Packets Distributing Evolutionary Algorithm Based on PSO for Ad Hoc Network

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Abstract. Wireless communication network has such features as limited bandwidth, changeful channel and dynamic topology, etc. Ad hoc network has lots of difficulties in accessing control, bandwidth distribution, resource assign and congestion control. Therefore, a wireless packets distributing Evolutionary algorithm based on PSO (DPSO)for Ad Hoc Network is proposed. Firstly, parameters impact on performance of network are analyzed and researched to obtain network performance effective function. Secondly, the improved PSO Evolutionary Algorithm is used to solve the optimization problem from local to global in the process of network packets distributing. The simulation results show that the algorithm can ensure fairness and timeliness of network transmission, as well as improve ad hoc network resource integrated utilization efficiency.

1 Introduction

Mobile Ad Hoc network is such a autonomous system as non infrastructure, full-distributed and multi-hopping, the network characteristics determines that the Ad Hoc network not only possesses fabulous military application value, also has highly commercial application value[1~2]. In recently years, with the continuous popularization of Ad Hoc knowledge in many fields, it is necessary to provide service quality support for Ad Hoc network, which becomes an important and challenging task. However, since the limitation of wireless network bandwidth, the conflicts are getting more and sharper between the limited wireless resource and complicated electromagnetic environment and service quality. Therefore, how to design a reasonable and effective resource distribution method becomes a key item to judge network performance.

Traditional wired network [3] merely affords transmission platform for data, it adheres to the design concept of end-to-end and the intermediate nodes are only responsible for retransmitting data. However, Ad hoc network is different from wired network in that it is data-centered wireless networks and the intermediate nodes also process data packets, as well as, the physical equipments of nodes are often subject to destruction and have limited energy and the wireless channel is vulnerable to be interfered with other transmission signals. All the characteristics mentioned above increase the difficulty to control the congestion of networks. Therefore, the traditional network congestion control schemes such as TCP, UDP, etc. can not meet the requirements of Ad Hoc network, which makes the research work of congestion for wireless networks more significant and challenging.

At present, some academicians make studies on self-origination wireless network resource distribution. Token bucket method is adopted on Fusion protocol[4] to make flows adjustment, a token will be accumulated by node after monitoring its father node transmits number of N data packets, and
cross-layer structure used to resolve transmission problems; but the structure has no transmission 
priority to distinguish process data packets. Literature [5–6] make study on price theory of traditional 
wire network, the theory reflects on the relationship between resource requirement and supply via 
price, to adjust resource distribution of multi-hopping data flow, moreover, the target function required 
to be strictly convex; although the algorithm can not be directly used for resource distribution of 
wireless self-organization network, it has perfect reference value for the study of Ad Hoc. Literature [7] 
studies price theory of wireless Ad Hoc network and proposes one resource distribution algorithm 
GPA, the algorithm converts resource optimization into Lagrange issue, non-linear programming 
method is applied to resolve the issue, but the calculation method is relatively complicated.

Although the existing schemes play important roles to improve network performance, however, 
fairness and timeliness is still a challenging area in wireless network. In this paper, a wireless packets 
distributing Evolutionary algorithm based on PSO for Ad Hoc Network is proposed in the paper. The 
Algorithm is divided into two parts: ①Firstly, parameters impact on performance of network are 
analyzed and researched to obtain network performance effective function; ②Secondly, the improved 
PSO Evolutionary Algorithm is used to solve the optimization problem from local to global in the 
process of network packets distributing.

2 PSO Evolutionary Algorithm

PSO Algorithm is a new Evolutionary Algorithm (EA) which is developed in recent years. PSO 
originates from the simulation of simple social system, it is an Algorithm based on swarm intelligence 
in computer field at the present time. The Algorithm is created by Doc. Ehebar and Doc. Kennedy [8]. 
The principle of the Algorithm is described as follows: Set random solution as an initial condition, 
search for the optimal solution after iterations for many times. And then overpass adaptive function to 
evaluate quality of the solution. However, the calculation rule of PSO Algorithm is simpler than that of 
Genetic Algorithm, without any superfluous Crossover or Mutation operation, follow on the optimal 
value currently searched to seek the complete optimization, it features easier accomplishment, higher 
accuracy and faster convergence. Therefore, it is more suitable for resource-constrained network 
system like Ad Hoc.

