Routing Algorithm Based on Delay Rate in Wireless Cognitive Radio Network

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Abstract—To reduce the end-to-end average delay of algorithm in wireless network, this paper proposes the real-time routing algorithm in spectrum network. It is analyzed that the dynamic changes of the radio network model and routing algorithm in spectrum network. Through using Markov state transition and adjusting the router with scaling factor, the high-quality resources in the network can be obtained and fully utilized, and then these can reduce the transmission time latency rate and timely adjust the route. After that the tendency of spectrum network and specific real-time algorithm are given. Finally, by using the network simulation NS-2, simulation experiments are used to estimate the performance test. Experimental results show that compared with the traditional algorithm, the proposed algorithm can obtain a lower end-to-end average delay and improves network throughput and the steady and reliability of the link connection.

Keywords—Real-time Routing; Protocol System; Bandwidth Capacity; Proportion

I. INTRODUCTION

Cognitive radio is an intelligent wireless communication system. It is able to perceive the external environment and uses artificial intelligence technology to learn from environment, and makes its internal state adapt to the statistical changes of received wireless signal by changing some operating parameters (such as transmit power, carrier frequency and modulation technology, etc.) so as to realize high reliable communication at any time and in any place and the effective use of spectrum resources [1].

With the rapid growth of the number of wireless subscribers and the rapid development of wireless communication technology, wireless spectrum resources become increasingly scarce [2]. In order to improve the spectrum utilization, Dr. Joseph Mitola first proposed the concept of cognitive radio; the report of Federal Communications Commission (FCC) also gives a definition of cognitive radio committed to solve the problem of spectrum scarcity, and the core idea is to make it have learning ability and interact information with the surrounding environment to percept and utilize the available spectrum in the space, and to limit and reduce conflicts [3-5]. It is remarkable for its flexibility, intelligence, reconfigurable properties. It can learn from the environment, sense the external environment and change intentionally certain operating parameters (such as transmission power, carrier frequency and modulation techniques, etc.) in real time to make the internal state adapt to the statistical variations of the received wireless, thus it can achieve highly reliable communication at all times and places and efficiently use of the limited radio spectrum resources on heterogeneous network environment [6-9]. The people in cognitive radio network research have focused on the physical layer, MAC layer (Media Access Control MAC) key technologies and network layer routing protocol [10]. Among them, the routing protocol is an important part of the cognitive radio networks, but so far do not have a representative routing protocol become important issues in cognitive radio network research for optimizing the routing algorithm [11-13].

In recent years, more and more attentions have been given to cognitive radio routing algorithm being, and some routing algorithms have been proposed. Literature MA Hui-Sheng and other proposed a single transceiver demand routing protocol, where do not need for using the control channel between nodes, and the gain and cost causing by node’s channel switching have been balanced, but there is no the specific solution for the problem of "deafness" while switching node [14-17]. The algorithm given by Chun LS based on the node local’s sensing information establishes the spectrum map, puts forward transmission indicators of opportunity link and uses the coordination mechanism to maintain throughput of the statistical quality of service (QOS) in the multi-channel
transmission. How KC proposes a routing algorithm with opportunity differentiated services; through a combination of transmit power control and opportunistic routing to obtain differentiated services, minimum delay and the most stable routing.

Bogliolo Alessandro and the others will solve the maximum flow problem of FF based on energy harvesting wireless sensor networks. Because when FF looks for a maximum flow path, it takes into account the capacity problem and establishes the connection between capacity and energy harvesting rate, it makes the algorithm well used for energy harvesting wireless sensor networks, but due to the arbitrariness of augmented link choice of FF itself, it improves the calculation complexity and it can not guarantee convergence to the maximum of flow. ZHU Jia and the others improve the energy detection performance in fading environment through the use of joint spectrum sensing method of multiple cognitive users. In the joint spectrum perception, the cognitive users send local perception results to the fusion center and fusion centers use the specific fusion rule to combine all the sensory information to make final decision about the presence or absence of authorized users [18-22]. SUN Chunhua and the others adopt the method of clustering cooperation awareness to improve the detection performance under fading channel, but they don’t give how to make clustering for cognitive user [22-25]. GUO Chen and the others use cluster nodes to make spectrum perception and send sensory information, but because other cognitive users are not involved in perception, the algorithm’s performance does not improve during the period of channel fading. In particular, when the channel is perfect, due to the shrinking of users’ participation in cooperation, perceived performance can reduce instead.

