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Multicast Routing and Spectrum Allocation Algorithm Based on QOS Constraints Load Balancing in Wireless Network

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Abstract

To deal with the issues like existing generation of congestion nodes and redundancy transmission in the traditional load balancing algorithm, this paper puts forward the load balance multicast routing and spectrum allocation algorithm based on QOS constraints. The algorithm adopts LBWC algorithm to calculate the wireless link weight, and carries out the structure of the load balancing multicast tree. Then, the QOS constraints spectrum allocation algorithm is adopted based on wireless channel broadcast feature to conduct channel allocation of wireless link. Algorithm in this paper is under the condition of wireless multicast QOS constraints satisfactions, which balance the node load, minimize the transmission times of the wireless multicast business and reduce the consumption of network resources. Finally, simulation experiments are carried out, such as the influence of wireless multicast business number on the performance of the algorithm, the influence of the number of multicast destination node on the performance of the algorithm, the influence of the number of available channel on the performance of the algorithm and the influence of the control parameter β on the performance of algorithm, etc. Experimental results show that in the case of wireless multicast service constraint, the algorithm avoids the congestion nodes and reduces the times of transmission.

Keywords*: Network Model, Problem Description, Weight Function, Control Parameters*

1. Introduction

Wireless Mesh network is a new type of broadband wireless network structure; it combines the advantage of the wireless local area network and ad-hoc network. It has the character of self-organization and multiple hops, and can realize effective integration of heterogeneous network. It has become the hot spot of next generation wireless broadband technology and the mobile Internet in the study. It can use variety means of communication such as the IEEE 802, 11 WIMAX technologies; it is considered to be a kind of new solution which can solve the bottleneck problem of wireless access "the last kilometer". In the wireless Mesh network, any wireless device nodes as the access points and routers at the same time, each node in the network can send and receive signals, and direct communication with one or more peer nodes. Radio characteristics of wireless Mesh network provides a good platform for the application of network coding, network coding is provided in 2000 by Ahlswede [1]. It is a major breakthrough in the field of communication after entering the 21st century, it is a concept blend of encoding and routing, allows the node to encode data packet from different link combination, make the network performance can achieve theory limitation of maximum flow transmission.

Cognitive Wireless Mesh networks has extensive application value in the scene of its low cost and easy deployment, build Wireless metropolitan area network, to provide high-speed broadband Wireless access, etc. In recent years, there are a lot of researches around the wireless Mesh network routing and load-balancing[2-6]. Existing load balancing routing algorithm in the wireless Mesh network cannot be directly used in the

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cognitive wireless Mesh network, multicast and the channel allocation in cognitive wireless Mesh network mainly has the following characteristics: 1) cognitive wireless Mesh networks in the environment of the channel dynamic variation; 2) the available channel in the cognitive wireless Mesh networks have heterogeneity, namely the use probability of these available channel are different under normal circumstances; 3) the available channel is a subset of all wireless environment channels in cognitive wireless Mesh network, and the subset is dynamic change [7].

Cognitive Wireless Mesh networks current research is not sufficiently, face many challenges. According to the routing problem of Cognitive Wireless Mesh networks, has made some research results[8-12]. According to the different available channel of multicast destination node, lead to each destination node successfully received data from multicast source node with longer total time problem.[13-17] In view of CR - Mesh router node with available channel heterogeneity,to reduce the end-to-end delay as the goal, Almasaeid H M proposes a CWMN multicast routing algorithm OMRA based on dynamic programming. Zhang GA proposed a distributed channel allocation strategy of joint routing. The main purpose is to maintain the channel allocation channel differences within the territory; the optimization performance index is the average throughput and average delay. Gu JY proposed a joint multipath routing and channel allocation strategy in the cognitive wireless Mesh network. The strategy set relay function of intersection node according to the situation of the selected path, and the minimum number of times of the main user used to occupy as a measure to select each channel, the optimization performance index is the average throughput and average delay. Li Y proposed a cognitive dynamic hierarchical graph routing mode under wireless Mesh network environment, using two state discrete time markov chain model nodes to aware the channel availability within the scope, build cognitive dynamic mode of wireless Mesh network topology and connectivity. Hicham H according to the law of activity in the PU and the location, choose the highest path which meet probability of wireless business as the path from source to the destination node. Ding L proposed a cross-layer opportunity spectrum access and dynamic routing algorithm ROSA; the goal is to maximize the network throughput. Kuang zhu-fang proposed a satisfy the QoS constrained routing and spectrum allocation algorithm SA2JR, SA2JR goal is: in the case of meeting wireless QoS constraint to maximize wireless business acceptance rate, make as many wireless business requirements as possible can be satisfied[18].

