Routing Algorithm based on Gravitational Field of Nodes

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Abstract: For the impact of nodes on packet delivery, this paper presents the he routing algorithm based on gravitational field of nodes. The gravitational field theory is used and expounded, and also the gravitational field equations of nodes and computational formula for gravity on data packet on the transmission path are established. Experiments show that the proposed algorithm effectively balances the network load, alleviates the network congestion and improves the network throughput.

Keywords: Data packet; Internet; Routing selection; Node

1. Introduction

In the conventional shortest routing algorithm, the packet is always along with the path nearest to the target nodes for delivery, and if the source node and the destination node are determined, the transmission path is determined [1-3]. Liu G et al indicated that the gravity theory can be used to study the transmission progress of the data on network and proposed a routing algorithm with the gravitational constraints [4-7]. Referral of node largely reflects the gravity impact of nodes on packet in the delivery process. From the perspective of reverse thinking, if the gravity effect of the nodes can be effectively controlled, the uneven distribution affected by gravity can be reduced. And in the transmission progress, the data packets can selectively avoid the nodes with heavy congestion. Also maybe the transmission capacity is improved to some extent and the congestion situation is improved.

To better meet the needs of distributed grid algorithm, this paper proposes an improved hierarchical semi-centralized network structure based on a hierarchical semi-centralized heterogeneous wireless networks structure. As shown in Figure 2, it maps each network radio resource in the heterogeneous network environment into different three-dimensional resource units in the frequency domain, time domain, code domain, and regards each three-dimensional resource unit as a grid. Wireless grid management unit (WGMU) includes: Information Server (IS), resource allocator (RA) and resource statistics (RS). RS is set in the access node to count and calculate grid resource information of their jurisdictional nodes; RA is responsible for collecting homogeneous network RS information in different coverage and upload it to the higher-level server IS. IS is used to adopt the grid scheduling algorithm according to the user's need for business to make distribution strategies, and allocate different three-dimensional resource units to the user by controlling R A.

2. Complex network theory

Definition 1 Approximate centrality

Assuming di j represents the number of edges on the path with node I as the starting point and node j as the end point, the approximate centrality of node i can be represented as the reciprocal of the sum of all other nodes in the network. The approximate centrality can be expressed as:

$$T = \{t_1, t_2, ...t_i, ...t_n\} \quad (1)$$

3. Gravitational Field of Nodes

The data packets always simultaneously attracted by different nodes on the network, so as for the gravity of any node, the data packet has trends of flowing to the node at a certain degree; and it is associated with the gravity effect of node to packet, transmission capacity of this node, the degree of congestion and the logical distance between packet and node, but has nothing with the packet itself. Thus, each node has a certain gravity effect on all the packets on the network, which can inspire a gravitational field; the ways to transfer the packets under the gravitational field of different nodes depend on the specific routing strategy, and the routing policy mainly considers how to control the gravitational field and the route selection based on the gravitational field. In the premise of not considering packet transmission of target nodes, assuming that the data packet is currently in node j, the gravity of node i to the data packet is as following:

$$c(t_i) = c_{ti} - c_{im} \quad (2)$$

The above formula can be seen as the equation of gravitational field; wherein Fi is the gravity of node i to packet; κ is a constant; ci is the transmission capability of node i, that is the maximum number of packet data can be deal with per unit time; qi is the number of data packets in the current cache queue of node i; ci/qi can be seen as the degree of unblocked of the current node i; dij is the shortest length of path between node i and node j; α and γ are two adjustable parameters, which can be used to adjust the degree of unblocked of data transmission to node, transmission capacity of nodes and the degree of dependence of the path length, and $\alpha > 0$, $\gamma > 0$. In the gravitational field theory, the virtual quality of one node's gravity in the gravitational field and dark energy is direct proportion to the product of the quality of the star, and it is inversely proportional to the square of the distance of the center of rotation; it is independent with the mass of the object.