The above is the algorithm of cognitive radio routing. Although there are some improvements on the reliability of delay, throughput and link, still it is necessary to study the routing algorithm. This kind of routing algorithm is aimed at finding the minimum end-to-end delay path. Traditional route is mostly based on the shortest hops, however, in cognitive radio network, and the state information of each link is different. The information includes bandwidth of each channel between chains, available probability and channels, so the traditional routing algorithm is not suitable in cognitive radio networks. This paper proposes the Dynamic Spectrum Variation real-time routing algorithm (DSVR); the main idea are as follows: When better (greater bandwidth or higher utilization) spectrum in cognitive radio networks is idle due to the exit of primary user, cognitive users can sense it through spectrum, and timely update the table; if there is a user using a better routing (such as: lower transmission delay) in the routing table, cognitive users take the initiative to withdraw current route and adjust to a better route. While the traditional routing protocols will not take the initiative to adjust the route in the case of cognitive users having routing to use; unless the existing route can not be used, cognitive users will find a new route. Finally, the following theoretical analysis and simulation prove the correctness of the proposed algorithm, and we can see that on the indicator of average end-to-end delay DSVR is significantly improved than traditional routing.

This paper mainly discusses the work of expanding and innovations in the following areas:

As to the defects of higher average end-to-end delay for the radio network in traditional routing protocols, firstly, the author proposes Dynamic Spectrum Variation real-time (DSVR), which analysis the radio network model and the routing algorithm in detail. Secondly, in the process of spectrum dynamic change, the Markov state transition is used to adjust the routing timely and the scaling factor \( \alpha \) and the TTT are introduced to balance the effect on the network in the process of routing, and then the Markov model is used to evaluate the average end-to-end delay of the entire network. To a certain extent, this method makes fully use of resources with high quality in the network and it can obtain a lower transmission delay. Finally, gives specific steps on Dynamic Spectrum Variation real-time routing algorithm. The algorithm in the process of dynamic Spectrum Variation uses the Markov state transfer, and timely adjusts the routing to make full use of quality resources on network to a some extent, and achieve lower transmission delay.

In order to further verify the algorithm’s correctness and effectiveness of lower transmission delay based on Dynamic Spectrum Variation real-time, the author makes a detailed experimental simulation in the radio network model, and experimental simulation results show that: DSVR algorithm has a lower average end-to-end delay compared with traditional routing algorithm in the case of channel’s availability probability greater than 0.5, and has a lower average end-to-end delay, which ensures the stability and reliability of the throughput the link.

Cognitive radio networks using cognitive radio technology show some characteristics different from the traditional network due to its unique spectrum reusability and huge coverage:

Allocating radio resources in the multi-system coexisting conditions. The link between the users needs to carry out an effective control and management, at the same time to meet the delay and bandwidth requirements, and to realize a data transmission scheduling.

The system should have the capability of multi-channel support. If it is needed the central controller should be able to multiple adjacent channel aggregation processing to improve system performance, and support users to use and occupy a wider coverage. It can the user indicate which channel groups can be polymerized for use in some control frame, so the user can adopt multichannel mode.

Coexistence problems faced by the system. The coexistence problems include two levels: the first is the interference on the primary user system; the second is the coexistence problems of cognitive network entities in the overlapping areas or partially overlapping. To avoid interference to the primary user, distributed spectrum senses, measures and detects algorithms, and manages spectrum. All the specific functions of cognitive radio
technology must be considered. In the reality, the plurality of cognitive radio cell with great coverage is likely to occur partially overlap, in the worst case it is even completely overlapped. Consequent self-interference problems can not be resolved, it will seriously affect cognitive radio network.

Since the cognitive radio network having a dynamic, flexible, intelligent features, and thus the requirements for the network protocol is also relatively high, the protocol with asynchronous real-time characteristics, must be adaptive in the availability of the terminal changes, changes in the wireless environment the dynamic changes in the spectrum resources, network topology changes. Therefore, in the design of cognitive radio network protocols, follow these guidelines:

The agreement should be designed to fully reflect the characteristics of the cognitive radio technology. The common communication protocol architecture is hierarchical, in the cognitive radio network design, it will mainly consider the physical layer and media access control (MAC) layer and the network layer. In the specific design process, and will draw on the existing physical layer, MAC layer and the network layer protocol hierarchy, on this basis, by adding a function of the characteristics of the cognitive radio module.

