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A Packet Routing Method for the Complex Networks based on Transient Chaotic Neural Networks

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Abstract—In this paper, we propose the packet routing method based on the mutually connected transient chaotic neural networks. The proposed routing method based on the mutually connected transient chaotic neural networks is compared with the one based on the Hopfield and Tank type mutually connected neural networks by the scale-free networks in this paper. From the results of the numerical simulations, the packet routing method based on mutually connected transient chaotic neural networks shows better performance for the scale-free networks.

1. Introduction

Recently, the data packet flows in computer networks increase because of the spread of the internet users or mobile interface. As a result, the data packets is often lost or delayed if the data packets in the computer networks are congested. An appropriated transmission method is needed to optimize carrying large data traffic. However, it has been shown that the shortest path protocol commonly employed in computer networks faces a serious challenge if the data volume continues to increase [1][2]. Specifically, the shortest path protocol transmits data packet using only the distance information of the communication network, therefore, the routers with a large number of shortest paths are easily congested [1]. Thus, to improve the packet routing algorithms, NN-O (Neural Network-Original) method was proposed for the packet routing problem [3]. This method determines the optimal path for the packet from the source to the destination using the mutually connected neural networks which evaluates the shortest distance of the packets to the destinations and the network congestion. The method [3] shows good performance for the regular networks, however, the performance of the method drastically decreases when the method is applied to the random networks or the scale-free networks [4]. Then, we proposed the packet routing method based on the mutually connected transient chaotic neural networks to improve performance on the scale-free networks in this paper. In our proposed method, each node in the computer networks has the mutually connected transient chaotic neural networks. Then, we expected that the decentralized effect which removes the packet congestion is realized by the chaotic dynamics of each node. From the results of the numerical simulations, the packet routing method based on the mutually connected transient chaotic neural networks shows better performance for the scale-free networks than the original routing method [3].

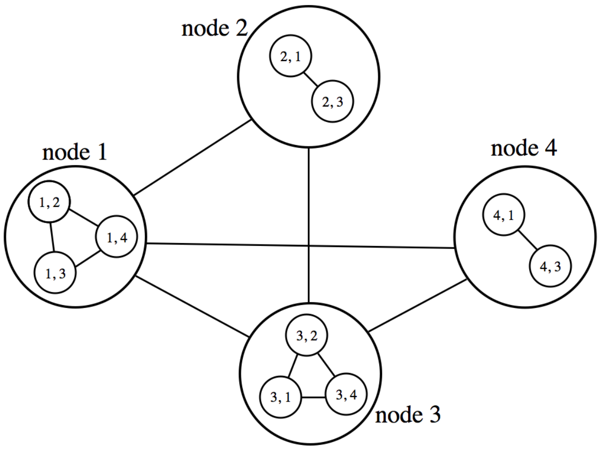

Figure 1: Schematic representation of the mutually connected transient chaotic network.

2. Packet routing method based on the mutually connected transient chaotic neural networks

Horiguchi et al. proposed a method for solving packet routing problem based on the mutually connected neural networks [3]. In the same manner as Ref. [3], we first assign the mutually connected transient chaotic neural networks to each node. In this model, the computer network model has N nodes and the node i has N_i adjacent nodes. The mutually connected transient chaotic neural networks are constructed by N_i neurons. Figure 1 shows the schematic representation of the mutually connected transient chaotic neural networks. In Fig. 1, the node 1 has three adjacent nodes. Then, the node 1 has the mutually connected transient chaotic neural network which consists of three neurons. In this transient chaotic neural network, the neuron il corresponds to the connection between the node i and the node l. Then, if the neuron il fires, a packet is transmitted to the node l from the node i.

Further, each node has buffer to store the some amount of packets. If the packet is transmitted to the node which has full of the buffer size, the packet is removed from the network. Also, we put the constraint on the packet movement on the computer networks. Then, if the packet is transmitted to the nodes beyond the constraints of the packet movement, the packet is removed from the computer network. In summary, this method has three objectives to transmit the packet as quickly as possible as follow:

- To minimize the total number of packets stored at each node.
- To minimize the total distance from between source nodes and the destination nodes.
- To transmit packet only to a single adjacent node.