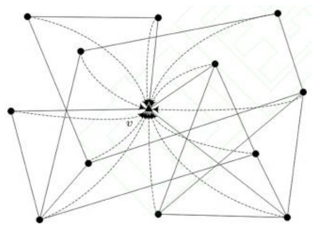

Figure 1. Gravitational field of nodes

4. Routing Algorithm

As shown in Figure 2, assuming the node set of the shortest path of source node s of the data packet, target node t, the current node v, its neighbor set of nodes N_v and neighboring node $i(i \in N_v)$ to destination node t is as N_{it} , and setting Nit contains the nodes i but does not contains the target node t. Because the t is the destination node of the packet transmission, and its traffic state has no effect on the transmission efficiency of data packets on node *v*, while the congestion situation of other nodes directly affects the transmission of data packet on node *v*. Since each node in N_{it} will stimulate a gravitational field, that is, each node has gravity effect on the data packets. To some extent, the data packets will transfer with the shortest path along with the node $i(i \in N_v)$ to the destination node t, but this possibility is not determined by one node on the path, but it is commonly determined by all the nodes. Thus the gravity expression of the shortest path to the packet is defined as the average value of gravity of all the nodes to the packet:

$$F_{it} = \frac{1}{n}(F_1 + F_2 + ... + F_n) = \frac{1}{N}\sum_{J \in N_{it}} F_j \qquad (3)$$

Wherein, Fit is the gravity of the shortest path from neighbor node i to destination node t to the packet; n is the number of nodes of Nit.

When the congestion of node occurs, as shown in Figure 3 (b) the gravity of the two paths passing node i, u, b and node j, e, f, g to packet are respectively as 0.1998 and 0.342, so node j is selected as the next routing node. The proposed routing algorithm ensures the packet along with the path with the maximum gravity and this path is the more smooth path of the shortest paths corresponding to neighbor nodes.

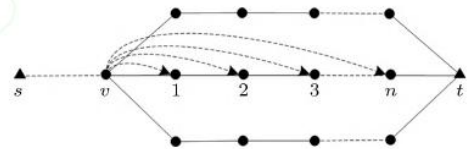

Figure 2. Routing Principles

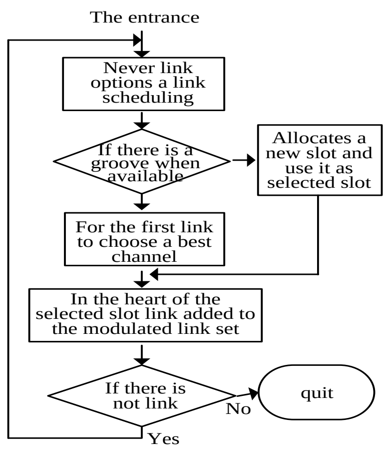

Figure 3. Routing Schematic

Ordered state parameters

With the increase of new added load R within unit time step, network traffic status will be transferred from the free flow sate to the congested state, and there is a critical load Rc. In order ot analysis the network traffic flow, a congestion index is defined to describe the transition of free state of the network traffic flow to the congestion flow:

$$\eta(R) = \lim_{t \to \infty} \frac{1}{R} \frac{W(t)}{t} \qquad (4)$$

Wherein, *W (t)* is the number of packets in the network at time *t*; *R* is the number of packets in the newly generated network per unit time step of; *η(R)* represents the ratio of the remaining number of packets in the network at the time t to the total generated number of data packets, which reflects the capabilities of network dealing with packet.

Wherein, Bi is the referral center value of the node *I*; *N* is the number of nodes in the network. B_i reflect the degree of aggregation of the connectivity of node *I*; when Bi is large, and the number of data packets passing through node *i* is large, so it more easily lead to congestion.