This article mainly research load balancing multicast routing and spectrum allocation problem which meet the QOS constraints in cognitive wireless Mesh network. Goal is: under the condition of wireless multicast service QOS constraints constraint satisfaction, to balance the node load, to minimize the times of the wireless multicast transmission business and to reduce the consumption of network resources. By consulting relevant literature, at present, load balancing multicast routing and spectrum allocation algorithm has not been reported in view of the cognitive wireless Mesh network. In this paper, study and put forward the algorithm for the problem for the first time.

This paper mainly conducts the development and innovative work in the following aspects as:

(1) In view of the traditional load balancing algorithm of congestion nodes amounts of generation and transmission, this paper puts forward the load balancing multicast routing and spectrum allocation algorithm based on QOS constraints. The algorithm research load balancing multicast routing and spectrum allocation problem meet the QOS constraints, considering the difference between the perceptions of the available channel, namely different channels with different bandwidth. Considering the influence between multiple wireless multicast businesses, the optimization goal is not only balance the network load, and minimize the transmission times of wireless multicast service. In this paper, a wireless link function based on weights load balancing is proposed, on this basis, puts

forward a satisfying load balancing multicast routing and spectrum allocation algorithm based on the QOS constraints.

(2) In order to further verify the correctness and validity of load balancing multicast routing and the spectrum allocation algorithm based on QOS constraints proposed in this paper, carry out simulation experiments such as the influence of wireless multicast business number on the performance of the algorithm, the influence of the number of multicast destination node on the performance of the algorithm, the influence of the number of available channel on the performance of the algorithm and the influence of the control parameter β on the performance of algorithm, etc. Experiments using Microsoft Visual C. Network topology for wireless access network of Shanghai Normal University, in the area of 2400m×2400m, CR-Mesh node number n=60, multicast source point and the destination node is randomly generated, achieve the goal of network load balance, and to achieve the goal of minimizing transmission times . Increase as the number of multicast destination node, and the average number of transmission is increased. The more network resources, the smaller the multicast tree of average transmission times can be constructed. The greater control parameter β, the node load is more equilibrium. Experimental simulation results show that the algorithm in the case of wireless multicast service constraint, avoid the congestion nodes and reduces the number of transmission.

2. Network Model

Cognitive wireless Mesh network of the stillness CR-Mesh nodes (including CR-Mesh routers and gateways) modeling for a simple undirected graph V=(S,E), S represents nodes collection of CR-Mesh. E represents connect two collection of wireless link which can communicate with each other CR-Mesh nodes. Each node $S_i \in S$ has a collection of available channel K and a cognitive radio frequency interface number N_i. Each node $S_i \in S$ has a communication distance T_R and an interference distance I_R. Usually have $3T_R > I_R > T_R$.

$d(S_i, S_j)$ represents physical distance between node S_i and S_j. Two CR-Mesh nodes communicating with each other must have the following conditions: (1) with the same available channel, namely $k_i \cap k_j \neq \varphi$; (2) free cognitive radio frequency interface number are available in distribution; (3) meet the constraints of communication distance, namely $d(S_i, S_j) < T_R$.

c(i,j)=k represents the wireless link (S_i, S_j) distribution channel is k, c(i,j)=0 indicates the wireless link (S_i, S_j) did not assign any channel. And, only each of the wireless links set a channel, or not assigns any channel. $C=\{c(i,j)\}_{n\times n}$ represents the channel set of all wireless link. B_k represents the bandwidth of the channel k, unit is Mb/s, due to different channel usually have different bandwidth, therefore, for different channel k and k', $B_k \neq B_{k'}$.

Studying in this paper is the problem that meets the wireless multicast service Qos constraints, multicast routing and spectrum allocation problem aim at node load balance and minimized transmission times. Assume that there is a public control channel is used to transfer control information among the SU.

In order to better describe the problem in this paper, a simple example of network topology is given, as shown in figure 1, there are 17 CR-Mesh routers, 4 CR-Mesh gateway. In the figure the $R_8\{1,2,3,5\}/5$ represents CR-Mesh routers R_8 aware available channel set for {1,2,3,5}, available number of the radio frequency interface for 5 through spectrum sensing algorithms. Namely k_8=4, I_8=5. Assuming that there are five available channel in the current wireless network environment, namely k={1,2,3,4,5}, the five available channel bandwidth are respectively B={15,20,23,30,35}, unit Mb/s.