Protocol architecture design should be combined with the results of algorithms and network architecture design systematically considering. Due to the design of cognitive radio network protocols and the network structure is closely related to the algorithm and the network structure is closely related to, among complement each other and influence each other. So in the process of designing network protocol, a preliminary framework should be established, and then combines with the results of algorithm design and network architecture design constantly revised, and finally completes the design of network protocols.

Protocol architecture design should, as far as possible, consider the compatibility, that is, considering the coexistence with other systems. The current communication pattern is coexistence of multiple systems, so when cognitive radio protocol architecture is designed should, it is really needed to take full account of the coexistence problem with other systems.

II. PROPOSED SCHEME

A. Radio Network Model

Cognitive radio network consists of N cognitive nodes, M link and m orthogonal channels within two adjacent nodes; each of the cognitive nodes has the same transmission range and interference range, and can access available channel set through the spectrum. The channel set dynamic changes over time and space. Cognitive radio network can be abstracted in Figure 1, where G <V (G), E (G)> G, V (G) = {V1, V2,...,Vm} means the cognitive nodes set in the network; E (G) = {e1, e2,..., en} means the available channel set between two adjacent nodes. Just as shown in Figure 1, the source node and the destination node, respectively, represented by s and t; a, b, c, d means the intermediate node, the connection ei ∈ {1, 2,..., m} between the nodes between nodes means that the available channel set.

![Figure 1. Topology of cognitive radio network](image)

Assuming that the probability of primary user occupying the channel is bi, then we can see:

\[ d_k = \frac{t_{on}}{t_{on} + t_{off}} \]

\[ t^k_e \] means statistical average time taken by the primary user in channel K with an active state; \[ t^k_{off} \] statistical average time taken by the primary user in channel K with an inactive state. Then the probability of two adjacent nodes vi and vj communicating together in channel (channel availability) is as follows:

\[ EI \frac{\partial^2 u(x,t)}{\partial x^2} + \frac{m}{L} \frac{\partial^2 u(x,t)}{\partial t^2} = 0 \]

\[ d_k^i = 1 - d_k \]

According to the Shannon formula, the capacity \( c^i_{vi} \) of nodes in the channel is as follows:

\[ c^i_{vi} = w^i_{vi} \log_2 (1 + snr^i_{vi}) \]

\[ u(x,t) = X(x)e^{iwt} \]

\( w^i_{vi} \) is the bandwidth between two adjacent nodes and inter-channel; \( snr^i_{vi} \) is signal-to-noise ratio of nodes.

Given packet length as L, the data transmission delay between nodes and the channel is as following:

\[ t_i = \frac{L}{C^i_{vi}} \]

\[ T_{u_i} + T_{f_i} = T_{u_i} + T_{f_i} \]

In the network topology Figure 1, the transmission delay between nodes represented by the value of the edge weights \( u_i \).

B. Routing Algorithm

According to the above instructions of the cognitive radio routing algorithm, in order to make it easier to describe the system, we establish a Markov link-state system model, n routes have been abstracted in the system; state 0 indicates no routing available; state 1 indicates that the route1 is available; P0 indicates probability that there is no route can be used; Pi indicates probability that route i cannot be used; P2 indicates probability that route 2 cannot be used; Px indicates the
probability that no route can be used. The probability that no route can be used is defined as \( p \), which is the joint probability of the probability that the route between nodes can not be used. Routing table sorts the routing with priority decreasing, as following: if the route 1 is optimal (minimum transmission delay), routing 2 is sub-optimal and routing n is the worst. The nodes select routers according to the priority. System state transition diagram is shown in Figure 2:

![Figure 2. State transition diagram of cognitive radio network routing](image)

From the above state transition diagram the state transition matrix composed by the state transition probability \( p_{ij} \) can be drawn as the follows:

\[
p = \begin{bmatrix}
    p_{00} & p_{01} & \cdots & p_{0j} & \cdots \\
    p_{i0} & p_{i1} & \cdots & p_{ij} & \cdots \\
    \vdots & \vdots & \ddots & \vdots & \ddots \\
    p_{n0} & p_{n1} & \cdots & p_{nj} & \cdots \\
    \vdots & \vdots & \ddots & \vdots & \ddots \\
  \end{bmatrix}
\]

\( p_{ij} \) in the state transition matrix means the transition probability from state \( i \) to state \( j \).

