Acta Technica *62* (2017), No. 6B, 1293–1308

DTN relay multicast routing based on reliable link analysis of relational model

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Abstract. In selection of wireless relay solutions of multicast routing, most of existing algorithms have allowed for the adjacent node relay search process. However, routing relay is selected mostly based on the received signal strength in terms of consideration of node relations. This approach to selection is too casual and cannot reflect the social attribute between nodes, the result of which is blind node selection and is prejudice to the reduction of protocol computing complexity and effective improvement of network performance. On this account, a link reliability relation is proposed to perceive DTN wireless relay multicast routing algorithm. This model introduces the node social relations model to provide guidance for the selection of relay node To improve the reliability of delay tolerant network (DTN) of Ad hoc network (CAN), a link reliability relation is proposed to perceive DTN wireless relay multicast routing algorithm. A comparison test is carried out in terms of the life cycle, delivery rate, controlled transmission volume, end to end transmission delay average, throughout, total transmission volume indexes to validate the effectiveness of the algorithm.

Key words. Routing Relay Reliability Tolerant delay network Ad Hoc Multicast routing.

1. Introduction

Mobile Ad Hoc network (MANET) is a kind of reconfigurable dynamic wireless routing network without basic communication [1]. The network is featured with mobile randomness that may result in unpredictable and frequent changes of topology, which will increase the routing burden of network task and affect the data transmission performance of Ad Hoc network. However, such type of network is mostly used in special multi-hop scenario, such as information recovery after disaster, distributed collaborative operation. When the information in Ad Hoc network

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is transmitted from the transmission point to a different receiving point, multicast routing algorithm will occur [2, 3]. At present, multicast routing algorithm can be grouped into three types [4]: tree, mesh and mixed strategies. It is designed in literature [5] that the signal strength is a stable path form of the evaluation criterion, and classifies the link into strong and weak connections. However, the form has a disadvantage that the strength average cannot reflect the node mobility property on a timely basis, leading to undesirable link stability and forecast results. The path stable multicast routing forecast protocol is designed in literature [5]. Packet delay and network throughput are treated as QOS restraint of the network. The network node periodically receives data from adjacent nodes and samples its signal strength in order to achieve stable communication link. The precision of forecast depends on the sampling interval. A small interval may lead to high node energy consumption, while a big interval may lead to reduced link stability. In literature [7], data is periodically received in packets from the adjacent nodes of the node. The strength information of packet data is sampled to obtain the change rate of the transmission strength of signals from neighbor nodes, through which the survival time of node is predicted. The essence is the substitute algorithm in literature [6]. However, this method requires auxiliary equipment, which will add computing complexity to the algorithm.

2. Reliability analysis of social relations

2.1. Pre-definition of reliability

According to the social relations as shown in Fig.1, four kinds of relations above between any two CR nodes of the network are obtained. It is presented herein that the concept of social relations may be applied to routing network [11, 12].

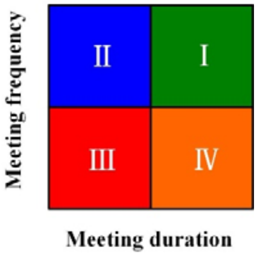


Fig. 1. Social relations

In Fig.1, there are four kinds of social relations: (1) close friends; (2) familiar stranger; (3) stranger; (4) ordinary friend. Firstly, a forecast solution is presented to determine the link reliability in a period. Definitions are given below.

Definition 1: (reliable link) if there is at least one common available channel between nodes i and j, and the available time on the common channel (i, j) exceeds the times required to transmit message, (i, j) can be defined as a reliable link [12].

Definition 2: (neighbor node) the neighbor node of node i is defined as a set of nodes within the transmission range R_0 of node i to be expressed in N_i.

Assuming at moment t_0, node i transmits information with size Q to the destination node d_i. If node i is distant from destination node d_i, direct data transmission will be impossible due to the energy limit. Therefore, node i must select relay for signal transmission. Assuming that nodes i and j meet at moment t, nodes i and j will obtain the available common channel by the form of spectrum sensing, as shown in Fig.2. The spectrum sensing process is:

$$\Gamma_{ij}^{t} = (ch1, \cdots, chk, \cdots, ch\pi)\,. \tag{1}$$

The effective bit rate of channel (i, j) can be calculated as:

$$R_{ij}^{k} = B_k 1og_2(1 + \frac{S}{N}) = B_k 1og_2(1 + \frac{P_i h_{ij}}{N_0 B_k})\,. \tag{2}$$

Where, B_k is the bandwidth of channel k. P_i is the transmission power of node i. N_0 is the spectral density of noise. $h_{ij} = \kappa / d_{ij}^{u}$ denotes the path loss between nodes i and j. κ denotes the path loss constant. d_{ij}^{u} denotes the distance between nodes i and j.