5. Experimental Simulation and Analysis

5.1. Experimental set

To test the effectiveness of the proposed algorithm, BA scale-free network model is chosen; the number of nodes is as N = 100, and m0= m = 4. During the simulation, each run has 10,000 steps, and then it can be considered that the flow on the network is basically steady. According to the average value of the last 1000 steps, the throughput Rc of network and the referral center value of the nodes Bi are determined, and for the different value of α and γ, the network routing efficiency are taken comparative experiments. What's more, data packets' maximum transmission time <Tmax>, average transmission time <Tavg> and average length of transmission path <Lavg> are the important indicators of measuring the network transmission performance. In order to further evaluate the efficiency of routing algorithm, this paper will also statistically analysis the <Tmax >, <Tavg> and <Lavg>. Without loss of generality, the dynamic characteristics of network traffic are analyzed under the situations of the transmission capacity of a node is equal to a constant (*c=1*) and the transmission capacity of a node is equal to a constant is equal to the degree(*c=k*).

5.2. Results analysis

Figure 5 shows when the transmission capacity is as c=1, the relationship of the shortest routing algorithm among. That the MLB (Maximum load balancing) algorithm is put forward by Sun Zhuo has superior performance in the hardware load balancing method; LOUHA K et al. proposed DLBD (Dynamic load balancing by dividing IP Flow) is a good algorithm in the soft performance in load balancing method by far. To verify the performance of GLBD algorithm proposed in this paper, we have carried on the simulation analysis among the GLBD algorithm and the MLB algorithm, the tap number of DLBD, business and network load balancing degree. The scenarios of simulation as shown in figure 4, simulation scenarios as shown in figure 4, the TD-LTE system area with the radius of 1.5 km and the WiMax system with 3 km radius overlap coverage, and the two systems center position overlap each other. Considering the multipath and path loss can lead to the difference of 3 d resource unit, the Rayleigh fading channel model is adopted here. At the start of the simulation, the user randomly distributed in the overlapping coverage area and move to the cell edge to change.

Figure 6 shows when the transmission capacity of nodes c = 1, the distributions of referral centers of nodes for the shortest routing algorithm under different load R, which gives distribution of the referral center value under R = 1, 5, 20, 60. Simulation results show that when R = 1 in the distribution of referral center value is dielectric most uniform; with the R increases, the degree of unevenness is weakened but still obvious unevenness. Figure 7 when the transmission capacity of nodes c = 1, the distributions of referral centers of nodes for the shortest routing algorithm under different load R , and it respectively make statistics of the referral center value with R = 1, 10, 16, 20, 40, 60,80, 100, and α =, γ = 2. As can be seen from the simulation results, with the amount of load R increases, the referral center value of the nodes shows the tendency of "uneven distribution-even distribution- uneven distribution"; when R=1, the distributions of the value of referral center of nodes are uneven, and the distribution is similar to the shortest route policy; with the increase of R, the value of referral center of nodes is tend to even, and when R ≈ 20, the level of even tends to the maximum; after that the distribution of the value of referral center of nodes is uneven with the increase of load R. When R = Rc, the value of referral center of nodes has been evenly, and when the distribution is the most even, the corresponding load is as R ≈ 20; all the value of referral center of nodes equal and approximately equal to 0.01.

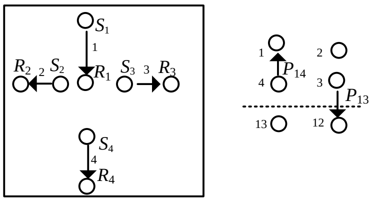

Figure 4. Changing situations of the shortest routing algorithm like ordered state parameters η,The maximum transmission time <Tmax>, mean transit time <Tavg>, average transmission distance <Lavg> and the load R (N = 100, m0 = m = 4, c = 1)