According to the traditional routing algorithms state transition matrix can be drawn as following:

\[
p = \begin{bmatrix}
    p_{01} & p_{11} & \cdots & p_{1j} & \cdots \\
    p_{i1} & p_{i2} & \cdots & p_{ij} & \cdots \\
    \vdots & \vdots & \ddots & \vdots & \ddots \\
    p_{n1} & p_{n2} & \cdots & p_{nj} & \cdots \\
    \vdots & \vdots & \ddots & \vdots & \ddots \\
  \end{bmatrix}
\]

The state transition of traditional routing algorithms can be described as follows: In Figure 2, if the system is in state 0, the system will select the route with the highest priority, and jump to the state 1; if the state 1 is not available, the system jump to state 2, 3.... n; these will stop when the system has been found the current network route with the highest priority. If the system’s current state \( i \) (\( i < n \)) are available caused by spectrum changes in the network environment due to the in the, the system continue to remain in the state (state can continue to use the case) according to the traditional routing algorithm. Take state 1 and state 2 as example: if the system is in state 2, and the state 1 at this time is available, the system can only stay in state 2, and the state transition probability is \( P_{21}=1-P_2 \). If the state 2 can not continue to use, the system will jump to state 1; transition probability of state 2 and state 1 is \( P_{21}=1-P_2 \). From the state transition matrix we can see that in the case of the original state available, the system can not use the current network of quality resources, make the high-quality resources in an idle state, and not make full use of network resources.

According DSVR algorithm the author proposed the following state transition matrix can be drawn:

\[
p = \begin{bmatrix}
    p_1 & p_2 & \cdots & p_n \\
    1-p_1 & p_1 & \cdots & p_{1n} \\
    \vdots & \vdots & \ddots & \vdots \\
    1-p_n & \cdots & \cdots & 1-p_n \\
    \end{bmatrix}
\]

Assuming that the system is in this state, if state 1 is available, from DSVR algorithms the system will jump from state j to state i (even if in the case states 1 and 2 of a state can continue to use). The author will describe DSVR algorithm by the state transition from states 1 to state 2. If the system is in state 2, and state 1 available, in accordance with the DSVR algorithm, the system will exit state 2 to the state 1 (even in the case of state 2 can be used); the state transition probability is \( P_{21}=(1-P_2) \). Compared with the state transition probability of traditional routing algorithms, the probability of backing to state 1 has been increased. So, compared with traditional routing algorithms DSVR algorithm can better make full use of the high-quality resources in the network to improve the overall network performance.

Hereinafter, the author makes mathematical verification on state transition diagram, just as shown in Figure 2; set the state transfer Picture as C, which is the non-empty subset of the state space \( I \); as to any state \( i \), when \( i \in c \) and, \( p_s = 0 \), which is a random closed set and all the state in random closed set are interconnected, so it is irreducible closed set; from state transition Figure 2 is easy to know that for each state, the cycle is equal to 1, so the state transition figure is the Markov chain of non-periodic irreducible closed set, in which the probability distribution \( \{ \pi_j, j \in I \} \) is steadily distributed, and satisfies:

\[
p_j = \pi_j p_{ij},
\]

\( \pi_j = \sum_{i=1}^{n} \pi_i p_{ij} \), \( \sum_{i=1}^{n} \pi_j = 1, \pi_j \geq 0 \)

\( \pi_j \) means the state transition probabilities; \( \pi_0, \pi_1, \pi_2 \) means the stationary distribution of \( p_0, p_1, \cdots, p_j \). From the equation (7), (8), (9), (10), (11) end-to-end average delay \( E \) can be drawn:

\[
E = \sum_{i=0}^{n} R_i \pi_i, \quad \sum_{i=1}^{n} \pi_j = 1, \pi_j \geq 0
\]

\[
E = \sum_{i=1}^{n} \pi_i p_{ij}, \quad \sum_{i=1}^{n} \pi_j = 1, \pi_j \geq 0
\]

\[
p = \begin{bmatrix}
    p_{01} & p_{02} & \cdots & p_{0n} \\
    p_{03} & p_{04} & \cdots & p_{0n} \\
    \vdots & \vdots & \ddots & \vdots \\
    p_{n0} & p_{n1} & \cdots & p_{nn} \\
    \end{bmatrix}
\]

\[
p = \begin{bmatrix}
    p_1 & p_2 & \cdots & p_n \\
    1-p_1 & p_1 & \cdots & p_{1n} \\
    \vdots & \vdots & \ddots & \vdots \\
    1-p_n & \cdots & \cdots & 1-p_n \\
    \end{bmatrix}
\]
Among them, $\pi_j$ indicates the stationary distribution backing to the $j$ route; $T_r$ means the transmission delay ($T_r$ is the accumulated transmission delay of the $i$ route between nodes) of the $i$ route.