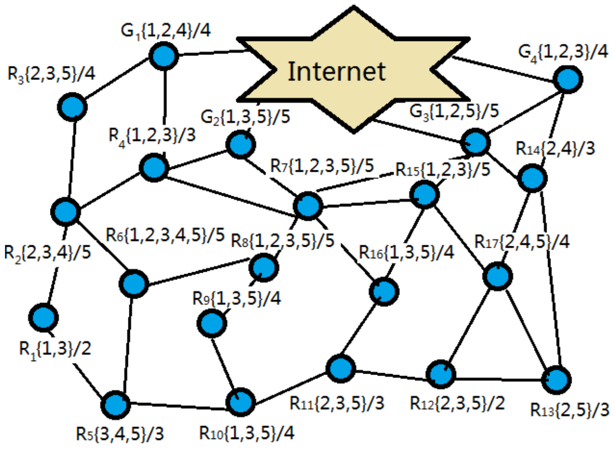


Figure 1. Cognitive Wireless Mesh Network Topology

Set $\Delta=\{\gamma_q=(s_q,d_q,b_q)\}$ for the wireless business requirements collection, among them, s_q represents the source point of wireless multicast γ_q , d_q represents the purpose nodes set ofγq , bq represents bandwidth constraintγq need. T(q) for the multicast tree is constructed by wireless business γ_q . The node in the T(q) can be divided into three categories: source point, transport nodes and leaf (purpose) nodes. FY(T(q)) represents transport nodes set in multicast tree T(q), HY(T(q)) represents the leaf node set in multicast tree T(q).

$H=\{h(R_i)|R_i\in l\}$ represents the load set of all nodes, $h(R_i)$ represents load of node R_i, unit for Mb/s, as shown in type (1)

$$h(R_i)=\sum_{m\in m_i} h_m(R_i)=\sum_{m\in m_i}\left(\sum_{\gamma_q\in\Delta} h_m(\gamma_q,R_i)\right) =\sum_{m\in m_i}\left(\sum_{\gamma_q\in\Delta}\left(h_m^{in}(\gamma_q,r_i)\right)+h_m^{out}(\gamma_q,R_i)\right) \quad (1)$$

Among them, $h_m(R_i)$ represents load of node R_i in the channel k . $h_m(\gamma_q ,R_i)$ represents the produced load in the channel m of node R_i by γ_q , the $h_m^{in}(\gamma_q,r_i)$ represents the node R_i 's load of wireless multicast γ_q into the channel m, $h_m^{out}(\gamma_q,R_i)$ represents the node R_i 's load of wireless multicast γ_q out of the channel m.

$\Pi_m(R_i)$ Represents available bandwidth of node R_i in the channel, namely $\Pi_m(R_i)=B_m-h_m(R_i)$. $B_m(R_i, R_y)$ represents the remaining bandwidth of the wireless link (R_i, R_y) in channel k, as shown in type (2) :

$$B(R_i,R_y)=\min\{B(R_i),B(R_y)\} \quad (2)$$

$\gamma_1 = \{G_2,\{ R_2, R_5, R_{10}\},100\}$ represents the wireless multicast business source point for G_2, multicast purpose nodes set for $\{R_2$ and $R_5, R_{10}\}$, wireless business γ_1 bandwidth constraints for B_1=100MB/s. Multicast path of the shortest average hop number from G_2 to D_1 as shown in table I. Path(G_i, R_y) represents Path as well as the distribution channel from G_i to node R_y.

Table 1. The Path and Channel Allocation from G2 to D1 members in the γ_1

R_y	Path(G_i, R_y)
R_2	$G_2 \xrightarrow{1} R_4 \xrightarrow{2} R_2$
R_5	$G_2 \xrightarrow{1} R_7 \xrightarrow{2} R_8 \xrightarrow{1} R_6 \xrightarrow{3} R_5$
R_{10}	$G_2 \xrightarrow{3} R_7 \xrightarrow{2} R_8 \xrightarrow{1} R_9 \xrightarrow{4} R_{10}$

$\text{Path}(G_2, R_{10}) = G_2 \xrightarrow{3} R_7 \xrightarrow{2} R_8 \xrightarrow{1} R_9 \xrightarrow{4} R_{10}$ Represent distribution channel 3 from G_2 to R_7, distribution channel 2 from R_7 to R_8, distribution channel 1 from R_8 to R_9, distribution channel 4 from R_9 to R_{10}.