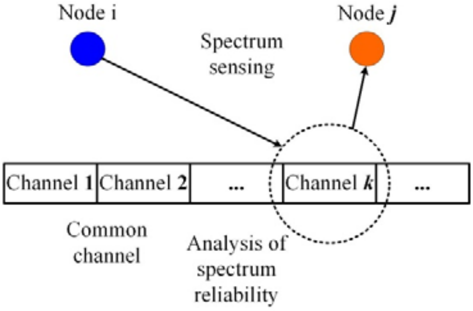


Fig. 2. Spectrum analysis of common channel

After the effective bit rate is R_{ij}^{k} obtained, the transmission time of data Q from i to j can be obtained:

$$t_{ij}^{k} = \frac{Q}{R_{ij}^{k}}\,. \tag{3}$$

Where, t_{ij}^{k} is the actual transmission time of data Q of link (i, j) on channel k. To achieve complete data transmission, the time of reliable link (i, j) should be longer than t_{ij}^{k}.

Next, the probability of reliability of link (i, j) on channel k in terms of time t_{ij}^{k} may be expressed as $L_{ij}^{k} = \left(t, t + t_{ij}^{k}\right)$, L_{ij}^{k} for short. If L_{ij}^{k} is greater than the given threshold, it can be said that link (i, j) is reliable.

Based on the definition above, L_{ij}^{k} can be defined based on two aspects: (1) unreliable interruption probability I_{ij}^{k} is mainly a result of transmission timeout; and (2) physical interruption P_{ij}^{k} is mainly a result of too long transmission distance.

Both probabilities above can be defined as:

$$\begin{aligned}&I_{ij}^{k}(t,t+t_{ij}^{k}) = \\ &= P\{\{d_{i,pU_k}(t') > \max\{\rho_{Pk},p_{Si}\}\} \cap \{d_{i,pU_k}(t') > \\ &\max\{\rho_{Pk},p_{Si}\}\} \cap \{d_{i,pU_{BS}}(t') > \max\{\rho_{p_{BS}},p_{Si}\}\} \\ &\cap \{d_{i,pU_{BS}}(t') > \max\{\rho_{p_{BS}},p_{Si}\}\}, t \le t' \le t+t_{ij}^{k}\}\,.\end{aligned} \tag{4}$$

$$P_{ij}^{k}(t,t+t_{ij}^{k}) = P\left\{d_{ij}(t') < R_o, t \le t' \le t+t_{ij}^{k}\right\}\,. \tag{5}$$

The social relations between nodes have influence on L_{ij}^{k} forecast. For this reason, different forecast mechanisms will be considered for different relation nodes.

(1) Close friend and ordinary friend relations: once two nodes meet, they will temporarily stay and chat. For this, Reliable data transmission time with long link (i,j) should be set. $L_{ij}^{k}=1$ is set here.

(2) Familiar stranger and stranger relations: when two nodes meet, they will have no communication in any form. The behavior of each node is independent. The forecast mechanism should be established based on the evaluation of I_{ij}^{k} and P_{ij}^{k}.

According to the social relations mobility model presented, once two nodes contact, the movement status of each node may be divided into two stages according to the mobility model: (1) current velocity is maintained till existing type of node relation end. The required time is t_1; (2) The velocity is changed after a new relation type begins, and the new velocity will be maintained. The required time is t_2.