The mathematics description of Evolutionary Algorithm for elementary PSO is shown as below:

In D dimension search space, one group contains number of N PSO, noted as \( X = [x_1, \ldots, x_N] \), 
position variety rate (speed) of PSO \( i \) is noted as \( v_i = [v_{i1}, \ldots, v_{id}]^T \), and its position noted
as \( x_i = [x_{i1}, \ldots, x_{id}]^T \), and \( i = 1, 2, \ldots, N \); the optimal position of \( i \) at the current iteration position is 
noted as \( p_i = [p_{i1}, \ldots, p_{id}]^T \), till the current iteration, the optimal positions corresponded for all the 
PSOs are noted as \( p_g = [p_{g1}, \ldots, p_{gd}]^T \), when the two values are found, the calculation of PSO will 
be updated by the formulas described as below:

\[
\begin{align*}
  v_{id}(t+1) &= v_i(t) + c_1 \cdot r_1 \cdot (p_{id} - x_i(t)) + c_2 \cdot r_2 \cdot (p_g - x_i(t)) \\
  x_{id}(t+1) &= x_{id}(t) + v_{id}(t+1)
\end{align*}
\]

\[
  v_{id} = \begin{cases} 
  v_{\text{max}} & v_{id} > v_{\text{max}} \\
  -v_{\text{max}} & v_{id} < -v_{\text{max}} \\
  v_{id} & \text{otherwise}
\end{cases}
\]

(3)

In the formula, \( i = 1, 2, \ldots, N \), \( d = 1, 2, \ldots, D \); \( c_1 \) and \( c_2 \) is learning factor, it is nonnegative 
constant, it is generally set as 2; \( r_1 \) and \( r_2 \) is a random number within \([0, 1]\); \( v_{id}(t) \) and \( x_{id}(t) \) is 
respectively represents the current speed and position of \( i \); \( p_{id} \) is the individual optimal position of \( i \); \( p_{gda} \) is the integrated optimal position of \( i \).
3 DPSO Algorithms

In the specific scene of Ad Hoc network, it is necessary to set reserved control of resource for bandwidth, channel, storage and time delay, etc. The first step of resource reservation is to select router. Routing protocol must firstly find a path with enough resource and meet application requirement, so that resource establishment protocol can walk along with this path gradually negotiate and establish resource reservation. In the Algorithm, each node is acted as PSO and corresponds one by one, those parameters impacted on network resource distributing will be integrated, and global performance function of network is obtained. PSO Evolutionary Algorithm is adopted to search for the optimal path during the data transmission.

3.1 Network performance function

In terms of whole network capability, there is so many parameters to decide network service quality, including: time delay, capacity, connection, jitter, security, throughput, transmission priority, anti-destroy, etc. In the proposal, those parameters impacted on time delay while data packets of network transmitting will be integrated to gain the Function of time-delay. As follow:

(1) The factor of density (D): Multi-hop is usually necessary since most of nodes are impossible to communicate with the base station directly. If the number of neighbor nodes surrounds the node is many enough, the range of router selection is correspondingly larger, therefore, it is easier to find a path with optimal time delay. Without loss of generality, we assume that the transmitting delay impact of density for node i is \( D_{i}(t) \).

(2) The factor of queue (Q): latency time of data package within the node is impacted by the queue model such as receiving sequence as well as cache capability of node data. Without loss of generality, we assume that the transmitting delay impact of queue for node i is \( Q_{i}(t) \).

(3) The factor of Power (P): Since the broadcasting feature of wireless channel, the links of network have interference with each other, which brings negative influence to network transmission. Furthermore, both topological structure and transmission capability of network is impacted by emission power. Without loss of generality, we assume that the transmitting delay impact of power for node i is \( P_{i}(t) \).

(4) The motion feature of node brings difficulty for network analysis and maintenance, and the motion of node is related with time. Without loss of generality, we assume that the transmitting delay impact of motion for node i is \( T_{i}(t) \).