New to the wireless multicast operations $\gamma_2 = \{G_1,\{R_8, R_{10}\},15\}$, a source point is G_1, multicast destination node set for $\{R_8,R_{10}\}$, wireless business γ_2 bandwidth constraints for B_2=150MB/s, without considering the influence of the existing multicast γ_1 for multicast business γ_2 , multicast path and channel allocation of the shortest average hop number from G_1 to D_2 as shown in table II.

Table 2. The Path and Channel Allocation from G1 to D2 Members in the γ_2

R_y	Path(G_i, R_y)
R_8	$T_2 \xrightarrow{1} R_8 \xrightarrow{2} R_7 \xrightarrow{3} R_{10}$
R_{10}	$T_2 \xrightarrow{2} R_8 \xrightarrow{3} R_7 \xrightarrow{5} R_{10}$

Through the analysis can found, the shortest average hop number as the structure of the wireless multicast routing of path routing, metrics and channel allocation methods exist the following problems:

(1) Because CR-Mesh routers R_7 can detect more available channel, and R_7 neighbor nodes have the same available channel with R_7, R_7 can establish wireless link with more neighbor nodes, namely the routing path constructed by the wireless business γ_1 and γ_2 go through R_7, this leads to R_7 carry more flow compared to other nodes. Actually R_7 is a representative of the type of node, this type of node for more available channel, leading to more wireless multicast service go through this kind of node, the node will become the performance bottleneck of cognitive wireless Mesh network, due to the heavy load of this kind of node will not be able to ensure that service quality of all wireless multicast service. Therefore, when making routing path structure and channel allocation, need to consider the load balance between the CR-Mesh nodes.

(2) In wireless business γ_1 , has been allocated a channel 3 for the wireless link (R_7,R_{10}), and wireless link (R_7,R_{10}) on channel 3's remaining bandwidth $B_3(R_7,R_{10})=120$, and γ2 bandwidth constraints for B_2=150MB/s, namely the $B_3(R_7,R_{10})=120<B_2$, so wireless link (R_7,R_{10}) distribution channel 3 cannot meet the bandwidth constraints of γ_2 . Therefore, for the wireless multicast business γ_2 , a new multicast routing path which meet Qos constraint must be constructed.

3. Load Balancing Multicast Routing and Spectrum Allocation Algorithm of QOS Constraints

Equalization network load and the minimized number of transmission is the goal of this article, network load balancing target is realized by the load balance of the multicast tree structure, the goal of minimizing the number of transmission is reached through QoS constraints' spectrum allocation algorithm LBMRSA in this section. In order to minimize the number of transmission times, LBMRSA algorithm using the wireless radio channel characteristics.

f(u,v) represents the wireless link (u,v) weight, also said that the load of the wireless link (u,v), f(u,v) the larger, the load of the wireless link (u,v) is heavier, as shown in formula (3):

$$f(u,v)=[(\frac{1+C(u)}{1+C(u)-l(u)})^{\alpha(u,v)}(\frac{1+C(v)}{1+C(v)-l(v)})]^{\beta} \tag{3}$$

β represents load balancing degree and delay control parameters. β is greater, the network load more balanced, at the same time, the network delay is also larger.

However, Not for the purpose of achieving load balancing, and the β value increases without limit. this may make could take a short cut to reach the destination node, in order to load balancing, and through other nodes, thus cause the delay increases. Therefore, we need to choose reasonable β value, as to balance between the load balancing and network delay.

DF(γ_q ,mi) represents in γ_q multicast tree T(q) , the node transmission times of the node m_i , as shown in type (4).

$$DF\left(\gamma_q,m_i\right)=\sum_{m\in m_i}B\left\{p^m\left(\gamma_q,m_i\right)\right\} \tag{4}$$

Among them, the $p_m(\gamma_q, m_i)$ represents in γ_q multicast tree T(q), whether node v_i is a transport nodes in the channel k , B{.} is a function conditions, determine whether is true.

