Research on dynamic route selection method of D2D communication under multi hop transmission

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Abstract. In order to find the best path in wireless sensor networks, a dynamic energy-saving routing strategy based on multi hop transmission is proposed. The dynamic state transition optimization rules are designed to increase the search probability of new nodes reasonably, so as to find the global optimal solution quickly and effectively, so as to save the search time, increase the optimal path search probability and prolong the network survival time. Simulation results and analysis show that the dynamic route selection method of D2D communication under multi hop transmission greatly increases the search probability of the global optimal solution, achieves the global optimal solution quickly and effectively, saves the energy consumption of nodes, and is conducive to extending the network survival time.

1. Introduction
Wireless sensor network is composed of a large number of sensor nodes with sensing, computing and communication capabilities in a self-organizing way, which is widely used in military and civil fields. Due to the high cost of battery replacement in the unattended monitoring environment, the routing design of wireless sensor networks focuses more on the minimization of node energy consumption[1]. For these reasons, nodes find the shortest path to communicate in a short time, which is not only conducive to effectively reduce the energy consumption of nodes, prolong the network survival time, but also greatly improve the work efficiency of wireless sensor networks, which is an important research direction of the current sensor network routing design. Based on this, the interference coordination problem of D2D communication in homogeneous network is studied. Although the D2D communication multiplexing cellular users’ wireless resources will inevitably cause the same frequency interference to the cellular users, because the distance between the two sides of the D2D communication is relatively close, the required transmission power is relatively low[2]. In wireless sensor networks, nodes don't need to know all about the global node location, they only need to save the routing of the nodes near them to achieve the best path finding of the whole network[3-4]. This greatly reduces the communication burden of the node, and also saves the energy consumption of the node. However, the basic routing algorithm has the problems of fast convergence and easy to fall into the local optimal solution in practical application, which leads to the global optimal solution being ignored. A dynamic energy-saving routing strategy based on multi hop transmission is proposed. Through the design of dynamic state transition rules, the search probability of new nodes is reasonably increased, and the global optimal solution is quickly obtained. Through the reasonable design of reward and punishment mechanism, the search time is further saved, the optimal path search probability is increased, and the network survival time is greatly prolonged.
2. Dynamic route selection method for D2D communication under multi hop transmission

2.1. Dynamic information collection of D2D communication route under multi hop transmission

Some text.

The convergence rate of this method needs to be optimized in practical application. In this paper, a scheme based on interference limited area (ILA) is proposed for D2D resource optimization\(^5\)-\(^7\). An interference limited area is planned around the D2D user. When the multiplexed cellular user is also in this area, the interference received by the D2D user will exceed a certain threshold. Therefore, the grave station should allocate the cellular user channel resources other than the ILA for the D2D user. Different from the planning method and the distributed method, the instantaneous channel state information is replaced by the empirical formula or statistical characteristics of the channel, so the method is independent of the instantaneous channel state information\(^8\). Although this method can only guarantee the QoS in the empirical and statistical sense, considering the complexity of other methods, this method has better realizability. When D2D communication multiplexes uplink cellular channel resources, it is the base station that is interfered by D2D users in the cellular link. The receiver of D2D is also interfered by the cellular link.

It is assumed that in a cellular communication system, there are multiple cellular communication users and a D2D communication user pair. In addition, D2D communication will also produce corresponding interference to cellular communication\(^8\). In order to ensure the quality of service requirements of cellular communication and D2D communication, D2D communication users should share the optimal wireless resources of cellular communication users to maximize the system capacity.

2.2. Optimal path selection algorithm for D2D communication under multi hop transmission

The D2D communication only needs to receive the auxiliary information of the base station, and the D2D users allocate and manage the wireless resources by themselves. This structure mode includes two important aspects: base station assistance and D2D autonomous communication\(^10\). The communication radius of nodes is RC, and the sensing radius of nodes is RS, so the network connectivity is ensured. If the Euclidean distance \(d(i,j)\) from node i to node j satisfies \(d(i,j) \leq Rc\), then I and j are adjacent nodes and can communicate directly. \(b(t)\) is set as the amount of information of node i at time t, \(r_{ij}(t)\) is the amount of information on path \((i,j)\) at time t, and m is the total number of routing information. In the process of moving, information \(k = 1, 2, 3\) In this paper, Tabuk \((k = 1, 2, 3, \ldots)\) is used In the search process, the state transition probability is calculated according to the amount of information on each path and path heuristic information. \(P_y^K(t)\) represents the state transition probability of information \(L\) from node \(i\) to node \(j\) at time \(t\).

