An Improved Task Scheduling Algorithm of NSGA-II for Wireless Ad Hoc Networks

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Abstract
In order to solve the problem of lower efficiency caused by the mobility and failure-prone of ad hoc nodes, a multi-object optimization task scheduling algorithm (MOTA) is proposed in this paper. Based on research of the traditional wireless Ad hoc network task the algorithm, gives a consideration at the same time general assignment completion time, task execution probability and node energy consumption scheduling multi-objective optimization algorithm. This algorithm can pursues the shortest task completion time, and takes into account the failure probability and energy consumption of the nodes. The MOTA avoids assigning tasks to the node with higher failure rate, reduce the impact of node failure on the system. Through experiment, the results show that compared with the traditional task scheduling algorithms the MOTA can get good balance between task completion time and energy consumption

Key words: Wireless Ad Hoc Networks, Task Scheduling, Multi-object Optimization, Make Span.

1. INTRODUCTION
Wireless network technology is a communication technology has developed rapidly in recent years, it allows users to use more convenient and flexible way to access the network, people can be equipped with wireless interface of portable computer or personal digital assistants (pdas) to implement in mobile communication(Amanda and Narayanan, 2008). At present, the wireless network according to its structure is divided into a center and center network (also known as Ad hoc network) with different center network has a fixed base station equipment (Sun, 2015), Ad hoc network, without a fixed base station equipment, wireless section by running the specific protocol, find each other and join into the net. Nodes in the communication as terminal as a router at the same time, both for pathfinding and forward functions for the data. In the war and disaster relief, it is difficult to guarantee the reliable cable communications facilities, therefore, their combination by communication nodes composed of a communication system is very necessary. Ad hoc network can meet these requirements(Li, 2016). At present, the Ad hoc network is mainly used for military and disaster relief.

The task scheduling for wireless Ad hoc network is mainly directed acyclic graph modeling tools, Independent set of tasks and variant load theory, etc. The main goal for these scheduling model is task scheduling on node with the shortest expected completion time. However general application environments, wireless Ad hoc network, the network complexity is high, the node may be unavailable because the battery run out of energy, or physical fault and cannot be assigned to the task. So How to do efficient task scheduling on wireless Ad hoc network is technical difficult.

This paper proposes a task scheduling algorithm which improve energy consumption and task execution efficiency by MOTA on NSGA-II wireless Ad hoc network.

2. RELATED WORK
Since Ad Hoc network are dynamic topology, limited node computing, unreliable data transfer, The fact is that task scheduling algorithm is required to consider real time, energy consuming, coordination to meet performance needs.

Up to now, all of the researcher who were mainly focus on real time, energy saving and combine with the theory of scheduling of the distributed real time system start to reform scheduling algorithm. As a result, proposed a set of task scheduling policy, like Min-Min, A*, Generic Algorithm etc heuristic task scheduling algorithm. But these scheduling algorithm improve energy consumption and task finished time and does not
consider node unreliable on the fly (Hu, Tang, and Wang, 2005). SEADTA algorithm proposed by Bokar is considering the node energy consumption, network lifetime and scalability of the entire network, but the effect is not good.

The scheduling policy is mainly on the premise of minimum energy consumption of nodes, as to task completion time scheduling goal, task scheduling to on node with the shortest expected completion time, get the task completion time as short as possible (Li, 2015). However, assigned to the task of the remote node may be because of mobile nodes, physical fault or attacked and unable to complete, and the complexity of the wireless Ad hoc network deployment environment, dynamic and open to increase the likelihood of this happening, and the current scheduling policies are not considering this problem, thus causes a task is assigned to the reliability lower nodes to perform, and make the task very easy to be interrupted because of node failure, reduce the efficiency and service quality of wireless Ad hoc networks.

Compared with the existing research work, the main contribution of this paper is to put forward the concept of task execution probability, gives a consideration at the same time general assignment completion time, task execution probability and node energy consumption scheduling multi-objective optimization algorithm, the algorithm in the pursuit of the shortest completion time and balanced energy consumption at the same time, also considering the probability of task execution, to avoid the task allocation to the relatively low reliability node to perform, so as to effectively reduce the influence of nodes failure of task execution. Algorithm in practical application, through to the task of reasonable allocation and reasonable calculation of fitness to complete tasks time performance and the node failure probability and achieve a better balance between energy consumption performance.

3. DESCRIBE THE PROBLEM

One of the natures for wireless Ad hoc network is that is deployed on very bad environment in common. The prerequisite of task completion is to have a stable running environment no matter hardware and software. But node movement, hard fault, energy exhaust depletion, and software link break error will lead to fail to task perform. Each node has a "normal" and "failure" two states. When the node is the failure state, the task cannot be executed on this node and execution status information will be lost or is invalid. The node will appear failure probability is called the node failure rate, make said $\lambda_i$ the failure rate of $n_i$ node, the completion of the task in the probability for $(1-\lambda_i)$. Assuming that node failure process were independent of each other, and in line with the Poisson process. The definition of task sets, assuming that task in the collection between tasks are independent of each other, and the task is not to decompose, the collection is called yuan task.