DF(γ_q) represents transmission number of all the nodes in γ_q multicast tree T(q) , a spectrum allocation algorithm LBMRSA target is proposed as shown in type (5).

$$\min\left(DF\left(\gamma_q\right)\right)=\min\left(\sum_{m_i\in m_j}DF\left(\gamma_q,m_i\right)\right) \tag{5}$$

LBMRSA basic idea is: any wireless link (m_i,m_j) in $q(T_q,d')$, first of all, whether x(i,j) is equal to zero, if $x(i,j)\neq 0$, indicates wireless link (m_i,m_j) have been allocated a channel, channel allocation is not needed; If x(i,j)=0, then calculate channel set $L'(m_i,m_j)$ of the wireless link (m_i,m_j) which satisfy the QoS constraints, namely $\forall k\in L(m_i,m_j)$, if $B_k>b_q$, the $k\in L'(m_i,m_j)$; Calculating v_i channel which most neighbor nodes have, namely: a channel k node v_i has, v_i neighbors also have at the same time, with the maximum number of channel k neighbor, formalization description as shown in type (6).

$$k'=\arg\max\sum_{m_i\in\left(M(m_i)-m_j\right)}B\left\{k\in L\left(m_i,m_j\right)\right\}k\in L'\left(m_i,m_j\right) \tag{6}$$

B{.} is the condition function, judge whether it is true. If get more satisfy (5) channel k ', and then choose the highest bandwidth as the selected channel, the wireless link (m_i,m_j) for channel allocation, namely x(i,j)=k' . Then, update the wireless link $(m_i,m_j)'$ weights link $g(m_i,m_j)=0$.

Finally, update the wireless link (m_i,m_j) weights $g(m_i,m_j)$ covered by wireless link (m_i,m_j) and channel allocation on the wireless link.

Algorithm : LBMRSA algorithm
The input: V=(S,E), γ_q =(S_q,D_q,b_q), q(s_q,d'), β,X
The output:T(q),X
1) L_0=L;X_0=X;m=|D_q|;
2)T(p)= S_q;
3) Calculate f(v_i,v_j) ; // link weight
4) while m≠0 do {
5) while $\forall$ d_i ∈ D_q do {
6) q(s_q,d_i)=Dijkstra(S_p,d_i);
7) }// end while
8) $d' = \arg\min_{d_i \in D_q} (\sum_{(u,v)\in p(s_q,d_i)} f(v_i,v_j))$;
9) if $\sum_{(u,v)\in p(s_q,d_i)} f(v_i,v_j) = \infty$ {
10) T(p)=φ;
11) return [T($_q$),X $_0$] ;
12) } //end if
13) While (m_i,m_j)=0 ∈ q(s_q,d_i) do {
14) if g(m_i,m_j)≠0 {
15) Computing R_k(m_i,m_j)=0 ;
16) }
17) else {
18) while $\forall g \in g(m_i,m_j)$ do {
19) if B_k>b_q {
20) g∈ G'(m_i,m_j);
21) }// end if
22) Calculate g' according to the type(6)
23) g(m_i,m_j) =g';
24) }// end while
25) } //end if
25) g(m_i,m_j) =0
26) while $\forall m_j \in (m_i)$ & $g' \cup g(m_i,m_j)$ do {
27) g(i,j)=k';
28) α(m_i,m_j) =0;
29) Update g(m_i,m_j);
30) }// end while
31) }// end while
32) T(p)=T(p)∪q(s_q,d')
33) DF(T(p))= DF(T(p)) ∪fwd(q(s_q,d'));
34) D_q= D_q-d';
35) m=m-1;
36) } // end while
37) while $\forall u \in T(p)$ do {
38) Calculate h(u) according to the type(1)
39) $C(u) = \sum_{k\in K(u)} B^k$
40) } // end while
41) return [T(q),X_0]

4. Simulation and Analysis

In order to verify the correctness and effectiveness of the proposed algorithm LBMRSA, we implemented OMRA algorithm proposed by LBMRSA. WCTB algorithm proposed by Liu T H is considered to be the MCMR wireless best algorithm for minimizing transmission times target in Mesh network, because the transmission frequency close to the optimal value. According to cognitive wireless Mesh network environment the algorithm is realized, the basic idea is: edge construction Multicast tree edge conduct spectrum allocation by adopting the idea of the spectrum allocation algorithm proposed in this paper. The difference between the WCTB and LBMRSA is: WCTB algorithm isn't consider load balancing, and only consider the goal of minimizing transmission times. OMRA algorithm is a kind of multicast routing algorithm based on dynamic programming in cognitive wireless Mesh network, the goal is to minimize the end-to-end delay.

