Encounter Delivery Strategy for Strongly Relational Relay Nodes in MSN

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Abstract. MSN has the characteristics of social network, and the nodes under intellectual consideration show social selfishness, which is characterized by kinship index. We propose an encounter delivery strategy based on strong-relationship relay nodes. Firstly, in the hierarchical communities and clusters based on the kinship index, the active strong relationship node set is obtained through the open strong relationship priority algorithm and Markov prediction. Then establish a kinship trust model, conduct behavior detection on active strong relationship nodes to obtain a comprehensive kinship trust value, and then screen out some of the "false kinship" nodes to screen out a set of trusted active strong relationship nodes. Finally, according to the kinship indication with the destination node, the node's kinship movement behavior is predicted, and the candidate relay node set is selected. Simulation experiment results show that this strategy can improve the reliability of message transmission, reduce network delay, and improve the efficiency of data packet transmission to a certain extent.

Keywords. MSN; kinship index; kinship trust model; false kinship.

1. Introduction
The mobile social network (MSN) is developed from the opportunity network [1-2], and there is no need for a complete link between the source node and the destination node. The encounter opportunity brought by the node movement is used to realize the "store-carry-forward-forward" mode of network communication, it has the mobile network Characteristics of social clustering [3]. With the increasing popularity of smart PDA (Personal Digital Assistant) devices, mobile social networks are gradually forming and showing an increasing trend. In the case of limited resources of mobile social network nodes, in order to more effectively carry out data transmission and sharing, inter-node communication increasingly depends on the social attributes of the nodes [4-5], such as social relations, node interests, selfishness, and altruism and many more. In an opportunistic network, without altruism, data cannot be transferred; while in selfishness, it is unwilling to be altruistic. Therefore, when the node is under intellectual consideration, the result of the game between the two is social selfishness [6]. In this paper, social selfishness is characterized by a kinship index. Nodes with a multi-community kinship index (strong relationship) have a high centrality of intervening numbers and are the key nodes for data transmission between families. There have been many works to study cross-region data transfer, but most of them use geographic location or trust to filter relay nodes, and ignore the kinship index.
2. Related Work
Due to the characteristics of the MSN and the mobility of the node, the number of encounters with other nodes in each cycle is affected by many factors, including the node’s moving speed, moving method, etc. Liu et al. proposed the use of gray Markov prediction method to predict the activity of nodes [7]. The gray system is a differential equation established for discrete sequences. Both nodes calculate the current activity according to the activity calculation formula, and according to the historical activity Predict the activity of the next encounter, and pass the comparison from the lower node to the higher node. In this paper, the activity sequence of multiple continuous time periods is regarded as a random process that constitutes a discrete event, and the distribution of the active state of the node in the next cycle depends on the state of the current cycle and is independent of the active state of the previous cycle. The stochastic process constitutes a discrete Markov chain, which converts the node activity evaluation problem into a node state prediction problem, and uses the Markov model to predict the state of the meeting node in the next cycle to find the active node set.

Deng et al. select nodes for information transmission based on social attributes [8]. Nodes determine the selection of the next hop node based on the comprehensive comparison of the four indicators of centrality, similarity, probability and trust value with other nodes. However, the calculation of the trust value ignores the relationship between the nodes and the trust of the intermediate nodes, which makes the generated trust value not accurate enough. Dou et al. comprehensively consider the social and trust relationships between nodes, and prefer to choose nodes with social relationships with the destination node as relay nodes from the nodes with higher trust values [9]. However, the algorithm ignores the “false kinship”, that is, there are Nodes that are socially unwilling to forward data for other nodes. The addition of such nodes will reduce the efficiency of forwarding and waste network resources to a certain extent. This article adds the node's own kinship index based on historical forwarding behavior to obtain the basic kinship trust value, and then evaluates the trust of the current behavior through the mutual monitoring and reporting of family nodes and strong relationship nodes, thereby obtaining direct kinship trust value, and finally selects the trusted active strong relationship node set according to the comprehensive relationship trust value.

3. Encounter Delivery Strategy Based on Strong Relationship Relay Nodes

3.1. Network Model
The research work of this algorithm is carried out in MSN layered according to the kinship index [10-11], and it is a 2D AP-free architecture. The nodes are relatively stable in the cycle. The social relationship models include: Home, Friend, and Colleague. Nodes with the same social relationship are in the same family, and there may be intersections between different families.

