}{t + M * m_0} * \frac{k_i}{\sum_j k_j} (i, j \in multi - local) \tag{3}$$

Using Eq. (3), the newly coming node linked to the network at every time step *t,* which are chosen with double preferential attachment. The new node selects the region and then connects the nodes from one of the multi-local world, but does not connect to the whole system as in the BA scale-free network model. Typically, we select several living areas for growth and preferential attachment. By the same way, the workspaces would be chosen.

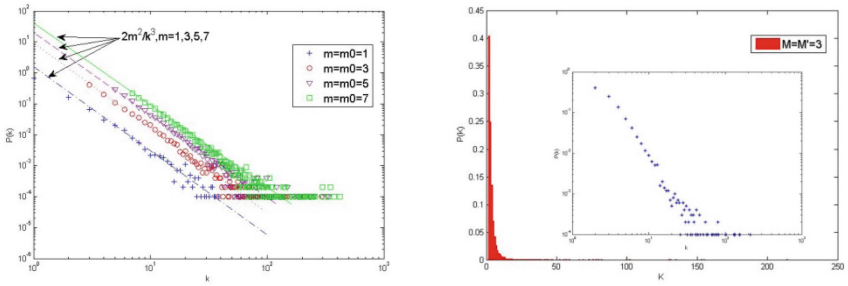
4 Simulations and Discussions

In this paper, we construct a multi-living area, multi-working area model and analyze its connectivity, scale-free characteristics and degree distribution. The parameters of simulation are shown as the Table 1.

Table 1. The multi-local world network model's parameter

Parameter	Value
The number of living area *M and* working area *M'*	3, 10
The initial number of nodes in a single region m_0	3, 10, 30
The number of edges connected *m*	1, 2, 3
The network size *N*	10000

By Matlab simulation, we built a multi-local world network model with living and working areas. As can be seen from the Fig. 1(b), this model has scale-free characteristics and the network diagram is connected.



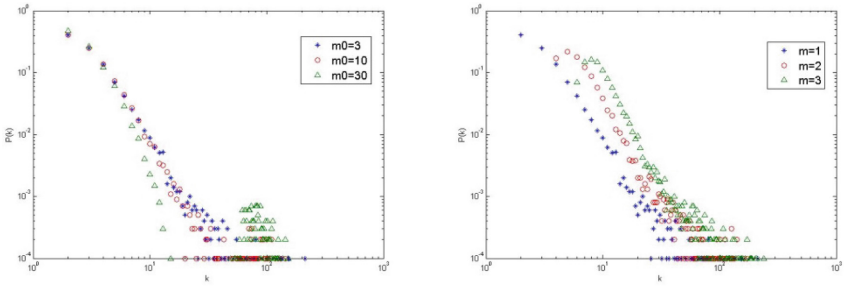
(a) (b)

Fig. 1. **(a)**. Degree distribution *P(k)* of the BA scale-free network model, with $N = 10000$ and $m = m_0 = 1, 3, 5, 7$, where the straight lines are the theoretical power-law scaling factors, $2\ m^2/k^3$, $m = m_0 = 1, 3, 5, 7$, respectively; **(b)**. Degree distribution *P(k)* of the multi-local world network model, with $N = 10000$ and $M = M' = 3$. The initial number of nodes in a single region $m0 = 3$ and $m = 1$.

The initial number of nodes will change the network distribution. We found that the degree distribution of the multi-local world network model will varies from exponential to power-law distribution because different m0. The greater m0 is, the larger proportion

it takes in the local-world after growth, the more homogeneous the evolving network. In contrast, the smaller m0 is, the smaller proportion of initial nodes in the evolutionary network will be. With the continuous growth of the number of network nodes, the final network model will become more and more uneven, as shown as Fig. 2(a).

In the real life, you will meet many people at one time when you come to a new place. So it is the same to the real-life network. The Fig. 2(b) demonstrates us that a new node adds in the multi-local world with not only one edge. The degree distribution characteristics of the multi-local world network will vary greatly. With the growing of *m* in the local-world, the more nodes are connected from one time to the next. The degree distribution curve becomes more and more curved. It means that the connections between nodes are closer and the networks of multiple LANS are getting evenly distributed.



(a) (b)

Fig. 2. (a). Degree distribution comparison in the log-log scale of the multi-local world networks. $M = M' = 3$, $m = 1$, $m_0 = 3, 10, 30$, $N = 10000$; **(b)**. Degree distribution comparison in the log-log scale of the multi-local world networks. $M = M' = 3$, $m_0 = 3$, m = 1, 2, 3, $N = 10000$.

5 Conclusions

In this paper, the multi-local world network model is more in line with human behavior in real society. In the real-life network, nodes usually selected the local area network which takes up a larger proportion in the overall network, and then choose the second priority according to the node degree distribution within the local-world. Through simulation tests, we get the multi-local world network model have exponential and power law changes due to different degree distributions of parameters. Furthermore, with growth it comes more connectivity.

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