Simulation programs are written using Microsoft Visual C++. The simulation of the network topology as ShangHai Normal University wireless access network, in the area of 1200 m by 1200 m, CR-Mesh node number n=100, multicast source point and the destination node randomly generated; There are several available channel and PU randomly occupy the channel. The channel bandwidth to [0,150], random generation, and the unit is Mb/s, the wireless demand bandwidth bq belongs to [0, 30], also randomly generated. Assuming that by default, the wireless multicast service arrive randomly, and random leave, reach the business number of multicast $|\Delta|=50$ within the prescribed length of time, the number of multicast destination node $|D_q|=0$, set the time length of 1800s; Available channel number is $|g|=9$, $\beta=3, T_r=60m, I_r=150m$.

All the simulation results are the average value based on 100 independent simulation results. The comparison of performance mainly includes the average utilization of utilization ratio and average transfer times. The formula of the average utilization ratio as shown in type (7):

$$\bar{O} = \frac{1}{m}\sum_{i=1}^{m} O(i) \tag{7}$$

Among them, O(i) represents the utilization of node R_i, the calculation formula as shown in type (8) :

$$O(i) = \frac{k(i)}{X(i)} = \frac{1}{X(i)}\sum_{m\in m}\sum_{\gamma_q \in s} h^m\left(\gamma_q . R_i\right) \tag{8}$$

The formula of average transmission times as shown in type (9):

$$DF\left(\gamma_q\right) = \frac{1}{m}\sum_{m=1}^{m} DF\left(\gamma_q, i\right) \tag{9}$$

Simulation mainly use Wireless multicast business number, multicast destination node number and the number of available channel as parameter, the simulation from the following two aspects: (1) the average utilization rate; (2) the average transfer times. And analyze the effect of control parameter on LBMRSA algorithm performance.

4.1. Wireless Multicast Service Number's Effect on the Performance of the Algorithm

In this simulation, analyze and compare wireless multicast service number's effect on the performance of the algorithm. The simulation results are shown in figure 2.

From figure 2 (a), the average utilization and utilization of LBMRSA algorithm below the WCTB and OMRA algorithm, this is because the LBMRSA algorithm aiming at the network load balancing, and the goal of WCTB algorithm is to minimize the transmission times, the goal of OMRA algorithm is to minimize the end-to-end delay; Increase as the number of wireless multicast service, the average utilization and standard deviations of utilization of LBMRSA, GCTB and OMRA algorithm increase, but the increasing speed of LBMRSA below WCTB and OMRA algorithm, it shows that the network load is heavier, LBMRSA performance of load balance algorithm is more obvious.

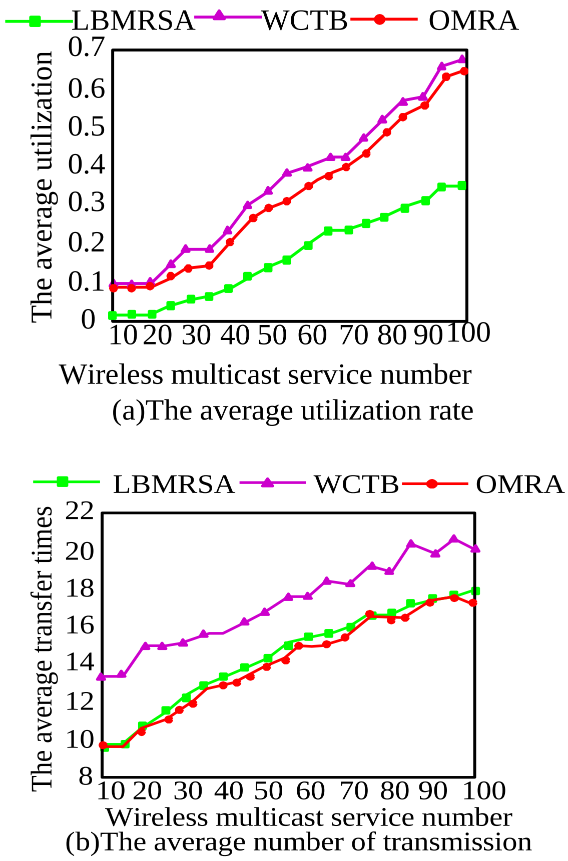
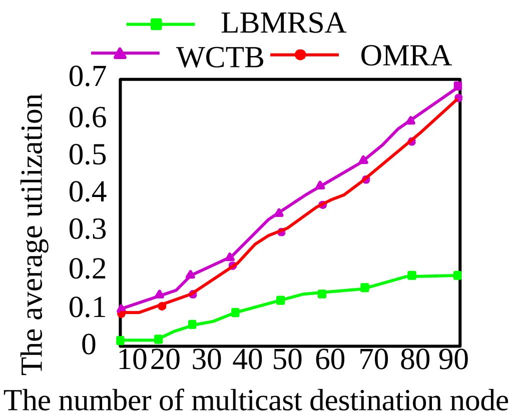