The strong relationship node set (3 degrees) refers to the node set formed by the intersection of the three families, and the second strong relationship node set (2 degrees) refers to the node set formed by the intersection of the two families. This algorithm studies the inter-family transfer of data, so the main discussion object is a node set of 2 degrees or more, hereinafter referred to as a strong relationship node set. This algorithm focuses on the layered model, which is mainly divided into three layers: social relationship layer, interactive evaluation layer and data transmission layer. Among them, the social relationship layer is to identify the active strong relationship node set through the kinship relationship, and the interactive evaluation layer is to conduct the “false relative” behavior detection on the selected nodes to obtain the trusted active strong relationship node set. The data transmission layer determines the set of candidate relay nodes by using kinship to predict the movement behavior of nodes to improve the efficiency of data packet transmission. Each node has a label B to indicate its family. The label of a single relationship node is H, F, or C, the label of a secondary relationship node is HF, HC, or FC, and the label of a strong relationship node is HFC.

For ease of description, we abstract MSN into a graph containing n nodes: \( G=(V, L) \), \( V=\{V_1, V_2, ..., V_n\} \) represents a collection of nodes (or individuals) in the network, \( \forall V_i \in V, V_i \) represents the i-th node in the opportunity social network, \( L=\{L_{ij}, L_{j}, ..., L_n\} \) is the set of links defined
on $G$, $k \in (0, n(n - 1)/2)$ (When $k = 0$, it means that the nodes in the network are not within the communication range of each other at a certain time). $\forall l_i \in L_i, L_i$ is the communication link in the network.

Each node has a one-dimensional array, which is used to store a single relationship index with neighbor nodes:

$$k_{s_{m,i}}^x = (k_{s_{i,i}}^x, m)$$

$x$ represents the type of kinship, $i$ and $m$ represent two nodes, and the single kinship index is the sum of the kinship of the family of node $m$.

Comprehensive Kinship Index $KSI_{m,i}^x$ is obtained by weighted summation of $k_{s_{m,i}}^{HL}$, $k_{s_{m,i}}^{HF}$ and $k_{s_{m,i}}^{HF}$. Within the same family, the corresponding $k_{s_{m,i}}^{c}$ of the family is greater than a threshold $Y$.

Each node has a two-dimensional array, which is used to store its neighbor nodes and the corresponding relationship index:

$$m = \left[ \begin{array}{cccc} i & \ldots & \ldots & \ldots \\ y_1 y_2 y_3 & \ldots & \ldots & \ldots \\ \vdots & \ddots & \ddots & \ddots \\ \vdots & \ddots & \ddots & \ddots \\ i_n & \ldots & \ldots & \ldots \end{array} \right]$$

For any node $m$, the first row represents the node with which it is related, and the second row represents the corresponding relationship index. $y_i (= k_{s_{m,i}}^{HL})$ is the index of kinship with his family, $y_2 (= k_{s_{m,i}}^{HF})$ is for friends and $y_3 (= k_{s_{m,i}}^{HF})$ is for colleagues.

### 3.2. Social Relations Layer

This paper proposes an OSRF (Open Strong Relationship First) algorithm based on the well-known OSPF link state routing protocol [12]. Considering the kinship between different nodes as a link, the node sends a packet to neighboring nodes, which includes its own family and a two-dimensional array that stores the kinship index. When receiving packets from other nodes, the nodes will integrate their kinship into a multi-dimensional array:

$$\begin{bmatrix} y & i_1 & i_2 & \ldots & i_n \\ i_1 & 999 & y_1^{12} & y_2^{12} & y_3^{12} & \ldots & y_1^{1n} & y_2^{1n} & y_3^{1n} \\ i_2 & y_1^{21} & y_2^{21} & y_3^{21} & 999 & \ldots & y_1^{2n} & y_2^{2n} & y_3^{2n} \\ \vdots & \ldots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots \\ i_n & y_1^{n1} & y_2^{n1} & y_3^{n1} & y_1^{n2} & y_2^{n2} & y_3^{n2} & \ldots & 999 \end{bmatrix}$$

Then the node will filter the data in the multi-dimensional array. If all three types of families are included, the label will be HFC to join the strong relationship node set. If only two types of families are included, different tags (HF, HC, or FC) are set according to different family categories, and the strong relationship node set is also added in this way.