Considering above objectives, we define the energy function E as follows:

$$E = -\eta \sum_{i=1}^{N} \sum_{l=1}^{N_i} \Big\{1 - \frac{1}{b_l}\Big(q_l + \frac{1}{2}\sum_{j\neq l}^{N_l} v_{jl}\Big)\Big\} v_{il} - (1-\eta)\sum_{i=1}^{N}\sum_{l=1}^{N_i}\Big(1 - \frac{d_l}{d_c}\Big)v_{il} + \xi \sum_{i=1}^{N}\Big(\sum_{l=1}^{N_i} v_{il} - 1\Big)^2, \quad (1)$$

where, η is a control parameter that decides the priorities of the first term and second term, b_l is buffer size of the adjacent node l, q_l is the number of stored packets at the adjacent node l, d_l is the shortest distance between the adjacent node l and the destination of the packet in the network, d_c is the longest distance in the network, and ξ is the parameter of guarantees the uniqueness of firing neurons. In Eq. (1), the first term represents minimizing the number of packets stored at the adjacent node l and second term represents minimizing the total distance between source node and the destination node. Further, the last term represents transmitting the packet only to a single adjacent nodes. The output of each neuron v_{il} is defined as follow:

$$v_{il} = \begin{cases} \dfrac{1}{1+\exp(-U_{il}/\epsilon)} & \text{(if the node } i \text{ adjacent to the node } l\text{)}, \\ 0 & \text{(otherwise)}, \end{cases} \quad (2)$$

where, U_{il} is the internal state of the mutually connected transient chaotic neuron il and ε is a steepness parameter of the output function ($\varepsilon > 0$). If the node i is adjacent to the node l, the internal state of the transient chaotic neuron U_{il} is defined as follow:

$$U_{il}(t+1) = kU_{il}(t) + \alpha\frac{\partial E}{\partial v_{il}} - z(t)\{v_{il}(t) - I_0\},$$
$$z(t+1) = z(t)(1-\beta), \quad (3)$$

where, k is the damping factor of nerve membrane ($0 \leq k \leq 1$), α is the scaling parameter, I_0 is the positive parameter, z is the self-feedback connection weight ($z(t) > 0$), and β is damping factor of the time-dependent ($0 \leq \beta \leq 1$) [5]. $\partial E/\partial v_{il}$ is obtained by partially differentiating Eq. (1) with respect to v_{il}. Then, $\partial E/\partial v_{il}$ is described as follows:

$$\frac{\partial E}{\partial v_{il}} = -\eta\Big\{1 - \frac{1}{b_l}\Big(q_i + \sum_{j\neq i}^{N_l} v_{jl}(t)\Big)\Big\} - (1-\eta)\Big(1 - \frac{d_l}{d_c}\Big) + 2\xi\Big(\sum_{k=1}^{N_l} v_{ik}(t) - 1\Big). \quad (4)$$

3. Simulation experiments

The packet routing method based on the mutually connected transient chaotic neural network is evaluated by the the scale-free network [6]. The computer network has scale-free property, so to evaluate the method by the scale-free network is important task. Also, we compare the performance of the proposed routing method with the one of the routing method with mutually connected neural networks [3]. The scale-free networks are constructed is the same manner proposed by Ref. [6]. The scale-free networks are constructed by the following procedure [6]. First, we make complete graph with m_0 nodes. Then, we put a new node with four links at every time step. Next, we connect four links of the newly added node to the nodes that already exist in the network with probability $\Pi(k_i) = k_i/\sum_{j=1}^{N} k_j$, where k_i is the degree of the node i (i=1,...,N) and N is the number of the nodes at the current iteration. We conducted computer simulations of the packet routing as follows. First, the packets are generated at all nodes randomly and destinations of the packets are determined at random. In these simulations, the values of parameters are set as follow [4, 5]: the number of nodes $N = 81$, $\xi = 0.3$, $\eta = 0.3, 0.5$ and 0.7, $k = 0.9$, $\alpha = 0.01$, $z(0) = 0.08$, $\beta = 0.001$, $I_0 = 0.65$, buffer size of each node $b_l = 100$, the threshold of each neuron $\theta = 0.9$ and the limit of packet movement is set to 20. ε is set to $1/250$ (proposed [5]) and $1/3$ (conventional method [3]). The routing methods are evaluated by the packet transmission for $5,000$ times using three different values of η in Eq. (4). To evaluate the performance of the routing method, we use the following evaluation measure [4]:

1. Average number of arrival packets:

$$\overline{A} = \frac{N_a}{N_g}, \quad (5)$$

where N_a is the number of arrival packets and N_g is the number of generated packets in the computer networks.

2. Average number of lost packets:

$$\overline{L} = \frac{N_l}{N_g}, \tag{6}$$

where N_l is the number of lost packets.

3. Average number of packets at each node:

$$\overline{S} = \frac{1}{N}\sum_{i=1}^{N} S_i(t), \tag{7}$$

where $S_i(t)$ is the number of packets in the node i at iteration t.

Figure 2 shows the average number of arrival packets and the average number of lost packets of the packet routing methods based on the mutually connected transient chaotic neural networks (Fig. 2 (a) and (c)) and the NN-O method (Fig. 2 (b) and (d)) for the scale-free networks. From the results of Fig. 2, the packet routing method based on the mutually connected transient chaotic neural networks and the NN-O method show similar performance in the case of the scale-free network. Both routing methods keep the average arrival packets almost 90% if the average number of packets at each node is less than 80. Figure 3 shows the number of arrival packets N_a and the number of lost packets N_l of the packet routing methods based on the mutually connected transient chaotic neural networks (Fig. 3 (a) and (c)) and the NN-O method (Fig. 3 (b) and (d)) for the scale-free networks. From the results of Fig. 3, we can see that the packet routing method based on the mutually connected transient chaotic neural networks is better performance than the NN-O method when the average number of packets at each node is $\overline{S}$ is less than 60.

4. Conclusion

In this paper, we proposed the packet routing method based on the mutually connected transient chaotic neural networks. Then, the packet routing method based on the mutually connected transient chaotic neural network is evaluated by the scale-free network. Also, the performance of the proposed routing method is compare with the original routing method using mutually connected neural networks [3]. From the results of the numerical experiments, the packet routing method based on the mutually connected transient chaotic neural networks shows better performance for the the scale-free networks. In future work, we analyze the effect of transient chaotic dynamics for removing packet congestion in more detail.

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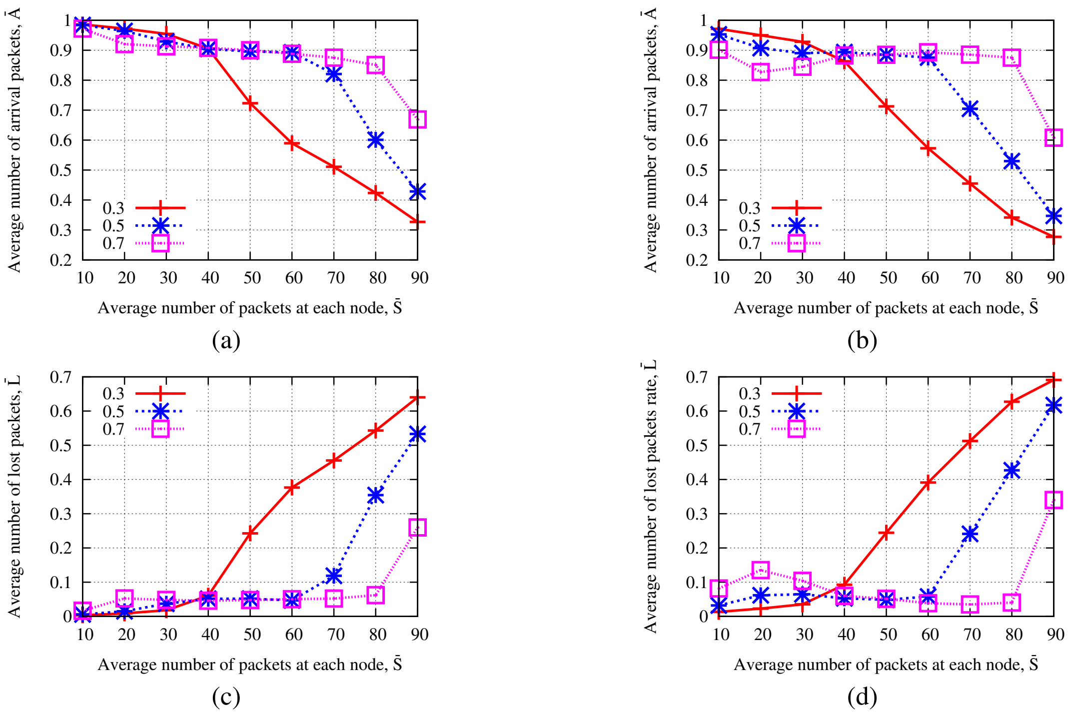