The DSVR algorithm has less propagation delay than the cognitive users, which are using the current router after the network routing table is updated, and can timely adjust the router. This makes a difference on the stability of communication and overhead of the network between the pair of nodes. For example: the losing of packet, re-transmission of packet, and the delay caused by switching channel. Therefore, this paper introduces the scale factor $\alpha$ and switch trigger time to balance these effects.

$$T = \begin{bmatrix} T_{00} & T_{01} & \cdots & T_{0y} & \cdots \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ T_{io} & T_{i1} & \cdots & T_{ij} & \cdots \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ T_{no} & T_{ni} & \cdots & T_{ny} & \cdots \end{bmatrix}$$

$$com = [T_{0j}^c] \times [T_{1j}^c] \times \ldots \times [T_{nj}^c]$$

$$T \leq T(1-\alpha)$$

In equation (9), $T$ represents the transmission delay before adjustment; $\alpha$ means the transmission delay after adjustment. When the above conditions have been satisfied, the route can be switched. The introduction of the scale factor not only can make effective control on routing adjustment, balance the influence caused by route switching, and ensure the quality of communication between nodes, but also can prevent frequent adjustment of the routing. TTT is equivalent to observations of a time window. In cognitive radio networks spectrum is dynamic and changes with time. When on the period of TTT, the system is only make detection on the routing, and not makes adjustment on routes; when observation time is over TTT, it makes route adjustment after satisfying (9). This also effectively prevents the over spectrum of route changes caused by the dynamic changes of cognitive radio networks spectrum; this makes the routing adjustment too frequent and shuffled adjustment between routes, generating a ping-pong efficiency; this affect the stability of the inter-node communication and increase network overhead.

The specific steps on algorithm DSVR are as follows:

a) Vector $[\alpha_j^k, w_j^k]$ indicates the characteristics between the two nodes; $\alpha_j^k, w_j^k$ are the available probability and bandwidth of the two nodes in the channel $k$. In the construct cognitive radio network $G<N\rightarrow G$, $E(G)>G$, the source node and the destination node are separately represented by $s$ and $t$.

b) From equation (2), (3) to obtain the channel capacity between two nodes as $c_{ij}^k$ and $t_{ij}^k$.

c) Finding out all the link of the destination nodes in the source nodes, and obtaining the transmission delay of each link by superimposition between two nodes.

d) Arranging all the links in the $c$ from small to large (fast row), and selecting $\min \{T_i\}$ from it. Using formula (4), (7) to draw the average network delay.

e) When $d$ is complete, sending the message of Hello every $2s$, making routing maintenance, and timely updating the routing table.

f) When $e$ is completed, if $T' \leq (1-\alpha) \min \{T_i\}$ and the observation time is greater than TTT, it is the updated routing table $\min \{T_i\}$. Using formula (5), (7) to get the average network delay.

g) If it is not satisfied $f$, it will back to the $e$.

Analysis of algorithm time complexity and space complexity:

The time and space complexity of traditional routing algorithms can be expressed as:

$$T = nO(\log n), s = O(n)$$

where: $n$ is the number of link in the network, which the source node $s$ can reach the destination node $t$.

The time and space complexity of the algorithm DSVR can be expressed as:

$$T = mO(\log m), s = o(m)$$

where: $m$ is the link number after the routing table in the network updated and satisfying the formula (8), so $m \ll n$. Therefore, the time and space complexity of the algorithm DSVR are less than the time and space complexity of the traditional routing algorithm.