In order to find active nodes in MSN with limited computing power, cache space and energy, we adopt a forwarding strategy based on Markov chain. During the operation of the network, in order to obtain the node’s activity in each time period, the node needs to count the number of encounters with other nodes in the period at the end of each time period, and calculate the activity of the period based on the number of encounters. The first-order Markov chain is composed of the activity sequences of multiple continuous periods of nodes. According to the Markov property, the activity state $M_i$ of node $m$ in $i + 1$ period is only related to the state of current period $i$:

$$M (n_{i+1} = S_a \mid n_i = S_b, n_{i-1} = S_c, \ldots) = M (n_{i+1} = S_a \mid n_i = S_b) = h_{a,b}$$

(4)
\( n_{i+1}, n_i, n_{i-1} \) represent the activity of node \( m \) in different periods, \( S_{a}, S_{b}, S_{c} \) means active state, \( h_{b,a} \) is the probability of node \( m \) transitioning from state \( S_b \) to state \( S_a \).

Multiple state transition probabilities \( h_{b,a} \) of node \( M \) form a two-dimensional state transition matrix. According to the state transition probability matrix of node activity and the state of previous period activity, we can get the property of Markov chain:

\[
r_{i+j}(a) = \sum r_{i+j-1}(b) h_{b,a}
\]

(5)

The active strong relation node set is composed of strong relation node set and active node set. During filtering, nodes will be filtered from the active node set according to label B of each node.

3.3. Interactive Evaluation Layer

The relative trust of the nodes in the active strong relationship node set will affect inter-family forwarding to a large extent. In order to interactively evaluate their relative trust value, this paper examines it from two aspects: the relative trust value of historical behavior and Kindness trust value of the current behavior, as shown in figure 1.

![Composition chart of comprehensive kinship trust value.](image)

According to the node’s historical interactive information behavior, define the node’s basic kinship trust value \( T_{b}^n \), it’s initial value is the comprehensive kinship index: \( KSI_{m}^n \). The basic kinship trust value is updated through the feedback of each cycle. According to the node behavior of the i-th cycle, the correctness of the report behavior of the node of the i-th cycle can be known [13], the algorithm is:

\[
T_{b}^n (n) = \begin{cases} 
T_{b}^n (i - 1) + 0.5 \times |KSI_{n}^i - KSI_{m}^i|, & l = 1 \\
T_{b}^n (i - 1) \times \frac{1}{2}, & l = 0 
\end{cases}
\]

(6)

The definition of direct kinship trust value is the evaluation of trust obtained by direct communication between node \( m \) and its neighboring family nodes in the past time, we can use Bayesian formula to calculate. The node reputation distribution follows the Beta distribution, and the trust value between nodes is measured by the expected value. The direct trust \( T'_{d(h,m)} \) of the family node \( h \) to node \( m \) is expressed as:

\[
T'_{d(h,m)} = (\alpha_{hm} + 1) / (\alpha_{hm} + \beta_{mh} + 2)
\]

(7)

\( \alpha_{hm} \) and \( \beta_{mh} \) respectively represent the number of successful and unsuccessful interactions between node \( m \) and family node \( h \) in the past cycle time.
The trust value will decline with time, and the time decay factor is introduced into the calculation of kinship index, which will also decline with time. Therefore, a single kinship index is used to calculate the direct kinship trust value:

\[ T_{d(h,m)} = T_{d(h,m)}^* k s_{l,m,h}^x \] (8)

The node’s comprehensive kinship trust value is obtained from the basic kinship trust value and direct kinship trust value through the MolrTrust recommendation model proposed by Massa et al:

\[ TK_m = T_{b(m)} + (T_{d(h,m)}[k s_{l,m,h}^1 - T_{h(m)}] + T_{d(f,m)}[k s_{l,m,h}^2 - T_{f(m)}] + T_{d(c,m)}[k s_{l,m,h}^3 - T_{c(m)}]) / (T_{d(h,m)} + T_{d(f,m)} + T_{d(c,m)}) \] (9)

\[ T_{b(m)} \] is the basic kinship trust value of node M, \( T_{d(h,m)} \), \( T_{d(f,m)} \) and \( T_{d(c,m)} \) are the direct consanguineous trust values of family nodes h, f and c to node m, respectively. \( T_{h(m)} \), \( T_{f(m)} \) and \( T_{c(m)} \) are the basic family trust values of h, f and c. \( k s_{l,m,h}^1 \), \( k s_{l,m,f}^2 \) and \( k s_{l,m,c}^3 \) are the single kinship indexes of family nodes h, f and c to node m respectively. x1, x2 and x3 represent different kinship.