2.2. Forecast course of $I_{ij}^{k}\,(t_1)$ and $P_{ij}^{k}\,(t_1)$

As mentioned earlier, $I_{ij}^{k}\,(t_1)$ is the probability of link (i,j) on channel k in time t_1 without unreliable interruption. If nodes i and j are not friends, their mobility model will be considered to be independent. The computational form of $I_{ij}^{k}\,(t_1)$ is:

$$\begin{aligned}I_{ij}^{k}(t_1) =& I_i^{k}(d_{i,pU_k}^{t},t_1)\cdot I_j^{k}(d_{j,pU_k}^{t},t_1) \\ &\cdot I_i^{BS}(d_{i,pU_{BS}}^{t},t_1)\cdot I_j^{BS}(d_{j,pU_{BS}}^{t},t_1)\,.\end{aligned} \tag{6}$$

Where, $I_i^{k}(d_{i,pU_k}^{t},t_1)$ and $I_j^{k}(d_{j,pU_k}^{t},t_1)$ denote the non-interruption probabilities of nodes i and j to pU_k state at the initial distances d_{i,pU_k}^{t} and d_{j,pU_k}^{t}in time t_1. $I_i^{BS}(d_{i,pU_{BS}}^{t},t_1)$ and $I_j^{BS}(d_{j,pU_{BS}}^{t},t_1)$ denote the non-interruption probabilities of nodes i and j to pU basis state. I_i^{k}, I_j^{k}, I_i^{BS} and I_j^{BS} have similar computational processes. I_i^{k} is explained as an example.

In moment t to t $t+t_1$, the node keeps existing velocity unchanged, assuming that existing velocity of each node is known. Node i is computed as an example. Existing velocity is v_i, and the movement direction is C_i. The location of pU_k is set at P. Assuming that the location of node i at moment t is A, the location to which node i arrives at after time t_1 will be B. Making $P=d_0$, $BP=d$, ϕ_i denotes the angle between $\vec{AB}$ and $\vec{AP}$, $\phi_i \in [0, \pi]$, $I_i^k(d_0, t_1)$ may be expressed as:

$$I_i^k(d_0, t_1) = \begin{cases} 1, s.t.(1)(2)(3) \\ 0, otherwise \end{cases} \tag{7}$$

Where (1) $\phi_i \in [\frac{\pi}{2}, \pi]$; (2) $\phi_i \in [0, \frac{\pi}{2})$, $d_0 \cdot \sin\phi_i > \max\{\rho pk, \rho Si\}$; (3) $\phi_i \in [0, \frac{\pi}{2})$, $v_i \cdot t_1 < d_1$,$d_0 \cdot \sin\phi_i \leq \max\{\rho pk, \rho Si\}$.

Where,

$$d_1 = d_0 \cdot \cos\phi_i - \sqrt{\max\{\rho pk, \rho Si\}^2 - (d_0 \cdot \sin\phi_i)^2}\,, \tag{8}$$

denotes the residual probability of nodes i and j at moment t_1 within the transmission range R_0. The mobility of both nodes brings enormous computing complexity. It is thus necessary to substitute by means of approximation. Assuming that existing node velocity and location are known, the node location following time t_1 may be calculated. Making $d_{ij}^{t+t_1}$ as the distance between nodes i and j following moment t_1, link (i, j) is defined to interrupt at $d_{ij}^{t+t_1} > R_0$; that is:

$$p_{ij}^k(t_1) = \begin{cases} 1, if d_{ij}^{t+t_1} < R_0 \\ 0, otherwise \end{cases} \tag{9}$$

Under the stranger relation, the residual probability of reliability of link (i, j) on channel k at moment t_1 may be obtained:

$$L_{ij}^k(t_1) = I_{ij}^k(t_1) \cdot P_{ij}^k(t_1)\,. \tag{10}$$

2.3. Forecast course of $I_{ij}^k(t_2)$ and $P_{ij}^k(t_2)$

In time frame t_2, a new velocity different from that in stage t_1 is selected for each node. The node velocity at this moment is unknown. It is necessary to allow for all of the possibilities. Similar to the definition of $I_{ij}^k(t_1)$, $I_{ij}^k(t_2)$ may be defined as:

$$\begin{aligned} I_{ij}^k(t_2) = & I_i^k(d_{i,pU_k}^{t+t_1}, t_2) \cdot I_j^k(d_{j,pU_k}^{t+t_1}, t_2) \\ & \cdot I_i^{BS}(d_{i,pU_{BS}}^{t+t_1}, t_2) \cdot I_j^{BS}(d_{j,pU_{BS}}^{t+t_1}, t_2)\,. \end{aligned} \tag{11}$$