\[
P_y^K(t) = \frac{\left[\tau_{ij}(t)\right]^{\alpha} \left[\eta_{ij}(t)\right]^{\beta}}{\sum \left[\tau_{ij}(t)\right]^{\alpha} \left[\eta_{ij}(t)\right]^{\beta}}
\]

\[
\eta_{ij}(t) = \frac{1}{d_{ij}}
\]

Where: \(\alpha\) is the information factor, which reflects the amount of information accumulated in the process of moving; \(\beta\) is the expected heuristic factor, which reflects the amount of information accumulated in the process of guiding path search; \(\eta_{ij}(t)\) is the amount of information accumulated in the process of guiding path search; and \(d_{ij}\) represents the distance between two adjacent nodes, which is used to represent the expected degree of information \(K\) transferring from node \(i\) to node \(j\). In order to avoid too much residual pheromone flooding heuristic information, we need to update the residual information after traversing all \(n\) nodes. The amount of information at \(t+\tau\) time on the path \((i,j)\) is adjusted, as shown in the formula.
\[
\begin{align*}
\tau(t + t_n) &= (1 - \rho) \times \tau(t) + \Delta \tau_{ij}(t) \\
\Delta \tau_{ij}(t) &= \sum_{k=1}^{m} \Delta \tau_{ij,k}(t)
\end{align*}
\]

(3)

The calculation formula is: \(\rho\) is the volatile coefficient of pheromone, \(1 - \rho\) is the residual factor of pheromone, and its value range is \([0,1]\). In this cycle, \(\Delta \tau_{ij}(t)\) is the increment of pheromone on the \((i,j)\) path, and the initial value is 0, that is, \(\Delta \tau_{ij}(t)=0\). \(\delta \tau_{ij,k}(t)\) is the amount of information left on the path \((i,j)\) at time \(t\) in this cycle.

\[
\Delta \tau_{ij,k}(t) = \frac{Q(t)}{L_k}
\]

(4)

Where: \(Q\) is the strength of pheromone, and \(L_k\) is the length and length of all the paths that information passes through in the whole cycle. Assuming that there are orthogonal channels in cellular communication network, D2D users need to detect the transmitted power on each channel to avoid serious interference. Generally speaking, if the distance between the D2D user and its potential D2D receiver is smaller than the distance between the D2D user and the base station, the channel power gain coefficient between the D2D user and the base station will also be greater than that between the D2D user and the base station. It can be seen that the direct link between users is better than the link from user to base station, so D2D users prefer to work in D2D communication mode, otherwise, they work in cellular mode. Therefore, for D2D user equipment, the mode selection index is defined as:

\[
\lambda_k = \frac{h_{k,n}}{h_{k,p}}
\]

(5)

Binary variables are introduced to simplify the expression:

\[
\beta_k = \begin{cases} 
0, & \lambda_k \leq 1 \\
1, & \lambda_k > 1 
\end{cases}
\]

(6)

2.3. Implementation of dynamic route selection for D2D communication
In cellular network, D2D users reuse cellular user resources can improve resource utilization and reduce the load of cellular network base station, but it also brings the problem of interference between D2D users and cellular users. To solve this problem, in addition to reasonable resource allocation, effective power control can not only reduce the interference, but also ensure the normal communication quality and improve the overall performance of the communication network in the cell. The whole resource sharing process is shown in figure 1.

![Fig. 1 D2D communication resource channel allocation flow](image)

According to the radio resources used in D2D communication, the working modes of D2D communication can be divided into three types: dedicated mode, shared mode and cellular mode. Among them, the dedicated mode refers to the D2D communication users using dedicated wireless resources for communication.
The core idea of the algorithm is to reuse the resources of the cellular user farthest away from the D2D user, so as to minimize the interference between the cellular user and the D2D user, and ensure that the interference between the D2D user and the base station is within a certain range. This allocation algorithm reduces the interference between D2D users and cellular users. The interference of D2D users to the base station is solved by introducing relevant power control.