3.1. Task Completion Time

A wireless Ad hoc network composed of $N = \{n_1, n_2, \ldots, n_m\}$ by $m$ nodes, $n$ separate tasks to competition use nodes, these tasks allocation goal is to put it reasonable distribution of the task to $m$ nodes on execution, make the minimum total completion time. The results of the task scheduling in 2 d matrix to show $\text{ofn} \times m$ is $X$, wherein $x_{i,j} = 1(x_{i,j} \in X)$ said the task will $r_i$ be scheduling to $n_j$ node on execution, otherwise $x_{i,j} = 0$.

Task of each node in the execution time according to the mission types can be by forecasting technology and actual history processing to estimate, and the concrete of the execution time can use $\text{an} \times m$ two dimensional matrix to say, the $y_{i,j}$ element of $\text{omn}_j$ node said $r_i$ mission estimated execution time. The execution time of $n_j$ node for distribution to the nodes of the task execution of all time, said specific as follows:

$$ T_j = \sum_{i=1}^{\text{an}} y_{i,j} \quad (1) $$

Then $n$ tasks scheduling in $m$ nodes according to the results $X$ of operations last the duration of the general mandate proposed specific says the following:

$$ T(\Gamma, N, X) = \max_{n_i \in \Gamma} T_j \quad (2) $$

3.2. Task Completion Probability

Node of the task by the probability distributed system survivability concept and extended. Task can be continued viability says normal executive ability (Lverson, Ozguner and Potter, 1999).

Definition - task for the mission on node in the probability to the probability of normal finish.
Use \( P(\tau_i, n_j) \) said in the completion of the \( \tau_i \) task the \( n_j \) node probability. According to a previous section, that node in the \( t \) time in a "normal" probability for a state \( \exp(-\lambda_j \tau_i) \), because when processing nodes in a "normal" state task to normal executive, so can get:

\[
P(\tau_i, n_j) = \exp(-\lambda_j \tau_i)
\]  

(3)

\( P(\Gamma, N, X) \) is \( n \) tasks scheduling result in accordance with the said in \( m \) nodes of the mission \( X \) complete probability, it is:

\[
P(\Gamma, N, X) = \exp[-\sum_{i=1}^{\infty} \sum_{j=1}^{m} \lambda_j x_{i,j} \tau_i]
\]  

(4)

Finished the job as the purpose of probability scheduling goal is to avoid the task was assigned to reliability lower node up execution. Failure to reduce nodes, the impact of task, as far as possible the maximization of the task \( \Gamma \) set the probability of normal operation, that is, through certain scheduling strategy get the right \( X \) makes \( P(\Gamma, N, X) \) the maximization of as much as possible, so as to effectively improve wireless Ad hoc network quality of service(Xie and Qin, 2008).

Make \( L(\tau_i, n_j) = \lambda_j \tau_i \), can see if want to improve \( P(\tau_i, n_j) \) will reduce \( L(\tau_i, n_j) \), similarly to:

\[
L(\Gamma, N, X) = \sum_{i=1}^{\infty} \sum_{j=1}^{m} \lambda_j x_{i,j} \tau_i
\]  

(5)

Can see maximizing \( P(\Gamma, N, X) \) also is as far as possible to minimize \( L(\Gamma, N, X) \) as much as possible. Therefore, in order to maximize the probability of the task scheduling algorithm as the objective is to make \( L(\Gamma, N, X) \) the minimum as far as possible.

3.3. Energy Consumption

Due to the node energy limited usually, difficult to complement, wireless Ad hoc network design problem of the core becomes reduce power consumption and prolong service life. The energy consumption of the node mainly by communication energy consumption and energy consumption constitute a mission. In dealing with a node tasks for energy consumption is \( C_p \), on a mission, the communication process for energy consumption is \( C_c \). The wireless nodes in the network of total energy consumption for:

\[
C(\Gamma, S, X) = \sum_{n=1}^{n} (C_p + C_c)
\]  

(6)

4. ALGORITHM DESCRIPTION

A multi-objective genetic algorithm (ga) is the core of the coordinate several of the relationship between the objective function, find out the objective function can try to achieve are small (or more) the optimal solution of the set. 1989 first Goldberg is put forward based on the concept of Pareto optimal solution calculation method of individual fitness, with the aid of non-inferior solution of the level and the corresponding selection operators in China population optimization process Pareto optimal solution of the evolutionary direction. The idea has produced a variety of Pareto optimal solution based on multi-objective genetic algorithm (MOGAs), such as FFGA, NPGA, SPGA, etc. Among them is the most direct embodiment NSGA algorithm Goldberg thought algorithm(Kim and Siegel, 2008). In 2001 the NSGA-II Deb proposed algorithm is based on the NSGA algorithm, after improvement and get a multi-objective genetic algorithm. It introduced rapid classification, constraint dominate and elite strategy, a operation can be won several Pareto optimal solution, therefore it has a fast convergence, small amount of calculation and good real-time, etc. In order to simplify the wireless Ad hoc network processing complexity, adapt to the dynamic changes of the network, the first NSGA-II wireless Ad hoc network algorithm introduces the task scheduling scheme, use the solution described in this paper, the multi-objective optimization problems.