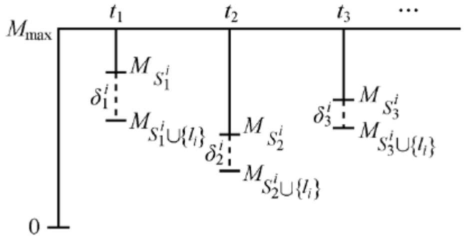

Figure 5. The proposed routing algorithm ordered state parameter η,maximum transmission time <Tmax>, average transmission time <Tavg>, average transmission distance <Lavg> and load R (N = 100, m0 = m = 4, c = 1)

The congestion situation of nodes of the shortest routing algorithms and routing algorithm are statistically analyzed; as shown in Figure 8 when the transmission capacity of node c = 1, the congestion situation of all l nodes on network is the number of packets in the node cache queue N (P). Figure 8 (a) and (b) are the results under the condition of load R> Rc, so the network is in a congested state. As can be seen from the simulation result, the network flow is distributed uneven under the shortest routing policy; wherein 58% node congestion level is as 0 and less than 90% congestion degree is less than 3, and the maximum congestion is 25712; The flow of network nodes is distributed evenly under the proposed routing algorithm, the distribution is greatly improved; 97% congestion degree is between 100-700, and the maximum congestion is as 703; compared with the shortest routing algorithm, the maximum extent of congestion is reduced by nearly 37 times. From the principle of the proposed routing algorithm, on the transmission process packets considers the extent of congestion, and then they can promptly and effectively avoid the heavy congested nodes and transferred the packet to other more idle nodes; gradually the he extent of congestion is eased, and ultimately the equalization of entire network load is realized . Meanwhile, since the packet transmission considers the impact of the path length, the data packets do not pass excessive detour on the network, thus ensures a strong network transmission capacity.

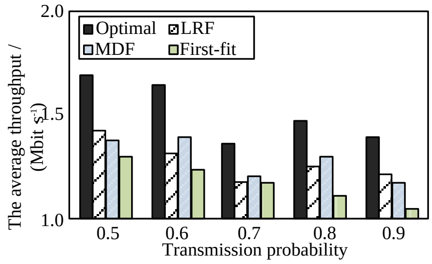

Figure 6. Distribution of the value of referral center of nodes of the shortest routing strategy under different load R N = 100, m0 = m = 4, c = 1

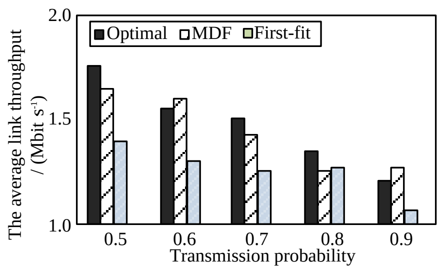

Figure 7. Distribution of the value of referral center of nodes of the proposed routing strategy under different load R N = 100, m0= m = 4, c = 1, α = 1, γ = 2

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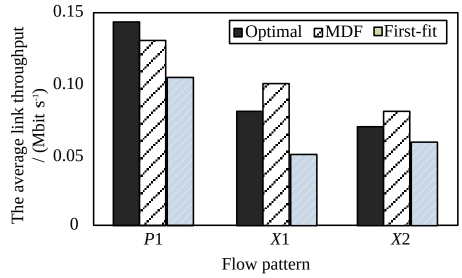

Figure 8. Simulation results of network congestion N = 100, m0 = m = 4 (a); the shortest routing algorithm R = 20, c = 1, N (P) ; the total volume is as 63716; (b); the total volume of proposed routing algorithm is as R = 20, c = 1, α = 1, γ = 2, N (P)

6. Conclusion

Meanwhile, the algorithm effectively balance the distribution of the referral center value of nodes, especially when the transmission capacity of nodes c = 1, the referral center value of all nodes to some extent are the same. This algorithm takes the length of the transmission path, the level of congestion of nodes on path and transmission capacity of nodes into account. Experimental results show that: the proposed algorithm effectively balance the network load, alleviates the network congestion and improves the network throughput.

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