In accordance with the resource factors, combining with node recourse and network function environment, the assigning function of transmitting delay to each node is:

\[
\text{Delay}_{i}(t) = D_{i}(t) + Q_{i}(t) + P_{i}(t) + T_{i}(t) \tag{4}
\]

3.2 PSO Algorithm optimal resource

In the paper, take the time delay between the neighboring nodes (1hop) as local optimal value of PSO algorithm, all the time delay in the path from source node to target node is regarded as integrated optimal value of PSO algorithm. The detailed of algorithm is described as follows:

(1) PSO optimal Algorithm

Since PSO Algorithm is hard to simultaneously have local and integrated optimal value, therefore, formula (1) is revised as per literature [9], the detailed is described as follows:

\[
v_{i}^{t+1} = \omega(t) v_{i}^{t} + \xi^{t} \left[ P_{i}^{t} - (y_{i})^{t} \right] \tag{5}
\]

There into:

\[
\omega(t) = \omega_{0}^{t} - \frac{\omega_{0} - \omega_{n}}{T_{m}^{t}} = \frac{0.9}{2T_{m}} \tag{6}
\]

In the formula, \( \omega(t) \) is inertia weight; \( t \) is the number of iteration; \( T_{m}^{max} \) is the maximal iteration.
number.

(2) Optimal path selection method of resource distribution

Since PSO Algorithm exists a lot of circulation calculation as well as variables, hence, time delay performance function and PSO Evolutionary Algorithm is integrated in the mode of matrix. The specific path selection process is shown as below:

Step1: Matrix and initialization the variable and parameter, such as speed and the optimal position for each PSO (matrix mode of unknown and global optimal position for PSO has already been described in the last section).

If: \( V = [v_1, \cdots, v_n] \), \( P = [p_1, \cdots, p_n] \)

\( v_i \) represents reciprocal of time delay from transmission data of source node I to target node, if \( v_i \) is bigger, \( Delay_i(t) \) is smaller, namely, the faster of transmission data, the time delay is smaller, and network performance is better; if \( v_i \) is smaller, \( Delay_i(t) \) is bigger, namely, the slower of transmission data, the time delay is bigger, and network performance is worse. In order to obtain effective convergence of Algorithm, \( p_i \) represents the optimal path of transmission for network data package from source node i to target node.

Step2: Update each speed of PSO in accordance with inertia weight:

\[
V(t+1) = \frac{1}{Delay_i(t)} \ast \varepsilon \ast (0.9 - \frac{t}{2T_{max}}) \ast V(t) + c_1 \ast r_1 \ast (P(t) - X(t)) + c_2 \ast r_2 \ast (p_s(t) - x_{id}(t))
\]

Namely:

\[
\varepsilon = T_y^{data} \left( t \right) \ast \left( R_y^{data} \left( t \right) + T_y^{data} \left( t \right) \right) \\quad r_1 = r_2 = S_y(t) \left( t + F_y(t) \right) / S_y(t+1) \left( t + F_y(t+1) \right)
\]

\( T_y^{data}(t) \) represents number of data packet required to be transmitted, \( R_y^{data}(t) \) represents node j number of retransmission data packet after feedback of ACK; \( S_y(t) \) represents number of passing times of data packet from node i to node j, \( F_y(t) \) represents number of not passing times of data packet from node i to node j.

\( p_s(t) - x_{id}(t) \) represents the value after normalization processing between change of the current router and the optimal router set. For example, the current path is A[i,1,4,8,10,j] from node i to node j, after updating PSO, the optimal path is B [i, 4, 8 ,j], now the variable is 2, and the normalization processing after updating is 2/6, the number of factor in Set A is 6. The meaning of \( P(t) - X(t) \) is the same as above mentioned, which is the processing result of the normalization of matrix.

Step3: According to extremism of PSO speed to update speed.

\[
\begin{align*}
\text{if } v_i(t+1) = 0 & \quad Delay_i \geq Delay_{max} \\
\text{if } v_i(t+1) \neq 0 & \quad 5 < Delay_i < Delay_{max}
\end{align*}
\]

\( Delay_{max} \) is the longest data transmission delay of the system can bear.