Similarly, $I_i^k(d_{i,pU_k}^{t+t_1}, t_2)$ is explained as an example:

$$I_i^k(d_{i,pU_k}^{t+t_1}, t_2) = \sum_{m=1}^{\omega} I_{i,m}^k(d_{i,pU_k}^{t+t_1}, t_2) \cdot \mathcal{X}_i^m\,. \tag{12}$$

Where, $\mathcal{X}_i^m$ denotes the probability of the movement of node i to zone m. $I_{i,m}^k$ denotes the probability of the movement of node i to zone m following time t_2 without subject to any interruption of pU_k. As shown in Fig.3(a), pU_k locates at P. The initial location of node i at moment $t + t_1$ is A. Node i reaches location B following time t_2. Where, $AP = d_0$, $BP = d$. ϕ_m^k denotes the angle between $\vec{AB}$ and

$\overrightarrow{AP}$, and $\phi_m^k \in [0,\pi]$ ϕ_m^k denotes the movement of node i to zone m. Superscript k denotes the positional distance between node i and pU_k. $I_{i,m}^k(d_0,t_2)$ may be defined as:

$$I_{i,m}^k(d_0,t_2) = \begin{cases} 1, s.t.(1)(2)(3) \\ \dfrac{\frac{d_1}{t_2} - v_{\min}}{v_{\max} - v_{\min}}, otherwise \end{cases} \tag{13}$$

Where: (1) $\phi_m^k \in [\frac{\pi}{2},\pi]$; (2) $\phi_m^k \in [0,\frac{\pi}{2})$, $d_0 \cdot \sin\phi_m^k > \max\{\rho_{pk},\rho_{Si}\}$; (3) $\phi_m \in [0,\frac{\pi}{2})$, $v_{\max} \cdot t_2 < d_1$, $d_0 \cdot \sin\phi_m^k \le \max\{\rho_{pk},\rho_{Si}\}$.

Where, as shown in Fig.3(a), d_1 may be defined as:

$$d_1 = d_0 \cdot \cos\phi_m^k - \sqrt{\max\{\rho_{pk},\rho_{Si}\}^2 - (d_0 \cdot \sin\phi_m^k)^2}\,, \tag{14}$$

$P_{ij}^k(t_2)$ denotes the residual probability of nodes i and j at moment t_2 within the transmission range R_0. As shown in Fig.3(b), the initial locations of nodes i and j at moment $t+t_1$ are A and B, respectively. $d_{ij}^{t+t_1}$ denotes the distance between nodes i and j. Following moment t_2, nodes i and j reach locations A' and B'. The spacing between nodes i and j turns to $d_{ij}^{t+t_1+t_2}$. Both nodes select to move towards the new movement direction of the destination zone. Assuming that node i moves to zone m, φ_m^i is the angle between $\overrightarrow{AA'}$ and $\overrightarrow{AB}$. Similarly, φ_n^j denotes the angle between $\overrightarrow{BB'}$ and $\overrightarrow{BA}$ in the course of movement of node j to zone n. $P_{ij}^k(t_2)$ may be defined as:

$$P_{ij}^k(t_2) = \sum_{m=1}^{\omega}\sum_{n=1}^{\omega} p_{i,m}^{j,n}(d_{ij}^{t+t_1},t_2) \cdot \mathcal{X}_i^m \cdot \mathcal{X}_j^n,. \tag{15}$$

Where, $p_{i,m}^{j,n}(d_{ij}^{t+t_1},t_2)$ denotes the approximate probability of nodes i and j always maintained within the transmission range R_0 at moment t_2 with the initial distance of $d_{ij}^{t+t_1}$ in the course of the movement of node i to zone m and of node j to zone n. Assuming that nodes i and j have average velocity, it can be estimated that the approximate distance between nodes i and j following moment t_2 is $\tilde{d}_{ij}^{t+t_1+t_2}$. If $\tilde{d}_{ij}^{t+t_1+t_2} > R_0$, link (i,j) will interrupt. It is shown in Fig.3(b) that:

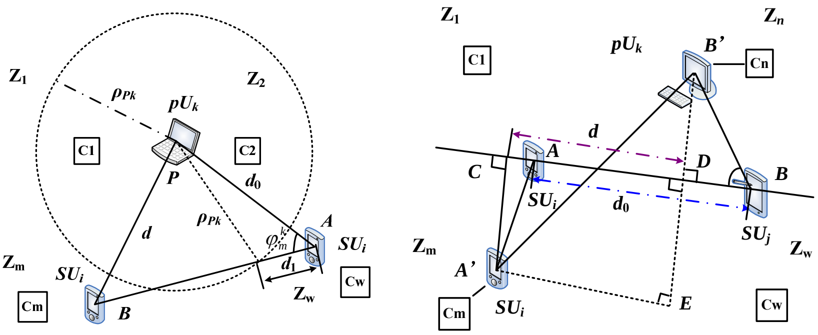
$$A'E = d_{ij}^{t+t_1} - E[v_i] \cdot t_2 \cdot \cos\varphi_m^i - E[v_j] \cdot t_2 \cdot \cos\varphi_n^j\,. \tag{16}$$

$$B'E = \begin{cases} E[v_i] \cdot t_2 \cdot \sin\varphi_m^i - E[v_j] \cdot t_2 \cdot \sin\varphi_n^j, case1\,, \\ \left|E[v_i] \cdot t_2 \cdot \sin\varphi_m^i + E[v_j] \cdot t_2 \cdot \sin\varphi_n^j\right|, case2\,. \end{cases} \tag{17}$$

Where, *case*1 denotes that nodes i and j moves from segment AB towards the same side; *case*2 denotes that nodes i and j moves from segment AB towards different sides.

According to the right angle $\Delta A'B'E$, it can be obtained that:

$$\tilde{d}_{ij}^{t+t_l+t_2} = d = A'B' = \sqrt{A'E^2 + B'E^2}\,. \tag{18}$$



(a) I_{ij}^k forecast (b) P_{ij}^k forecast

Fig. 3. I_{ij}^k and P_{ij}^k forecast

Then, $P_{im}^{jn}\left(d_{ij}^{t+t_l}\right)$ can be obtained from R_0:

$$P_{im}^{jn}\left(d_{ij}^{t+t_l}, t_2\right) = \begin{cases} 1, if\,\tilde{d}_{ij}^{t+t_l+t_2} < R_0 \\ 0, otherwise \end{cases} \tag{19}$$

So, the residual probability of link (i, j) on channel k at moment t_2 under the stranger condition can be obtained:

$$L_{ij}^k(t_2) = I_{ij}^k(t_2) \cdot P_{ij}^k(t_2)\,. \tag{20}$$

3. Reliability analysis and routing procedures

3.1. Procedures of reliability analysis algorithm

With the analysis above, the residual probability of reliability of link (i, j) on channel k from moments t_0 to $t_0 + t_{ij}^k$ can be obtained:

$$L_{ij}^k(t_{ij}^k) = \begin{cases} 1, & case1 \\ L_{ij}^k(t_1) \cdot L_{ij}^k(t_2), & case2 \end{cases} \tag{21}$$

Where, $case1$:i, j has friend relation, and $case2$: i, j does not have friend relation. If L_{ij}^k is greater than threshold L^*, it can be said that link (i, j) is reliable on channel k. If there is at least one channel being reliable, link (i, j) will be deemed to be reliable link, and the most reliable link will be selected. The reliable link forecast algorithm is shown in Algorithm 1.

3.2. Routing algorithm procedures

In the earlier section, a kind of link reliability forecast algorithm is presented. Based on such algorithm, it is presented here an opportunistic routing solution

Algorithm 1 Reliable link forecast algorithm

```
common channel of link $(i,j)$   $\Gamma_{ij}^{t}=(ch1,\cdots,chk,\cdots,ch\pi)$;
$NUM=0$;
for $k=1,2,\cdots,\pi$ do
    if $L_{ij}^{k}>L^{*}$ then
        link $(i,j)$ is reliable on channel $k$;
        $NUM=NUM+1$; $A_{ij}\to\left\{L_{ij}^{k}\middle|L_{ij}^{k}>L^{*}\right\}$;
    else
        link $(i,j)$ is not reliable on channel $k$;
    end if
end for
if $NUM\geq 1$ then
    link $(i,j)$ is reliable;
    sort $A_{ij}$ in descending order of value $L_{ij}^{k}$;
else
    link $(i,j)$ is unreliable;
end if
```

called SotRoute based on the social relations model. It selects the relay node in both reliable and effective manners.