Figure 2. Wireless Multicast Service Number's effect on the Performance of the Algorithm

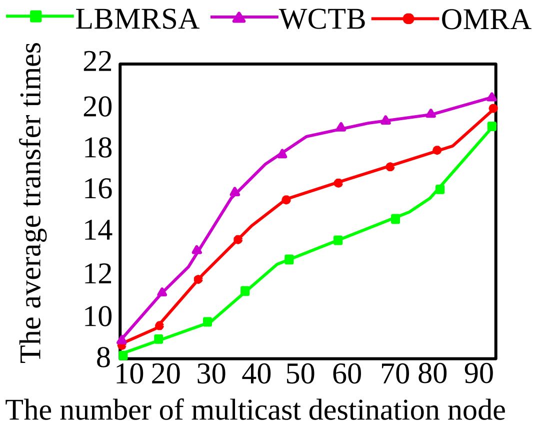
The figure 2 (b) shows that average transfer times of LBMRSA and WCTB algorithm lower than OMRA Algorithm, this is because the goal of LBMRSA algorithm, is not only the load of equalization node and minimize the wireless multicast transmission frequency of the business, WCTB algorithm uses the minimized transmission times as the goal, and OMRA algorithm aiming at the end-to-end delay. LBMRSA algorithm and WCTB transmission times were similar, while WCTB algorithm is considered to be the best algorithm for target is to minimize transmission times at current MCMR wireless Mesh network, so that LBMRSA algorithm not only achieve the goal of network load balance, and to achieve the goal of minimizing transmission times.

4.2. Node Number Effect of Multicast Destination on the Performance of the Algorithm

In this simulation, analyze and compare node number effect of multicast destination on the performance of the algorithm. The simulation results are shown in figure 3.



(a)The average utilization rate



(b)The average number of transmission

Figure 3. Node Number Effect of Multicast Destination on the Performance of the Algorithm

By figure 3 (a), the average utilization and utilization of LBMRSA algorithm is lower than WCTB algorithm and OMRA algorithm, with the number of available channels increase, the average utilization and the standard deviation of utilization of LBMRSA, WCTB and OMRA Algorithm is growing big, and LBMRSA algorithm the speed of the increase is below WCTB and OMRA algorithm. The figure 3 (b) shows that LBMRSA and WCTB algorithm transmission times lower than OMRA algorithm, likewise, LBMRSA algorithm and WCTB transmission times were similar, and, along with the multicast destination node number increases, the average transfer times also increase.

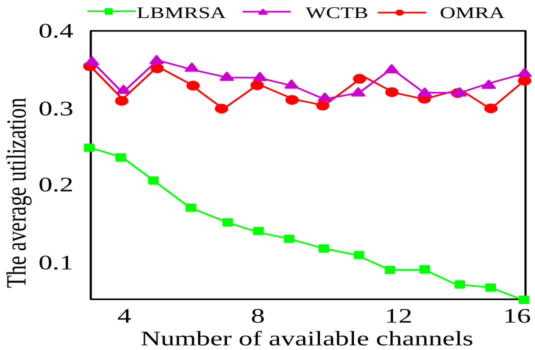
4.3. Available Channel's Effect to the Algorithm Performance

In this simulation, analyze and compare available channel's effect to the algorithm performance. The simulation results are shown in figure 4.

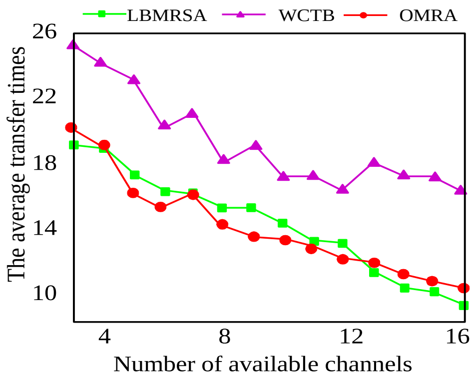
By figure 4 (a), the average utilization and utilization of LBMRSA algorithm is lower than WCTB algorithm and OMRA algorithm, and as the number of available channels increase, network load balance performance of LBMRSA algorithm become more obvious, this is because the more the available channel number, nodes perceived available channel also increase, no available channel for network load node can shoulder some of the network load, therefore, the performance of network load balance is better.