Wireless Ad hoc network scheduling problem has its particularity, for example involving massive constraints, so have to NSGA-II do the following algorithm improved:

1. The individual coding scheme: the Boolean type coding scheme, which USES a Boolean matrix that task-node relating matrix. The NSGA-II is floating-point coding scheme, and wireless Ad hoc network scheduling concerns the task-node incidence matrix, this is a 0/1 Boolean matrix of the type, the floating point plan will lead to low efficiency of the evolution of algorithm: on the one hand, it is difficult to make the individual genetic operation of gene location 0 ~ 1 change, often make genetic operation failure, and Boolean type coding as long as change a gene location, can make the individual have change; On the other hand, the
floating-point coding genetic operation of the slower than Boolean type coding the execution speed of the much slower.

2) Resources constraint processing: wireless Ad hoc network scheduling problem restraint of the natural resources and scale "X number of wireless nodes task" quite, the population to meet individual so many constraints is very difficult. Literature deal with the method of constraint condition is not meet the constraints of individual fitness set to try to small Numbers, the only meet the constraint condition of feasible individual can into the next generation. Wireless Ad hoc network because the task scheduling problem involving the constraints of the large scale, it is difficult to meet the constraints of all individuals, lead to long-term evolution process lack of available individual or feasible individual small number, makes the low efficiency of evolution. In view of this situation forced correction method of the individual, individual not meet a sacrificed if constraint, the task is to random assigned to a node, until the individual to satisfy all constraint so far. The purpose of this operation is to be done all individuals forced into a feasible individual, as to get excellence individual, not about the questions here, at least after the operation after the whole population were satisfied constraint.

3) The individual forced variation operation: in each generation after evolution, is any two individuals, if the same two individuals, the one part of the individual executive variation operation, and only for a gene mutation position execution. Introducing the operation of the reason is that in the experiment observed a repeat of the individual appear phenomenon, makes the population evolution speed slow. NSGA-II in dealing with wireless Ad hoc network task scheduling problem in performance is good, because the Pareto solutions for problems in number and relatively evenly distributed, and suitable for the NSGA-II search ability and excellent individual species distribution characteristics of the uniform. But wireless Ad hoc networks in the task scheduling problem, the number of excellent individual only a few, and tend to focus on, so in the experiment appear afore-mentioned problems. The individual compulsory compiled after operation, the method in the evolutionary process continuously explore the solution space, and enhance the ability of search algorithm.

The flow chart of algorithm is shown in figure 1:

![Algorithm flow chart](image)

Figure 1. Algorithm flow chart

5. THE SIMULATION ANALYSIS

In the simulation experiments, parameters Settings are:

1) Set up the population size is $P = 50$, crossover probability is $P_c = 0.9$ and mutation probability is $P_m = 0.025$;
(2) Assumed that a network of over 50 nodes. Node of the inner energy consumption for the 80 estimated cost of the execution time, the cost of in 0.5 - 1.5 scope to the center as a normal distribution. Wireless Ad hoc network communication energy consumption by a \( m \times m \) matrix that, matrix for 2 - 8 in scope to the center as the 5 normal distribution;

(3) Each task in each node of the execution time meet 0.01 - 0.1 uniform distribution;

(4) Handle node of the failure rate \( 10^{-4} - 10^{-3} \) meet interval evenly distributed.

Will take five experimental results from the average of the final result of the experiment.

Figure 2 is for 3D plot of statistical information 3 d schemes. The chart shows, the NSGA-II algorithm to optimize the scheme of the relationship between the dominant are based, well distributed in a 3 d surfaces. Given that the plan is good reflected in the rule of the equilibrium between multiple targets consideration, the optimal solution of the distribution of very good.

And the algorithm EADTA, SEADTA more, research task completion time and node energy consumption situation.

![scheduling algorithm statistical information](image)

**Figure 2.** Scheduling algorithm statistical information

Figure 3 show that Comparing to another algorithm, MOTA has the shortest time delay and Figure 4 show that MOTA have more balanced energy consumption.

![Task Completion time vs task number](image)

**Figure 3.** Task Completion time vs task number
6. CONCLUSIONS

It is first time for MOTA to leverage NSGA-II to task scheduling under the situation of Ad hoc wireless network. Based on the characteristics of the wireless Ad hoc network MOTA optimize the task scheduling with respect to task completion time, energy consumption, task execution efficiency. Through mathematical model and simulation, MOTA have better result and get good balance between task completion time and energy consumption.

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