### TABLE I. SIMULATION PARAMETER SETTINGS

<table>
<thead>
<tr>
<th>Simulation Setup</th>
<th>Simulation parameters</th>
</tr>
</thead>
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<tr>
<td>Data Type</td>
<td>CBR</td>
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<td>Multiplexing method</td>
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<td>5s</td>
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<tr>
<td>$\alpha$</td>
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### III. SIMULATION AND ANALYSIS

#### A. Simulation Parameter Settings

For performance analysis of the DSVR algorithm, the author uses common network simulation NS-2 to evaluate the performance. Simulation environment is as follows: N cognitive nodes randomly distributed within a range of 1200m*1200m; the physical layer and the MAC layer of the wireless transmission adopt the IEEE802.11 protocol; the wireless transmission is ideal, i.e. no error and delay. Five groups of different nodes are randomly selected from the collection of nodes in the simulation.
between two nodes can be updated in the updated routing table. The phenomenon are as follows: based on the Markov state transition matrix, the greater the channel available probability, the greater the steady-state probability of selecting lower transmission delay path, so under the same parameters of the number of nodes, channel bandwidth and the number of channels the between nodes, the DSVR routing’s average delay is significantly lower than traditional routing. Moreover, with the increase in channel availability, this trend is more and more obvious. The reasons for this phenomenon are as follows: based on the Markov state transition matrix, the greater the channel available probability, the greater the steady-state probability of selecting lower transmission delay path, so under the same parameters of the number of nodes, channel bandwidth and the number of channels the between nodes, the DSVR routing’s average delay is significantly lower than traditional routing. Meanwhile, it can be seen from Figure 3, the probability of channel availability is from 0.5 to 0.6; DSVR routing average delay is lower than the conventional route by 10%, and this is consistent with the equation (6), which indicate that at this time the routes adjustment occurs. The vector \( \left[ a_{ij}^0, w_{ij}^0 \right] \) represents the characteristics between the two nodes; \( a_{ij}^0 \) and \( w_{ij}^0 \) are the available probability and bandwidth of the two nodes on channel k. In construct cognitive radio network \( G \langle V (G), E (G) \rangle G \), the source node and the destination node are respectively presented as s and t. b) the channel capacity and \( t_{ij} \) between two nodes can be obtained through equation (2) and (3). c) Identifying all node links which the source node can reach the destination and overlying two nodes to get the transmission delay of each link. d) Arranging all the links according to the ascending mode (using fast row) and selecting min \( \{T_i\} \). Using Equation (4) and (7) derived get average network delay. e) When d finished, Hello message is sent once every 2 seconds for routing maintenance and updating routing tables. f) When e complete, if and the observation time is more than TTT, the min \( \{T_i\} \) in updated routing table is appeared. The average network delay is got by using formula (5) and (7). After the network routing table updated and satisfied the link number in formula (8), the \( m < n \). It can be seen that, compared with traditional routing algorithm, the time complexity and space complexity of DSVR algorithm time are much less, and its average delay is significantly reduced.

From Figure 3 it can be concluded that in the case of the parameters of DSVR routing and the traditional routing algorithm are the same, the advantage of DSVR routing is mainly reflected in the channel’s probability above 0.5. So, we set the channel’s probability are \( \Pi_1 = 0.6 \). As can be seen from Figure 4, when the channel’s probabilities are the same, with the number of channels available increased in the network, the source node and the destination node has more routes to choose from. According to DSVR routing algorithm, the probability of router adjusted to the lower transmission delay is greater, so the average delay of DSVR cognitive routing algorithm is significantly reduced compared to the average delay of traditional router.

As can be seen in Figure 5, with increase of the number of nodes in the network, the average delay gradually increased. But after using DSVR the average delay is significantly lower than the traditional route, and growth of the average delay is slower than traditional route. The causes of this phenomenon are as follows: with the increase nodes’ number, the size of the entire network becomes large, the number of hops of the source node and the destination node increase, so the average end-to-end delay increases; But with the increase of the number of nodes, available route in the network also
increase, while the system can timely adjust the route by adopting DSVR, and make use of route with a smaller transmission delay, which can make some compensation to the transmission delay caused by the increase in the number of hops. Therefore the average delay adopting DSVR route is lower than adopting traditional routing.

IV. CONCLUSIONS

This paper presents a kind of DSVR algorithm, which mainly takes the impact of the route caused by dynamic spectrum in cognitive radio network into account. According to the size of the route’s transmission delay, the system timely adjust the routing, introduce the scale factor $a$ and switch trigger time (TTT) to balance the impact on the network in the process of adjusting the routing, and then use a Markov model to evaluate the average end-to-end delay of the entire network. Finally, after the analysis of simulation and comparison, the author concludes that compared with traditional routing algorithm DSVR algorithm has a lower average end-to-end delay under the circumstances channel’s probability greater than 0.5. The next study is to improve the routing algorithm and all aspects of performance.

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