Based on the big data volume observation, it is concluded higher probability of meeting applies to the persons who have met frequently. On this basis, node i will select the node with the most frequent contact with the destination node as the relay node for information transfer, which will lead to higher success rate of message transmission. The information relay transmission algorithm based on social relations is included in Algorithm 2.

Assuming that the information destination carried by node i is d_i, the transfer strategy of node i may be classified into the following stages:

Step1: (spectrum sensing) once node i meets its neighbor node j, node j will send its location information, existing velocity and existing social relations information to node i via common control channel. It is assumed that SUs may obtain the location of PUs by accessing to the database. Node i detects the common reliable channel with node j.

Step2: (selection of social relations relay) node i checks the social relations between node j and destination node. If node j is destination node or close friend of destination node, node i will further detect whether the link of node j is reliable. If not, the algorithm process will end.

Step3: (selection of reliable path) node i computes the reliability L_{ij}^{k} of the link of all common reliable channels with node j. Node i then determines whether node j is reliable relay. If node j is reliable relay, node i will transfer the message to node j.

Assuming that node j the most suitable relay of node i obtained by using the algorithm above, node j accordingly executes the same action till the message is sent to the destination node.

Algorithm 2 Information relay transfer algorithm based on social relations

```
initialization: information is transmitted from node $s_i$ to $d_i$,$Flag = False$,$i \leftarrow s_i$,node $i$ carries existing information;
while $i \neq d_i$ do
    update neighbor node of node $i$,assuming that node $j$ is the neighbor of node $i$;
    if $j = d_i$ then
        detect reliability of link $(i, j)$ based on algorithm 1;
        if link $(i, j)$ is reliable then
            $send(Q, d_i), i \rightarrow d_i$;
            return $Flag = False$;
        end if
        if $j = CF_i$ then
            detect reliability of link $(i, CF_i)$ based on algorithm 1;
            ▷$CF_i$ denotes a close friend of $d_i$;
            if link $(i, CF_i)$ is reliable then
                $send(Q, CF_i), i \rightarrow CF_i$;
                return $Flag = True$;
            end if
        end if
        if $f_{j,d_i} > f_{i,d_i}$ then
            detect reliability of link $(i, j)$ based on algorithm 1;
            ▷$f_{j,d_i}$ denotes meeting frequency of nodes $j$ and $d_i$;
            if link $(i, CF_i)$ is reliable then
                $send(Q, j), i \rightarrow j$;
                return $Flag = True$;
            end if
        end if
        if $Flag = False$ then
            existing neighbor node $j$ is not suitable relay, information is stored in existing node;
        end if
    end if
end while
```

4. Experimental analysis

4.1. Experimental setting

The protocol performance is evaluated based on NS-2 simulation platform. In the wireless network, the nodes are distributed on $1000m \times 1000m$ plane. Nodes use consistent wireless receiver-transmitter hardware. The data transmission radium is $R_0 = 250$m. The channel transmission capacity is 2Mbit/s. A medium control access protocol (MAC) is constructed based on IEEE 802.1. In simulated execution, destination and source nodes use constant bit rate value CBR to simulate data volume. Assuming that the contract rate is 5 packets/s, and the packet length value is 512bit. The mobile nodes use random Way point data model. The mobility node of the node selects the coordinate of the next destination node in a random manner and moves towards the destination node at constant velocity. The velocity value is a random value from 0 to the maximum velocity. The stay time of the node at the destination node location is set to be 5s. Subsequently, the next destination code is selected randomly. These procedures are repeated till convergence occurs. The simulation termination time is set to be 600s. To reduce the random deviation, the average of 30 experiments is selected.

To validate the stability of channel link, the performance comparison algorithm is selected: MAODV protocol [14], MAODV extended protocol RSM [6] and Guo [7] based on different stability forecast features of the link. Table 1 gives the simulation parameter setting values. The performance evaluation criteria of the protocol: life cycle of multicast routing, delivery rate, controlled transmission volume, end to end transmission delay average, throughput, total transmission volume are selected to analyze network performance.

Table 1. Experimental parameters

Experiment No.	Network size	Number of source code	Number of destination code	Node maximum velocity (m/s)
1	50	5	10	0∼30
2	50∼100	Proportion 10%	Proportion 20%	15

4.2. Analysis of experimental results

During the experiment, 50 network nodes are randomly configured, with the movement velocity increasing from 0m/s to 30m/s. The threshold is $L^* = 50m$.