3. Analysis of experimental results

In order to analyze the performance of different D2D communication modes and verify the effectiveness of D2D communication mode selection algorithm based on communication network capacity maximization, this part will use MATLAB software to build a communication network level simulation platform of introducing D2D communication technology into LTE communication network. Suppose there is a D2D communication user pair in a cellular communication cell.

The main simulation parameters are as follows:

| Parameter                              | Value          |
|----------------------------------------|----------------|
| Cell radius                            | 1              |
| carrier frequency                      | 2.5GHz         |
| Base station antenna height            | 15m            |
| Antenna height of user terminal        | 1.5m           |
| Base station transmit power            | 43dbm          |
| Maximum transmitting power of user terminal | 20dbm     |
| Path loss index                       | 4              |
| Resource block bandwidth               | 180KHz         |
| SINR threshold of cellular communication| 10dB           |
| SINR threshold of D2D communication     | 5dB            |
| noise power                            | -104dBm        |

The simulation results in figure 2 show that D2D communication users sharing the wireless resources of uplink communication links of different cellular communication users will bring different communication network performance. When the distance between D2D communication users and cellular communication users is long, the communication network can achieve higher communication network capacity by allowing D2D communication users to share the uplink communication link resources of cellular communication.

Fig. 2 Comparison of transmission distance of communication routes

The simulation results in figure 9 show that when the D2D communication user pairs are far away from the base station and the distance between the D2D communication user pairs is small, the communication network can obtain better communication performance and higher communication network capacity gain by allowing the D2D communication user pairs to share the uplink
communication link resources of the cellular communication user. Moreover, with the increase of the distance between D2D communication user pairs, the capacity gain of the communication network will gradually decrease. When the communication distance between D2D communication user pairs is greater than a certain extent, the capacity performance of D2D communication network sharing the uplink communication link resources of cellular communication will be lower than that of cellular communication.

![Fig. 3 Communication network capacity gain when D2D Communication shares uplink resources of cellular communication](image)

When the D2D communication user is very close to the base station, due to the strong interference from the base station, the D2D communication performance deteriorates sharply. At this time, the D2D communication user will not bring better communication network capacity gain to the downlink communication link resources of shared cellular communication. When the D2D communication users are close to the base station, only when the distance between the D2D communication users is very small, can the communication network make the D2D communication share the downlink communication link resources of the cellular communication users to achieve better communication network performance. The simulation results are shown in figure 4.

![Fig. 4 Relationship between D2D user sum rate and D2D user logarithm K](image)

When the number of D2D users is the same, the sum rate of D2D users in D2D communication mode is higher than that in multiplexing mode. Because D2D communication mode includes multiplexing mode and dedicated mode, there is no cellular user on dedicated subchannel, only D2D user can multiplex dedicated subchannel, so there is no interference from cellular user to D2D user. Moreover, if multiple pairs of D2D users are allowed to reuse the same dedicated subchannel, the
spectrum efficiency will be improved, and the sum and rate of D2D users will also be increased. However, for the multiplexing channel with cellular users, the maximum transmit power of D2D users will be limited to ensure the communication performance of cellular users. Therefore, the resource allocation scheme in this paper is better than that in reuse mode.

4. Concluding remarks
In order to avoid falling into the local optimal solution and accelerate the search speed, this paper studies the problem of finding the optimal path in wireless sensor networks, proposes a dynamic energy-saving routing strategy based on multi-hop transmission, and carries out theoretical analysis and experimental verification. The simulation results show that the strategy effectively increases the search probability of new nodes through the dynamic state transition rules, and achieves the purpose of finding the global optimal solution quickly and effectively; through the design of reward and punishment mechanism, it saves time, further increases the search probability of the optimal path, effectively reduces the cost, and prolongs the survival time of the network.

Acknowledgments
The study was supported by 2020 Basic Research Capacity Enhancement Program for Youth Teachers in Guangxi Universities (Grant No. 2020KY80006).

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