However, with the increase of available channel, the average utilization rate and the standard deviation of utilization of WCTB and OMRA algorithms' change is not big, this is mainly because WCTB algorithm try to minimize the transmission times as the goal, and OMRA algorithm aiming at the end-to-end delay.

By figure 4 (b), the average transmission time of LBMRSA and WCTB algorithm is lower than OMRA algorithm, and, along with the increase in available channel number, the average transmission time of LBMRSA and WCTB algorithm is smaller, this is because the more the available channel number, the more available network resources, so the multicast tree can be constructed with the smaller transmission rate.



(a)The average utilization rate



(b)The average number of transmission

Figure 4. Available Channel Number Effect the Performance of the Algorithm

4.4. Influence of Control Parameter β on LBMRSA Algorithm Performance

In this simulation, analysis and comparison the influence of control parameter β on LBMRSA algorithm performance, network topology for a total of 16 4×4 CR-Mesh nodes in the network environment, multicast destination node number $|D_q|=4$, and randomly generated.

Table III is that influence of control parameter β changes on standard deviation of the utilization ratio, the average times of transmission and the average end-to-end delay, average end-to-end delay for the sum average value from multicast source point to the destination node delay. The table 4 shows that the greater the β, the smaller the standard deviation of utilization ratio and the average time of transmission, the greater the average end-to-end delay, but all of the β value, average end-to-end delay is within a tolerable range, it just shows the LBMRSA in the process of seeking network load balancing, network end to end delay also increase, therefore, in order to balance the network load balancing and end-to-end delay, need to select the reasonable control parameter β.

Table 3. Effects of control parameters on LBMRSA algorithm

β	The average number of transmission	The standard deviation of utilization ratio	Average end-to-end delay
1	0.0454	6.477	12.452
2	0.357	5.896	13.654
3	0.132	5.126	14.215
4	0.112	5.033	16.899
5	0.103	4.867	18..011
6	0.091	4.562	20.331
7	0.79	4.488	24.459

Figure 5 shows that node utilization of 16 CR-Mesh nodes in cases of β=1,2,5 . β=1 , the network load is very uneven, the utilization of part of nodes is 2 times of the other nodes; β=3 , compared to network load balancing situation of β=1 has a lot to improve, basic has reached the network load balancing; β=5, compared to network load balancing situation of β=3 is better, the utilization rate of each node is less than 12%. This shows that the greater the control parameter β, the node load is more equilibrium.

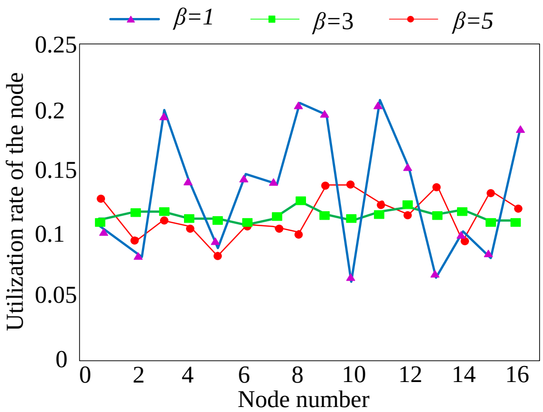


Figure 5. Control Parameters' Influence on the Utilization Ratio of Node

5. Conclusion

Network load balance and minimized number of transmission as the goal in Cognitive wireless Mesh network meet the Multicast routing and the spectrum allocation problem of Qos constraints. This paper proposes a wireless link weighting function of the load balancing, this paper proposes a load balancing multicast routing and spectrum allocation algorithm LBMRSA which satisfy the Qos constraints. First, the algorithm use algorithm to calculate wireless link weights and carry out load balancing the structure of the multicast tree, and then use the Qos constraints spectrum allocation algorithm LBMRSA based on wireless channel broadcast feature conducts channel allocation on the wireless link. The simulation found that reasonable parameter Settings, LBMRSA can achieve the goal of balancing network load. Load balancing performance of LBMRSA algorithm is better than WCTB and OMRA algorithm, and average transfer times of LBMRSA algorithm is lower than OMRA algorithm, and is basically the same with WCTB algorithm. To minimize the multicast tree transmission times is goal of WCTB algorithm, it is considered to be the optimal algorithm for the index at present, therefore, in equalization network load conditions, LBMRSA is thought to minimize the multicast tree transmission times and optimize the use of network resources. In the next step of work, the distributed load balancing multicast routing and spectrum allocation algorithm which satisfy Qos constraints will be studied.

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