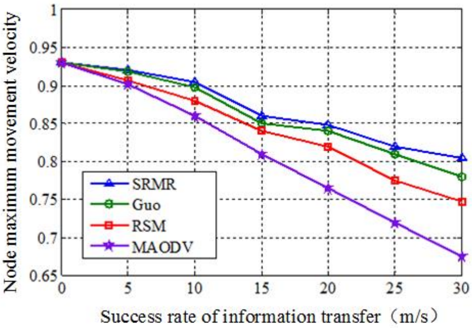


Fig. 4. Success rate of information transfer

Fig.4 gives the relations between node movement velocity and data delivery rate. It is seen from data in the figure that as node velocity increases, the delivery rate of several algorithms decreases, among which MADOV routing process experiences quickest velocity decrease. In this paper, SRMR routing protocol presents the slowest velocity decrease process. Guo and RSM protocols have the decrease of delivery rate between the protocols above. Such difference is increasingly obvious as node velocity increases due to the fact that MAODV routing is subject to node velocity. This will add more chances to link interruption and data loss. However, the link of SRMR routing protocol in this paper has the best stability feature primarily due to the fact that addition of social attribute increases link stability. In particular, when node movement velocity increases to 30m/s, Guo, RSM and this SRMR routing protocols have the delivery success rate of more than 73%.

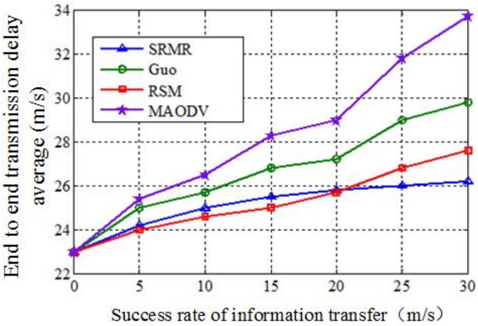


Fig. 5. End to end transmission delay average

Fig.5 gives the process of influence of node movement velocity on end to end transmission delay average. It can be seen that as the movement velocity of network node increases, the data transmission delay value of these routing protocol above will increase. However, Guo, RSM and this SRMR routing protocols have slowly increasing rate in terms of the transmission delay average. Relatively speaking, MADOV routing delay average gains significant increase. Such delay is primarily a result of queue waiting and retransmission. With the increasing node velocity, network structure presents great changes, thus leading to communication link interruption and routing form change and an increase of transmission delay. Data in the figure reflects that RSM and routing in this paper have the minimum delay indicator, and MAODV routing has the maximum delay indicator. In particular, increasing node velocity leads to increasingly significant difference.

Fig.6 shows the data of comparison of influence of node velocities on network throughput. Compared to Guo, RSM and MAODV routing forms, SRMR routing form in this paper has the maximum network throughput indicator. In particular, when node movement velocity increases to 15m/s, the network throughput indicator of SRMR routing in this paper will change to 0.258 data transmission rate per second, and such indicator of MAOD routing protocol will change to 0.21 data transmission rate per second.

Fig.7 shows a comparison of influence of network node movement velocities on the controlled transmission data volume of the packet. When the network node velocity is less than 12 m/s, the controlled transmission data volume of MAODV routing will be less than that of Guo, RSM and this SRMR algorithm. However, as the velocity