Figure 2: Relationship between the average number of packets at each node $\overline{S}$, the average number of arrival packets rate $\overline{A}$ and average number of lost packets rate $\overline{L}$ for the with scale-free networks by the packet routing method based on transient chaotic neural networks ((a) and (c)) and the NN-O method ((b) and (d)).

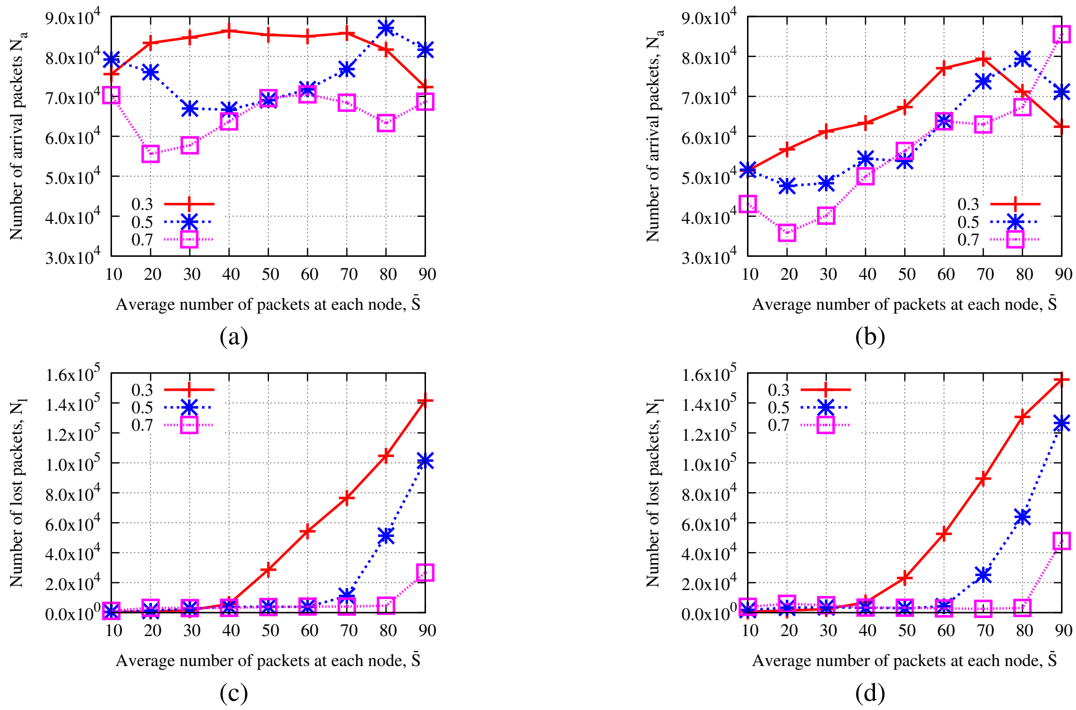

Figure 3: Relationship between the average number of packets at each node $\overline{S}$, the number of arrival packets N_a and number of lost packets N_l for the with scale-free networks by the packet routing method based on transient chaotic neural networks ((a) and (c)) and the NN-O method ((b) and (d)).