3.4. Data Transmission Layer

The SRRN (Strong Relationship Relay Node) based on strong relationship relay nodes is based on a set of strong (second strong) relationship nodes divided by kinship, and belongs to the inter-family forwarding in the KMDS algorithm (Kinship Meeting Delivery strategy) Part, so the control of the number of copies is also part of the BSW algorithm (Binary Spray and Wait) [14]. In order to avoid blindly inter-family forwarding in the BSW algorithm, the algorithm relies on the help of trusted active strong relationship nodes to focus on the relationship with the destination node to optimize blind forwarding, and uses the kinship movement of the candidate relay nodes predicted by the relationship as the basis for forwarding, the message is always transmitted in the direction with a large probability value, so that it is more reliably transmitted to the destination node.

The third-degree trusted active strong relationship node set may cause link blocking due to its strong relationship, so this algorithm will filter based on the comprehensive kinship trust value and a single kinship index before using the third-degree trusted active strong relationship node set to minimize its use.

4. Experiment

Our algorithm uses ONE (Opportunistic Network Environment) [15] simulator for experimental simulation, the data set uses MIT Reality Trace [16], the algorithm uses its trajectory as the node’s trajectory in the experiment. In order to reduce the scale of the experiment, the experiment only used the experimental data of the data set for 300 minutes. The algorithm studies the inter-family transfer of data, so the main discussion object of the experiment is the node set of 2 degrees or more. In the experiment, it is referred to as the strong relationship node set J. The simulation parameter settings are shown in Table 1, where \( T/J \) represents the proportion of trusted active strong relationship node sets to strong relationship node sets.

We compare the proposed encounter delivery strategy based on strong-relationship relay nodes with two other routing algorithms SimBet [17] and Bubble Rap [18]. In order to verify and analyze the feasibility and effectiveness of the encounter delivery strategy based on strong relationship relay nodes, the reference index mainly has the following three aspects:

- Delivery success rate: The message delivery success rate refers to the proportion of the number of messages that successfully reach the destination node in the total number of messages generated.
- Message transmission delay: The average time of successfully delivered messages from source node to destination node.
- Average number of hops: The average number of hops a message must take in order to be successfully delivered.
Table 1. ONE simulation parameter settings.

| Parameter name     | Value          |
|--------------------|----------------|
| Scene size         | 500m*500m      |
| Community node     | 97             |
| Number of communities | 3             |
| T/J                | 0%-60%         |
| Node cache         | 5MB            |
| Interface range    | 10m            |
| Simulation time    | 300min         |
| Mobile model       | MIT Reality Trace |

The experimental results are shown in figures 2-4. Figure 2 shows the delivery success rate of the three routing protocols with different sets of trusted active strong relationship nodes. Figure 3 compares the message transmission delays of the three routing protocols. Figure 4 plots the average hop count of the three routing protocols.

![Figure 2](image1.png)

**Figure 2.** The delivery success rate changes with T/J.

![Figure 3](image2.png)

**Figure 3.** Change chart of message transmission delay with T/J.

![Figure 4](image3.png)

**Figure 4.** Change chart of average hops with T/J.

In conclusion, the simulation results show that the encounter delivery strategy based on the strong relationship between relay nodes achieves a better delivery success rate than the classic routing protocols SimBet and Bubble Rap without affecting the message transmission delay.
5. Conclusion
This paper proposes an encounter delivery strategy based on strong-relationship relay nodes. First, the strong-relationship node set found by the OSRF algorithm and the active-node set found based on the Markov chain forwarding strategy are used to determine the active strong-relationship node set. Then calculate the comprehensive kinship trust value through the trust model, and use this to identify the trusted active strong relationship node set. Finally, based on the kinship indication with the destination node, predict the node's kinematic movement behavior and filter out the candidate relay node set. Experiments show that this strategy can improve the reliability of transmission, reduce network delay, and improve the transmission efficiency of data packets to a certain extent. However, over-reliance on strong-relationship nodes will lead to the emergence of isolated nodes, which will lead to the blockage of the link, so how to discover these nodes in time and carry out incentives requires further research.

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