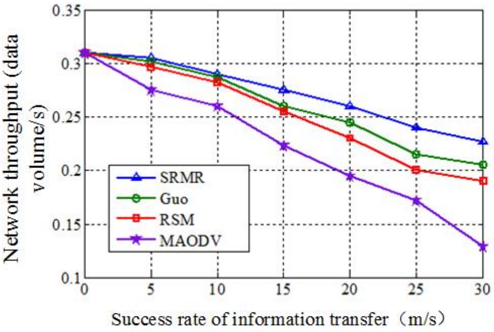


Fig. 6. Network throughput

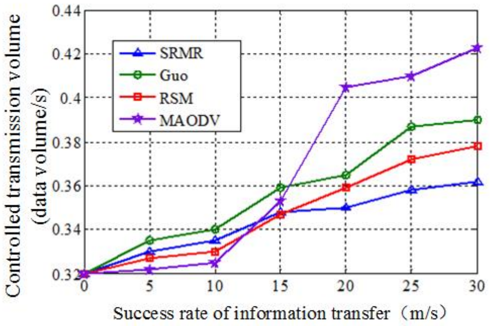


Fig. 7. Controls the amount of transmitted data

increases, several algorithms show contrary trend. Such contrast of the controlled transmission data volume is due to the fact that: (1) in Guo, RSM and this routing protocol, more RREP and RREQ messages are required to support considering improvement of link forecast stability. Additional routing controlled message will increase the controlled data volume. MAODV does not take link stability into account; (2) an increase of node movement velocity causes different packet controlled transmission data volume. In contrast, MAODV routing reduces the expenditure of controlled transmission. Application of MAODV routing form leads to increasing node movement velocity, which will sharply changes network structure. To fix link interruption and reconstruct routing operation, this will reduce link stability.

Fig.8 gives the trend of influence of node movement velocity on total packet data transmission volume. It can be obtained from data comparison that increasing movement velocity leads to an increase of total packet data transmission volume. Guo, RSM and this routing relay protocol reduce the chance of link interruption based on link stability forecast to eliminate increasing data transfer transmission volume due to retransmission operation. As node velocity increases, SRMR algorithm in this paper performs better when it comes to the adaptability of reconstructing routing operation and network structure change.

Fig.9 shows the influence of node movement velocity on the survival period of multicast routing. It can be obtained from data comparison that increasing move-

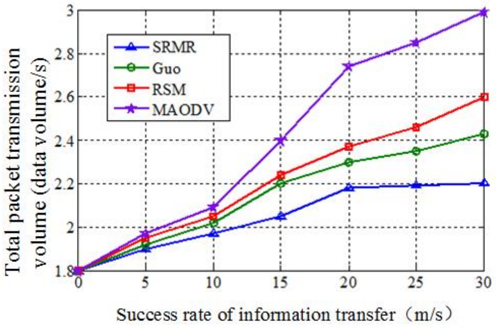


Fig. 8. Packet transmission

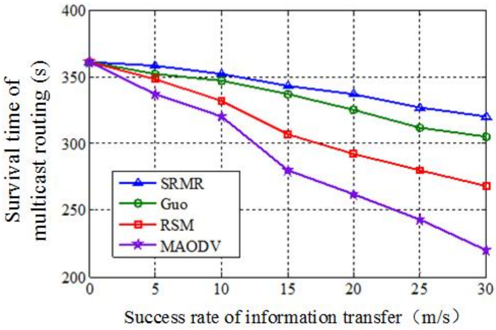


Fig. 9. The survival period of multicast routing

ment velocity leads to a decrease of path survival period primarily due to the fact that an increase of node movement velocity results in weak link. The survival period of Guo routing protocol is longer than that of RSM routing protocol. However, both protocols have shorter survival period than the one of the routing protocol in this paper. GUO, RSM and this SRMR routing protocol allow for link stability feature, which has been analyzed and described earlier. SRMR algorithm in this paper makes reference to the characteristics of GUO and RS, routing mechanisms and is optimally designed. SRMR routing protocol in this paper can not only improve link stability but also achieve an increase of survival period.

5. Conclusion

This paper proposes a DTN relay multicast routing algorithm based on reliable link analysis of the relations model in terms of the blindness problem of relay node selection existing in multicast routing algorithm. Firstly, a relevant model based on reliable link of relations model is given. Spectrum analysis is given to the common channel by using the spectrum sensing process; secondly, routing integration and relay selection are achieved based on the link reliability of the new social relations sensing mobility model. Different forecast solutions are designed according to different relations of the node to obtain the relay node selection with the maximum chance of meeting; thirdly, the experimental results show that this social relations routing solution will greatly improve routing algorithm performance and reduce network computing complexity. Improvement is primarily given to link stability in future work. In addition, the influence of time power sampling on model precision shall be allowed for. The processing form as time sampling window shall also be considered. Weighted processing method shall be used to classify the multicast routing zone so as to enhance use pertinence of social relations model.

Acknowledgement

National Natural Science Foundation of China (61473047); special fund for basic scientific research of Central University (2014G3322008).

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Received May 7, 2017