Step4: Update position of each PSO.

\[
X(t+1) = X(t) + V(t+1)
\]

Step5: In accordance with adaptability function to update optimal position of each PSO and the integrated position for \( f(x) \).

\[
p_s(t+1) = \begin{cases} 
  p_s(t) & f(p_s(t)) \leq f(x_i(t+1)) \\
  x_i(t+1) & f(p_s(t)) > f(x_i(t+1))
\end{cases}
\]

\[
p_s(t+1) = \min f(p(t+1))
\]
Step 6: Check whether arrives at the maximal iteration steps. If meets, output the integrated optimal positions and optimal adaptability, otherwise, it will turn to Step 2.

4 Simulation

We use C++ language as simulation tool to analyze the performances of the DPSO algorithm in this section. The concrete simulation scene is a square area, with 100 nodes randomly deployed. Each particle stands for one user node in a network instance, suppose that the user node (particle) randomly distributed in a three-dimensional space, and set each parameter as follows: The number of user nodes: 100; Circulation periods: 100 times; Transfer probability and volatilization coefficient of information element \((e, r_1, r_2)\) will be automatically adjusted in the operation process. In order to \(Delay_{(t)}\) is not negative, we substitute square of \(Delay_{(t)}\) for \(Delay_{(t)}\). The simulation results are shown in Fig. 1.

Figure 1 The result of simulation
From Fig.1, we can see that the different paths have great influence on the performance of the network in the process of data transmission. In the 100 times particle optimization process, the results of the second time is worst, it is 1530.79, the results of the 91 time is best, it is 0.0295076. This is because: in the second time particle optimization process, the direction of the particle search and data transmission in the direction of the opposite, so the data transmission is far away from the destination address. In the 91th time particle optimization process, the algorithm achieves the optimal values. Certainly, in the actual case, the optimal value of the particle optimization results and the difference is not so big. This is because: in this paper, in order to avoid negative values of particle algorithm, we use the square of $\text{Delay}_i(t)$ to calculate the optimal value of particle. The simulation results show that the algorithm can ensure fairness and timeliness of network transmission, as well as improve ad hoc network resource integrated utilization efficiency.

5 Conclusion

The different paths have great influence on the performance of the network in the process of data transmission. A wireless packets distributing Evolutionary algorithm based on PSO (DPSO) for Ad Hoc Network is proposed. Firstly, parameters impact on performance of network are analyzed and researched to obtain network performance effective function. Secondly, the improved PSO Evolutionary Algorithm is used to solve the optimization problem from local to global in the process of network packets distributing. The simulation results show that the algorithm can find the optimal transmission route in the process of network data transmission.

References

[1] M. Gerla. Ad hoc networks: Emerging applications, design challenges and future opportunities. In Ad Hoc Networks: Technologies and Protocols, P.Mohapatra and S. Krishnamurthy, 2004, 1:1-45.

[2] Xueyuan Su, Chan S., Manton J.H. Bandwidth allocation in wireless ad hoc networks: Challenges and prospects [J]. IEEE Communications Magazine, 2010, 48(1): 80-85.

[3] Chiu, D. M.; Jain, R. Analysis of the increase and decrease algorithms for congestion avoidance in computer networks. Compute Networks and ISDN Syst. 1989, 17(1), 1-14.

[4] Hull B, Jamieson K, Balakrishnan H. Mitigating Congestion in Wireless Sensor Networks. In: Proceedings of the 2nd ACM Conference on Embedded Networked Sensor Systems, New York, USA, 2004, 134-147

[5] F P Kelly, A K Mauled, D K H Tan. Rate Control for Communication Networks: Shadow Prices, Proportional Fairness and Stability [J]. Journal of the Operational Research Society, 1998, 49(3): 237-252.

[6] Ronaldo M. Salles, Javier A. Barria. Lexicographic maximum optimization for fair bandwidth allocation in computer networks [J]. European Journal of Operational Research, 2008, 185(2): 778-794.

[7] Y Xue, B. Li, K. Nahrstedt. Optimal resource allocation in wireless ad hoc networks: A price-based approach [J]. IEEE Transactions on Mobile Computing, 2006, 5(4):347-364.

[8] Kennedy J, Eberhart ILA new optimizer using particle swarm theory[C]. In: Proceeding sixth International Symposium on Micro Machine and Human Science IEEE service center, Nagoya, Japan, 1995: 39-43